Ken Evans (MS ’72) and his wife Karen hosted a reception for ExxonMobil employees who are UA Geosciences Alums at their home in Houston on January 25th. Department Head Susan Beck, College of Science Dean (and former Geosciences Department Head) Joaquin Ruiz, and graduate student Aaron Martin attended from the UA. Aaron has accepted a permanent position with ExxonMobil when he finishes his Ph.D this year.

During the evening, ExxonMobil representative, Mike Loudin presented Geosciences with a check for $30,000 to support diversity programs. This money will go to the Students Across the Borders program that Faculty members Bob Butler and Peter Kresan have put together to bring high school teachers and students from Tucson, and Yuma, and Sonora, Mexico, to the UA campus for a week in June.

It was a fun evening for everyone. We hope to have more of these events in the future!
DONORS

The Department of Geosciences expresses its gratitude to alumni and friends who continue to support programs and scholarships through their generous contributions.

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From the Department Chair

Despite a difficult year with an additional mid-year budget cut, the Department has continued to move forward at the University of Arizona.

GeoDaze was a huge success this spring with a record 42 oral and 28 poster presentations. We were thrilled to hold the event at the new Student Union on campus. Graduate student co-chairs Allison Drake and Becca Walker did a great job organizing and running the symposium. A special thanks goes to all the contributors that made GeoDaze possible (see page 12).

Our Alumni Advisory Board met during GeoDaze again this year. We added two new members to the board: Carlotta Chernoff (PhD ’02), and Jeffrey Seekatz (BS ’74). Carlotta just started work at ConocoPhillips, and Jeff has been at ExxonMobil (formerly Exxon) for 25 years. See page 11 for more information about Carlotta and Jeff.

Our Houston alumni have been active in organizing Geosciences alumni socials (see page 1). Another alumni social was planned for early May. Some of our Advisory Board members have agreed to help make this an annual event for UA Geoscience alumni and friends in the Houston area. Watch for an article and photos about the May event in the next newsletter.

John Sutter (Team Chief Scientist, Western Earth Surface Processes Team, USGS) and I are working on plans for a joint U.S. Geological Survey (USGS) and University of Arizona (UA) Earth Surface Processes Research Institute (ESPRI). For many years, our goal has been to improve and increase the partnership between the UA and the USGS. The USGS plans to increase their presence in Tucson in coming years. The development of ESPRI will provide a venue for groundbreaking research on landscape change and ecosystems response in arid and semi-arid environments. Currently, the Geosciences and Hydrology and Water Resources Departments, the Laboratory for Tree-Ring Research, the Office of Arid Lands Studies, and the Institute for the Study of Planet Earth are all engaged in research on earth surface processes. We are currently developing joint research project plans with USGS earth surface process researchers from four science disciplines; geology, hydrology, geography, and biology.

ESPRI will focus on four areas of surficial processes:
(1) Quaternary bio/geochronology – to develop accurate and precise means to determine the age of an event at various scales over the past million years, (2) quantitative geomorphology – by using accurate measures of time to determine the rates of processes that modify the surface of the solid earth, (3) quantitative hydrogeology – model processes and process rates that affect groundwater availability at the surface, and, therefore, to the geomorphic processes, and (4) forecasting landscape change and ecosystem response – using accurate process rates, forecast effects of climate variability and of anthropogenic events on the landscape and ecosystems. We plan to have science strategy meetings over the summer in order to produce a science plan by fall.

In this issue, we have highlighted some of the geophysics projects going on in the Department. We are excited about the new project Roy Johnson has with Mary Poulton, Bob Casavant, and Charles Glass (Mining and Geological Engineering) on Natural-Gas Hydrates. George Zandt is working on crust and upper mantle interactions in the Sierra Nevada region. And I continue to work on large earthquakes like the Denali Fault Earthquake of last November, the largest strike-slip earthquake to occur in the U.S.

I want to thank all of our Geoscience alumni and friends for their continued support of the Department. With all of the recent budget cuts, your support is more important than ever.
Spencer Titley
Receives Advisory Board’s Outstanding Faculty Award

This year’s Outstanding Faculty Award was presented to Spence Titley for his many years of service to the Department of Geosciences and his enormous contribution to the field of economic geology.

On April 10th, sixty-five people attended a dinner in Spence’s honor at the University’s newly renovated Student Union. The evening was a great tribute to Spence and his many years of teaching and guidance of students in the Department.

The crowd included many of Spence’s former students who came from near and far to participate in the celebration.

Steve Naruk, chair of the Advisory Board, presented the Award, and Eric Seedorff summarized Spence’s professional career.

Spence has been an advisor to over 100 graduate students: 34 PhD and 89 MS graduates, and 2 PhD and 4 MS students with works in progress.

A slide show with photos of Spence over the years was narrated by Susan Beck (Department Head), Steve Enders (PhD ’00), John Dreier (PhD ’76), Will Wilkinson (PhD ’81), Peter Megaw (PhD ’90), Libby Youngblood Anthony (MS ’79, PhD ’86), Cori Hoag (MS ’91), Stacie Gibbins (current PhD Student).

Spence has a limitless love for teaching students and training professionals, and he has a remarkable breadth of scientific curiosity, expertise, and experience, which continues outside of science. He greatly deserves this special award and recognition!
Shallow Natural-Gas Hydrates Beneath Permafrost

A Geophysical Challenge to Understand an Unconventional Energy Resource

By Roy Johnson

UA Natural-Gas Hydrate Project

Researchers in the UA's Departments of Geosciences and Mining and Geological Engineering have recently embarked on an ambitious, multi-year research project to evaluate the occurrence and seismic properties of natural-gas hydrates, a substance that may become a significant future source of natural gas. In collaboration with colleagues from BP Exploration (Alaska), Inc., the University of Alaska Fairbanks, and the U.S. Geological Survey, researchers from the Department of Geosciences (Dr. Roy Johnson and students Casey Hagbo and Andrew Hennes) are working with researchers from the Department of Mining and Geological Engineering (Dr. Mary Poulton, Dr. Robert Casavant, Dr. Charles Glass, consultant Ken Mallon, and students Bo (Alex) Zhao and Justin Manuel) on a project entitled “Resource Characterization and Quantification of Natural-Gas Hydrate and Associated Free-Gas Accumulations in the Prudhoe Bay – Kuparuk River Area on the North Slope of Alaska.”

This research project was formally initiated last November and focuses on the Prudhoe Bay area of Alaska's North Slope (Fig. 1), a major petroleum production province since 1969. The project could extend for up to four years, bringing up to $2M to the UA, and is one of three new projects funded by the U.S. Department of Energy (DOE) in Alaska and the Gulf of Mexico. These projects will develop a better understanding of the occurrence and commercial potential of this unconventional energy resource.

What is Natural-Gas Hydrate?

Natural-gas hydrate is a frozen framework of water and methane (or other light hydrocarbons), a combination called a “clathrate.” Clathrates form by weak molecular bonding between water and gas molecules under limited ranges of pressures and temperatures referred to as the hydrate-stability field (Fig. 2). In effect, molecules of methane are bonded in a latticework of water molecules forming a rather strange type of ice. An amazing property of methane-gas hydrates, the target of the UA study, is that they can store enormous volumes of methane in a small space: about 160 times as much 96–100% pure methane can be trapped in a given volume of a hydrate than is present in the same volume of free gas (Sloan, 1998). This property makes them an attractive unconventional resource.

Methane hydrates occur within and beneath 300–700m thick permafrost in Alaska, Siberia, and other arctic regions, and they can occur anywhere that relatively low-temperature, high-pressure conditions combine with water and methane, such as in sediments near the ocean floor in deep-water basins (Collett, 1993). The source of the methane can be from leakage of light gas from deeper hydrocarbon accumulations along fractures or fault zones (thermogenic methane) or from the breakdown of organic matter by bacterial action (biogenic methane). In 2000, a surprised commercial fishing crew pulled up their net with a catch of odd-looking, foaming ice that was snagged from a gas-hydrate pinnacle at the bottom of the Pacific Ocean southeast of Vancouver Island, British Columbia (Spence et al., 2001). Although generally occurring within sediments, it’s clear that gas hydrates can remain stable under the right pressures and temperatures even at the sea floor. Gas hydrates are surprisingly common around the world, and may eventually become an important energy resource because of their widespread distribution and because they may provide a fuel that is cleaner burning than conventional hydrocarbon fuels.

Seismic Imaging of Hydrates

Our initial research goal is to delineate the extent of in-situ gas hydrates and associated free gas beneath an area near Prudhoe Bay, Alaska (Fig. 1) based on seismic reflection character and seismic attributes from 3-dimensional seismic reflection data sets (Fig. 3). In shallow sedimentary rock sequences in which pressure and temperature conditions are favorable for formation of gas hydrates, the gas hydrates themselves may form an impermeable barrier to upward migration of free gas. Below the hydrate stability zone, trapped free gas may fill pore spaces. Gas hydrates that fill pore spaces have relatively high seismic velocities much like those of permafrost (water ice). In contact with free-gas-filled pore spaces, the change in seismic velocity and density is striking and often causes high-amplitude seismic reflections (Fig. 4). In fact, it is the free-gas/gas-hydrate contact that is most likely responsible for “bottom-simulating reflections” (BSRs) seen on many deep marine seismic reflection surveys around the world. Drilling by Ocean Drilling Project (ODP)
teams in such areas as the Blake Ridge (offshore Georgia and Florida) and other areas show that these “bright” reflections, which mimic the topography of the sea floor, are related to gas-hydrate occurrences.

A major part of our current research involves calibration of gas-hydrate occurrences identified from borehole data with seismic properties in the 3-D seismic reflection data. In the longer term, we plan to develop effective techniques to facilitate automatic detection and characterization of potential concentrations of gas-hydrates using neural network analyses of seismic properties.

**Reservoir Characterization**

Oil and gas are produced from deep reservoirs in the Prudhoe Bay area, but very little is known about gas-hydrates that lie at shallow levels above producing horizons within these fields. An essential element of our efforts to characterize shallow gas-hydrate reservoirs and assess their in-situ properties is seismic calibration of known gas-hydrate occurrences with available well data. This is a tricky process, since gas hydrates have similar physical properties to those of water ice (permafrost). Our research team is working to identify gas-hydrate zones that have been confirmed by drilling, tie these zones to the seismic reflection data, and evaluate changes in seismic and well-log properties as trends are tracked between wells.

The UA research effort also includes structural and stratigraphic analyses of methane-hydrate-prone sequences, and where possible, interpretation of deeper structures that may control the location, orientation, and physical nature of methane migration paths and reservoirs. For instance, aligned sub-vertical fractures and faults, which result from regional and local stress patterns, may serve as conduits for migration of methane gas (or other light hydrocarbons) into the shallow subsurface.

Reservoir characteristics that are favorable for gas-hydrate accumulations may vary depending on combinations of reservoir lithologies, supporting matrix (i.e., what role lithology, permafrost, and gas-hydrates have in determining the mechanical properties of the reservoir), concentrations of light hydrocarbons, presence of free gas, fracture systems, and other factors. Integration of all related geophysical, geological, and petro-physical data provides a broader basis for interpretation of geological variability, inherent physical properties, and calculated seismic attributes.

One approach our research team uses to identify the characteristic properties of gas hydrate accumulations in seismic reflection data is neural network analysis. Neural networks, which are computer programs to process widely varying types of information, work much like the human brain in sorting information into meaningful patterns that can be recognized. The benefit of this approach is that a neural net-work can be “trained” to recognize the properties of hydrates where they are known to occur. The neural network then can be used to automatically pinpoint other areas that show similar characteristics throughout large volumes of data. Humans ultimately decide whether these areas bear further, more detailed investigation.

**Another Reason to Understand Gas Hydrates**

Considerable interest has developed about gas hydrates because of their possible importance for meeting future energy needs, but also because they are believed to be involved in sequestering methane, an important green-house gas (Kvenvolden, 1993, 1994). If not trapped in clathrate structures, this gas could circulate in the atmosphere, potentially contributing to global warming.

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**Figure 3**

Three-D seismic data cube that shows shallow trends of mapped faults, are difficult to detect in standard displays such as this. Careful analysis of seismic attributes is used to help pinpoint areas of methane-hydrate occurrences.

**Figure 4**

Seismic model of contact between free-gas and hydrate-saturated zone within reservoir rocks. a) Velocity model. Hydrate-saturated zone has significantly higher velocity than the gas-saturated zone. b) Synthetic seismic response. Gas-saturated reservoir reflection has strongly negative amplitude compared to the positive amplitude reflection from hydrate-saturated zone. Note the low-frequency of the reflection from the gas-saturated zone and the reversal in polarity along the horizon. Migrated synthetic seismic data with added random noise. (Figures courtesy of Casey Hagbo)
The UA hosted the 3rd Congress of the International Association of Limnogeology (IAL) March 29 – April 2. Professor Andy Cohen (Geosciences) chaired the organizing committee which included faculty members from the Department of Geosciences, the College of Science, and the Institute for the Study of Planet Earth. Approximately 250 scientists involved in coring sediments and geological history from some of the most scientifically important lakes on the planet showcased their lake-drilling activities at this conference.

The IAL is a relatively new organization that links scientists who study both ancient and modern lake basins for new insights on climate change, biological evolution, and potential natural resources.

Keynote speakers at the conference gave talks on lake sediment drilling in South America’s Lake Titicaca and in Africa’s Lake Malawi; lake records of climatic effects on human civilization in Mexico; and lake sediments on Mars. Participants discussed the many very detailed records of North American climate change now available from lake sediments covering the past few centuries to put recurring drought, modern global warming, and other concerns in perspective.

Andy Cohen is director of the UA Nyanza Project, which supports university students and high school teachers in paleoclimate research at Lake Tanganyika.

### Second Annual Tucson Alumni Social

Thursday, October 2nd, 2003, has been selected as the date for the next Tucson Alumni Social. Mark your calendars now and plan to join us then. Watch the mail for invitations and please encourage other Tucson alumni to join us for a meet, greet, and eat evening of fun.
Hawai‘i Volcanoes
Sigma Gamma Epsilon Field Trip

By Andrew McCarthy
Photos by Dave Maher

Nine graduate students traveled to Hawai‘i in mid-March and participated in a nine-day tour of the geology of the Big Island. The trip was led by Professors Mihai Ducea (UA) and Jason Saleeby (Caltech), with students commenting in their areas of expertise.

The adventure began in Hilo, a town largely destroyed by tsunamis in 1946 and 1960. Here we entered the jungle-blanketed flanks of Kilauea, the most active volcano in Hawai‘i. The Kilauea summit area (4,000 feet) is surrounded by a variety of unique volcanic features formed during the current eruptive pulse which began in the 1950s. Drs. Ducea and Saleeby led our group to intermediate-sized shield volcanoes, fissure eruption sites, lava trees, ash deposits, landslides, and pahoehoe and a‘a’ flows. We viewed the Kilauea caldera complex from several vantage points and discussed its human and geologic history. We also hiked over a variety of young volcanic features, many still emitting scalding fumes, and explored two different lava tubes to examine volcanic processes from the perspective of molten lava. We returned via the Chain of Craters road to an active lava flow. We walked a mile beyond the tourists across recently hardened lava (still hot and glowing) to reach a point where lava gushed, hissing and steaming, into the waters of the Pacific. We then took turns sampling molten lava from the toe of a viscous, slow-moving flow.

Our next destination was the summit of Mauna Kea (13,796 feet) which gave us an opportunity to discuss the eruptive styles of Mauna Loa and Mauna Kea. Clear weather allowed us to examine the geomorphology of much of the Big Island. We also viewed evidence of recent glaciation on Mauna Kea while trying to catch our breath in the thin, cold air.

During the last few days of the trip, we explored the southwest and east side of the Big Island, visiting some cultural sites, a coffee plantation, black sand and green sand beaches, and a cinder cone. We stopped at a number of lava flows to search for crustal and mantle xenoliths and discussed lava chemistry, flow mechanics, and mantle source melting. At a location near Holualoa, the group collected from a sizable deposit of peridotite xenoliths.

Our last stop was at Kalopa State Park on the north coast. From here we visited Kohala, an old, deeply eroded volcano. The trip ended with some free time that most of us used to explore coral reefs near Kona.

Six months of organizing and fundraising by SGE members made this inaugural SGE field trip a success. Fundraising efforts included sales of geologic maps, a raffle, and a bake sale. Planning and fundraising for a 2004 field trip is already underway. In addition to bake sales, SGE is seeking alumni sponsors to support what we hope will become a Geosciences tradition: an annual, student-run trip to an area of extraordinary geologic interest. Look for the “Virtual Field Trip” on the Geosciences web page for more information.
The Denali Fault Earthquake

By Arda Ozcar and Susan Beck

On November 3, 2002, a Mw=7.9 strike-slip earthquake occurred in central Alaska rupturing over 300 km of the Denali Fault system. The 2002 Denali Fault earthquake occurred 140 km south of Fairbanks in a sparsely populated region of Alaska. Fortunately no deaths and very little damage occurred as a result of this event. The Denali Fault earthquake is the largest earthquake ever recorded in central Alaska and the largest strike-slip event in the US since the San Francisco earthquake in 1906. The shaking from the earthquake triggered many landslides off the steep slopes of the Alaska Range and aftershocks continue to occur. The Denali Fault earthquake ruptured the segment of the fault that is beneath the Trans-Alaska Oil Pipeline which carries 17% of the US domestic oil supply (USGS Fact Sheet 014-03). The pipeline did not break despite nearly 6 m of surface offset where the pipeline crosses the fault. This was very good news because a major oil spill would have been a large economic and environmental disaster.

The tectonic setting of Alaska is characterized by oblique convergence that is partitioned between active subduction along the Aleutian trench and right-lateral motion along crustal strike-slip faults (Fig. 1). In central Alaska, the recent earthquake sequence started with a foreshock on October 23 (Mw=6.7) and was followed 10 days later by the November 3, 2002, Denali Fault earthquake. Both foreshock and mainshock resulted from slip on the Denali Fault system, which is an arcuate right-lateral strike-slip fault acting as a major boundary between accreted litho-tectonic terrains. According to the field data, the Denali Fault earthquake produced 40 km-long surface rupture along the north dipping Susitna Glacier thrust fault and ruptured to the east along the strike-slip Denali and Totschunda faults. Total surface rupture reached up to ~340 km in length with a maximum surface offset of ~9 m (Denali Earthquake Geologic Field Team, 2002). With our colleague Doug Christensen at the University of Alaska, we have analyzed broad-band P-waves of this sequence in order to derive the rupture history and correlate the seismic slip distribution on the fault at depth with field data, aftershock locations, and gravity anomalies. We used vertical component teleseismic P-waves recorded by the Global Seismic Network stations and a pulse-stripping method based on Kikuchi and Kanamori (1982) that allows us to solve for a sequence of subevents with a fixed focal mechanism.

Our results for the Denali Fault earthquake are shown in Figure 2. The inversion results show the total source duration is at least 120 sec with two distinct episodes of moment release on asperities. During the initial 15 sec, rupture occurred near the hypocenter with a slight westward propagation and released nearly one-fourth of the total moment (1.3 x 1020 Nm) along an asperity located near and slightly west of the hypocenter. This initial subevent (Mw =7.3) can be attributed to thrusting along the

Figure 2

a) Seismo-tectonic map of the rupture area with aftershock locations from ABC Catalog. b) Source time function of the Denali Fault earthquake for our preferred source model. c) Mapped horizontal surface offsets from USGS. d) Slip distribution determined from our preferred source model with aftershock locations.

Susitna Glacier fault where 3 m of vertical displacement has been mapped. Approximately 10 sec after the first asperity failed, the rupture propagated unilaterally to the east with strik-slip motion along the Denali Fault with a relatively fast rupture velocity (~3.4 km/s). Most of the moment release was contained in an energetic asperity located 170 km east of the hypocenter, adjacent to the rupture transfer from the Denali Fault to the Totschunda Fault, which bifurcates towards the southeast (Denali Earthquake Geologic Field Team, 2002). We contour the moment release of each grid point for an area of 320 km x 20 km by using fixed boundaries on both sides and convert to slip with the area of the largest asperity and its associated moment. This results in a very smooth version of the slip distribution on the fault where the maximum slip (~8 m) associated with the asperity in the east corresponds well to the largest horizontal surface offsets (Fig. 2). Along the segment in between, moment release is less well resolved but is overall relatively low. In this region, there are two deeper patches of slip that do not correlate very well with the mapped surface offset.

In general, the overall extent of the rupture agrees with the aftershock locations (ABC Catalog). Foreshock rupture and related seismicity is located in the vicinity of the initial subevent and may have provided the trigger for the mainshock (Fig. 2). Widely distributed aftershock clusters also indicate a potential for possible triggering of nearby faults that may explain the aftershock occurrence within the asperities. Of particular interest is the lack of aftershocks within a 30 km long segment centered 40 km east of the hypocenter (Fig. 2). We will continue to work on this important strike-slip earthquake and compare it to other major strike-slip earthquakes around the world.

References


A Coney Fellowship Recipient

I am grateful for the opportunity to continue my research through the support of the Peter J. Coney Fellowship. I believe that Peter would appreciate both the scope and the multidisciplinary nature of my dissertation project. My research focuses on the regional tectonic evolution of the Annapurna Range, located in the central Nepal Himalaya. Some of the questions I am addressing through my research are shown in italics below.

1) Where is Main Central Thrust (MCT) in the Annapurna Range, and how can we locate it?

The MCT is regarded as one of the most important structures in the Himalaya because it stretches the entire length of the thrust belt, accommodates up to 100 kilometers of top-to-the-south shortening, and places higher-grade Neoproterozoic Greater Himalayan metasediments onto lower-grade Paleoproterozoic Lesser Himalayan metasediments. Despite the importance of the MCT, the exact location of the boundary between Greater and Lesser Himalayan rocks is poorly known because the lithology of the units on both sides of the boundary is the same: metamorphosed shale. The chemistry of the two shales is very different, however. I am using Neodymium isotopes of the shales, in conjunction with Uranium-Lead ages of detrital zircons contained in minor interbedded quartzites, to locate the MCT with an accuracy of a few hundred meters. This chemical approach is integrated at all stages with my field mapping. My results show that the boundary between Lesser and Greater Himalayan rocks is located about 700 meters below the position commonly mapped in the field. This discovery means that the previously mapped location of the MCT is actually a fault within Greater Himalayan rocks, the first recognition of a thrust fault entirely within the Greater Himalaya.

2) What is the timing of structural development of the Annapurna Range? Did the MCT experience significant out-of-sequence thrusting (up to 40 km)?

I am testing whether exhumation of the MCT hanging wall in the late Miocene-Pliocene was the result of reactivation of the MCT, or whether exhumation was due to growth of a duplex beneath the MCT sheet that passively uplifted both the footwall and hanging wall of the MCT. I will test these models using Uranium-Lead ages of monazite inclusions within garnet combined with Argon-Argon ages of muscovite from the same rock. The results of my efforts to locate the MCT will be crucial for correctly placing the ages within a tectonic framework. The implications of this study extend beyond the Himalaya, in part because this magnitude of reactivation of the MCT would be the largest out-of-sequence event on a thrust fault ever documented. Alternatively, confirmation of the duplex model would validate the paradigm of forward-breaking thrust faults observed in many fold-thrust belts around the world.

3) What is the lateral variability in geometry and kinematics of the thrust belt in the Annapurna Range?

Previous workers investigated the geology of the range using North-South oriented transects separated by up to 60 km. In addition to two previously examined transects, I mapped and sampled along three new transects separated by 15-20 km. This mapping and sampling campaign increases our knowledge of lateral variability in the Annapurna Range by a factor of 3-4. My results show some lateral changes in structural geometry across the Annapurnas; however, the first-order geometry remains the same.

The generosity of Coney Fellowship donors has helped ensure that research in tectonics will continue at the UA in perpetuity. I thank these donors for supporting my dissertation research.
The Journey of the Southern Sierra Nevada Drip

By George Zandt

Have you ever driven across the central California Sierras from Lee Vining to Fresno, perhaps on your way back from a ski trip to Mammoth Mountain in Long Valley? If so, you were paralleling the journey of an unusual geologic feature: the track of a mantle drip (the technical term is a convective instability) that initiated south of Mammoth Mountain about 3-4 million years ago and has been swept southwest to its current location south of Fresno.

Let's start this story at the beginning. In the early 1990s, an unusual mantle seismic anomaly was imaged beneath the southern San Joaquin Valley in central California. The anomaly is a high-velocity (and high-density) body located below the crust with the general shape of a vertical cylinder about 100 km in diameter extending from near the base of the crust to about 250 km depth (see Fig. 1). In map view, it is almost circular in shape with its center located south of Fresno near the town of Visalia, on the eastern edge of the southern Great Valley. It was later interpreted as a mantle downwelling associated with a local convective instability, or in simpler terms, a “mantle drip” (Zandt and Carrigan, 1993).

Recently, xenolith studies from the southern Sierras were published (by Geosciences faculty Mihai Ducea and his colleagues) making the case for delamination of the dense residual root of the central Sierra Nevada granitic batholith. Crustal and mantle xenoliths brought up in low-volume Miocene through Quaternary volcanism in the central Sierras provide the most direct constraints on the composition of the local lithosphere through time. Mid-Miocene age xenoliths reveal a lithosphere consisting of a ~30 to 35 km thick granitic batholith underlain by a ~40 km thick lower crustal root of mafic to ultramafic cumulates and residues, underlain by a peridotitic mantle. In contrast, the younger Pliocene and Quaternary volcanics that sample the Sierras lack garnet-bearing xenoliths; instead, xenoliths from 35 to 70 km depth indicate the presence of a hot peridotitic mantle. The available xenoliths constrain this change in the Sierran lithosphere to having occurred between 10 and 3 million years ago, and are strong evidence for the delamination of the eclogitic lower crust during this time period (Ducea and Saleeby, 1998). Ducea suggested that the thick granitic crust and its eclogitic root were built in Late Cretaceous time during a magmatic flareup that produced most of the Sierra Nevada batholith (Ducea, 2001). The production of a thick granitic batholith requires the concurrent production of an equally thick residual root. This root should have an eclogitic composition dominated by dense garnet pyroxenite at depths below about 35 to 40 km, suggesting that the batholithic root must reside in a metastable state within the surrounding continental mantle lithosphere.

It is now proposed that the mantle seismic anomaly marks the downwelling track of the delaminated batholith root sinking through the mantle, and the following sequence of events is envisioned. During the Late Cretaceous magmatic flareup, the thick Sierran granitic batholith was generated and emplaced in the crust with an equally thick or even thicker residual root extending into the upper mantle. With continuing subduction through the mid-Cenozoic, the high-density root remained in place in a metastable state within the strong upper plate lithosphere. With the passage of the Mendocino Triple Junction, and the opening of the slab window, the subducting Farallon plate was completely replaced by high-temperature asthenosphere by about 10 million years ago. The associated change in thermal and regional stress state was profound and initiated the delamination process, locally marked by mid-Miocene volcanism. However, the breaking loose of the batholithic root from the surrounding lithosphere took some time after initiation of extension, and the detachment was not completed until Pliocene time, marked by a sudden pulse of mafic potassic volcanism. This pulse of small-volume volcanism occurred between 3-4 million years ago in a circular area about 200 km in diameter centered just south of Long Valley (Fig. 1) and has been suggested to indicate both the locality and timing of the main delamination event (Manley et al., 2000).

Once detached, the heavy root sank rapidly through the upper mantle to the base of the asthenosphere at 250-300 km depth, leaving a cold downwelling trail (the drip). It is this drip that is imaged in the seismic tomography and partially entrained and swept southwest by a strong background mantle flow (the so-called mantle wind). There is evidence that the mantle drip is dragging on the base of the overlying lithosphere as it is swept laterally in the mantle wind. The surface projection of the current location of the drip coincides with a small crustal root and with a shallow embayment in the western edge of the Sierras, suggesting some downward force acting at the base of the crust (see Fig. 1). The present-day drainage patterns in the Sierra Nevada and Great Valley also appear to be influenced by a local downward flexure centered where the anomaly is currently located. Major rivers located north of the anomaly (San Joaquin, Merced, Tuolumne) flow westward into the Great Valley and then turn north to join the Sacramento River and eventually to the ocean. In contrast, major rivers crossing the anomaly (Kings, Kaweah, Tule) curve southward towards the internal drainage basin of Tulare Lake, as if the southern San Joaquin basin is subsiding more rapidly due to an extra tug at the base of the crust. The drag of the drip on the overlying crust is clearly not the sole cause of the local topography; but it appears to produce an observable effect on

Figure 1
A three-dimensional perspective view of the California/Nevada region, and a cross-section of the crust and upper mantle. On the cross-sectional view, the crustal thickness is shown with a tomographic image of the high-seismic-velocity, high-density "drip" anomaly. On the map view, the dashed circle is the proposed location for the initiation of delamination 3-4 Ma. The solid semi-circle is the surface projection of the current drip location and the arrow denotes the direction of the subsurface "journey" of the drip. The arrow indicates the "mantle wind" direction.
Jeffrey G. Seekatz

I am a rarity for someone my age, a native of Tucson. How old? When I was a boy, my home was near 22nd and Craycroft and surrounded by desert. I always enjoyed the desert and mountains, but my interest in geology was fueled by a friendship with James and Mark Zumberge while we attended Catalina High School in the late 1960s. James and Mark were sons of UA's College of Earth Science Head, Dr. John Zumberge. John would occasionally go with us on rock climbing trips and provide a running commentary on the local geology.

I entered the UA's College of Earth Sciences in the Fall of 1971, and I graduated with a BS in Geosciences in 1974. George Davis was my undergraduate advisor – from whom I learned both structural geology and the true meaning of “no blood, no foul” in basketball.

After attending one semester of graduate school at the UA, I entered the University of Texas at Austin where I received a MS in Geology. My thesis was a study of the stratigraphic and structural features of part of the Sigsbee Escarpment, northwestern Gulf of Mexico.

I now work as a Geophysical Advisor for ExxonMobil in Houston. During my 25 years at Exxon and ExxonMobil, I have had the opportunity to work on sedimentary basins from Alaska to Norway, Sakhalin Island to West Africa. Areas of particular interest have been seismic and sequence stratigraphy, hydrocarbon system analysis, and resource assessment. I am a member of the American Association of Petroleum Geologists and the Society of Exploration Geophysicists.

I live in The Woodlands, Texas, with my wife Arlene and our two boys, James and David. We enjoy bicycling and orienteering - a somewhat obscure sport that we learned to love while we lived in Norway.

Carlotta B. Chernoff

I am a geologist with ConocoPhillips in Houston, and I have been working with the Brazil Deepwater Team, a part of the New Ventures Exploration division, since August 2002.

I received a BS in geophysics and a MS in geology from the University of Texas at Austin. While at UT, I developed a keen interest in the interplay between the processes of deformation and metamorphic mineral growth, and I had the opportunity to investigate these problems among the beautiful scenery of the Picuris Range in northern New Mexico.

My Master's research focused on understanding the processes governing metamorphic garnet growth. As part of this work, I utilized cutting edge, three-dimensional imaging techniques (computed X-ray tomography) which today are considered the gold standard for non-destructive analysis of fragile specimens such as rare fossils or meteorites.

I enrolled as a PhD candidate in the UA's Department of Geosciences where I worked with Dr. Mark Barton. My dissertation focused on understanding the incorporation of trace elements into organic-rich sedimentary rocks and the processes responsible for redistribution of these elements during diagenesis and metamorphism. I also worked closely with the USGS-UA Center for Mineral Resources to oversee work developing global databases of economic resources and a digital geologic map of the US-Mexico border region. I graduated from the UA in 2002.

I was honored to be a co-chair of the 25th annual GeoDaze Symposium and look forward each year to the enduring tradition of GeoDaze.

I am pleased and honored to be joining the Department of Geosciences Advisory Board.

Sierra Nevada Drip, cont’d...

the surface. The southwestward migration of the drag on the base of the crust over the past 3-4 million years may eventually help to unify explanations for such diverse tectonic features as Long Valley volcanism (e.g. Mammoth Mountain), the geomorphic variations of valleys on the western flank of the Sierra Nevada (e.g. Yosemite Valley vs. San Joaquin River Valley), and recent San Joaquin Valley subsidence and sedimentation. So the next time you are driving across the Sierras, think about the amazing parallel journey of the southern Sierra Nevada drip, and its potential influence on the passing scenery.

This article is based on a paper in press in International Geology Review, Vol. 45, 2003.

References


The 31st annual GeoDaze Symposium was held at the newly renovated Student Union, April 10th and 11th. The 42 talks and 27 posters presented exemplifies the diversity and multidisciplinary nature of geoscience research today. Topics covered biogeochemistry, paleoclimatology, geoscience education, paleomagnetism, reflection seismology, geophysics, geoarchaeology, planetary science, sedimentology, paleoecology, economic geology, geomorphology, and tectonics. Graduate and undergraduate students from Geosciences participated, as well as individuals from other departments and institutions. Twenty-five awards were given during a ceremony that followed all of the presentations.

Dr. Francis Albarede, Geochemistry Professor at the Ecole Normale Superieure in Lyons, France, was the keynote speaker. He spoke about “The Cooling of the Lithospheric Mantle and the Earth’s Thermal History.”

The 2003 GeoDaze field trip, led by Emeritus Professor William Dickinson, visited Gardner Canyon and looked at sedimentology and tectonic context of the Mesozoic Strata in the Santa Rita Mountains, with a discussion of their regional context on the side.

The GeoDaze field trip visited Gardner Canyon in the Santa Rita Mountains.

A special thanks goes to the Co-Chairs Allison Drake and Becca Walker for all of their dedication and hard work. We are also very grateful to the individuals and companies who contributed financially to GeoDaze (see below).

Finally, a big round of applause goes to all of the students, faculty, staff, and alumni for making the GeoDaze tradition of showcasing student research another great success!

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Co-chairs Allison Drake and Becca Walker
GeoDaze Awards

Errol Montgomery Prize for Best Overall Talk
Jonathon Dorn

Murray Gardner Prize for Best Talk Based on Field Work
Shundong He

Best Graduate Poster
Aaron Thompson

Best Undergraduate Talk
Hector Hinojosa

Best Undergraduate Poster
Jake Bailey

Biogeochemistry
Prize for Best Talk
Kalbo Stevenson
Prize for Best Poster
Christa Placzek

Geoscience Education
ChevronTexaco Prize for Best Talk
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Prize for Best Poster
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Andrew Hennes

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Guilbert Prize for Best Talk
Steve Young
Enders Prize for 2nd Best Talk
Fernando Barra
Prize for Talk
Victor Valencia
Prize for Poster
Stacie Gibbins

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Kevin Anchukaitis
ChevronTexaco Prize for 2nd Best Talk
Kirsten Rowell
Prize for Best Poster
Jana Van Alstine
Prize for Talk
Carlos Cintra

Structure/Tectonics
Prize for Best Talk
Aaron Martin
Prize for 2nd Best Talk
Andrew McCarthy

Fall Degrees 2002

Bachelor of Science
Karen Bossenbroek • Christopher Call • Jennifer Fimbres
Vena Jones • Olena Krawciw • Erin Rosenberg • Samantha Rubinson

Master of Science and Doctor of Philosophy

Jason Barnes
Variable Denudation in the Evolution of the Bolivian Andes: Controls and Uplift-Climate-Erosion Feedbacks, Jon Pelletier

Julie Hamblock
Lithology, Alteration, and Mineralization in the Eastern Mexican Alkaline Province, Mark Barton

Elena Shoshitaishvili
Geophysical Investigation of Archean and Proterozoic Crustal-Scale Boundaries in Wyoming and Colorado with Emphasis on the Cheyenne Belt, Roy Johnson

Congratulations to all of our graduates, and best wishes in your new pursuits!
**Josef Chmielowski (MS '99)**
I was George Zandt's first student at the UA. I started in 1996, and I graduated in 1999 with an Master's Degree in Geoscience (Geophysics). I worked with George on the Bolivian Altiplano-Puna Volcanic magma body. My other two advisors were Susan Beck and Clem Chase. I started work with BP in October 1999, in Anchorage, Alaska as a geophysicist. I am a recruiter for BP on the UA campus. ~chmielj@bp.com

**Brooke Clements (MS '91)**
The photo below shows a group of UA alumni (Geoscience students with graduation dates spanning almost three decades) gathered at the Cordilleran Exploration Roundup in Vancouver, B.C., Canada, in January 2003. The Roundup is one of the world's major exploration conferences with over 3,000 delegates. ~brooke.clements@ashton.ca

Incredibly dismaying, as the issue of "recreational mining" skewers the public debate concerning mining on public lands. If the public-at-large only knew the reality of the situation — and of course, had Congress act on this knowledge, we could prevent much unnecessary damage to "our" lands, and focus instead (if we wish, and apparently we don't) on other public land issues that have more substance. Like actual mining — which is necessary, but carries a huge mortgage that our kids will most certainly pay. Now, I work for the National Park Service, and we live in the U.S. Virgin Islands. Who would have guessed that we'd live in Paradise, and yet long for the Sonoran Desert in the smallest fibers of our souls? We're expecting our first child in September, late bloomers through and through. We can't wait to get back to the Craton. ~ stjohnspock@earthlink.net

**Lisa Wald (MS ’87) & David Wald (MS ’86)**
In November of 2002, Dave and I made a bold move and transferred to the USGS office in Golden, Colorado. We love it here! ~lisa@usgs.gov

**David Schaller (BS ’70)**
David is the Sustainable Development Coordinator in the U.S. Environmental Protection Agency’s Denver, Colorado office. David was a member of the U.S. Government delegation to the United Nations World Summit on Sustainable Development held in Johannesburg, South Africa, August 26 to September 4, 2002. His responsibilities included teaching a short course on clean energy at the Smithsonian Summit Institute. ~schaller.david@epa.gov

**John Matis (MS ’70)**
I recently moved to Santa Fe to become BLM’s recruiter for New Mexico and Arizona. This includes all jobs, all levels, plus student positions. Priorities will be based on workforce planning needs and diversity objectives. Anyone with ideas feel free to email. ~jon_matis@blm.gov

**David Shafer (PhD ’89)**
As Associate Research Hydrogeologist for the Desert Research Institute, David manages DRI’s contract for the U.S. Department of Energy in the Nevada Operations Office. This multidisciplinary science and engineering contract includes work related to groundwater flow and contaminant transport, waste disposal and other vadose zone issues, flood hydrology, environmental monitoring, cultural resources, energy research, and long-term environmental stewardship and strategic planning. His research interests include Quaternary paleo-environmental contributions to present-day resource management for public lands, long-term stewardship of legacy waste, environmental monitoring, vadose zone hydrology, and arid region geomorphology. ~dshafer@dri.edu

**Walt Keyes (BS ’83)**
Until a year ago, I worked in several U.S. Forest Service offices, the last being in Tucson. I headed the Minerals Section (but functioned as a Civil Engineer), which means I dealt with issuing “Plans of Operation” to a dichotomous mix of real corporate miners and unreal (gold-feverish) “recreational miners.” This was an incredibly dismaying, as the issue of “recreational mining” skewers the public debate concerning mining on public lands. If the public-at-large only knew the reality of the situation — and of course, had Congress act on this knowledge, we could prevent much unnecessary damage to “our” lands, and focus instead (if we wish, and apparently we don’t) on other public land issues that have more substance. Like actual mining — which is necessary, but carries a huge mortgage that our kids will most certainly pay. Now, I work for the National Park Service, and we live in the U.S. Virgin Islands. Who would have guessed that we’d live in Paradise, and yet long for the Sonoran Desert in the smallest fibers of our souls? We’re expecting our first child in September, late bloomers through and through. We can’t wait to get back to the Craton. ~ stjohnspock@earthlink.net

**John Hite (MS ’65)**
I am working hard to develop a gold mine in Myanmar, but my real passions are my two grandchildren, Caroline and Pierce, ages 3 and 16 months. Oh yes, golf at our summer place at Priest Lake, Idaho. ~jhite@eagc.com

**Joe Chmielowski in Alaska**
I visit in the spring to attend GeoDaze and in the fall to conduct interviews. ~chmielj@bp.com

**Brooke Clements (MS ’91)**
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In November of 2002, Dave and I made a bold move and transferred to the USGS office in Golden, Colorado. We love it here! ~lisa@usgs.gov

**Seated, Tom McCandless (PhD ’94), standing left to right, Brooke Clements (MS ’91), James Lang (PhD ’91), Moira Smith (PhD ’90), Doug Silver (MS ’80), Wojtek Wodzicki (PhD ’94), Peter Megaw (PhD ’90), Stephen Enders (PhD ’00), Clancy Wendt (MS ’74), Robert Shafer (MS ’79), George Sanders (76-79), Lance Miller (PhD ’94), Stan Keith (MS ’78), William Wilkinson (PhD ’81), William McClelland (PhD ’90)**
1990s cont'd...

Alan Cutler (PhD ’91)
Alan, a geologist and writer affiliated with the Smithsonian, recently had a book published called The Seashell on the Mountaintop about the Danish scholar Nicolaus Steno who some refer to as the founder of geology. The book was reviewed by Kevin Padian in The New York Times (April 27, 2003). According to Padian, “Cutler’s book is marvelous for making one think about what qualifies as an explanation, and for exploring the endless debates that mix strands of partial knowledge with the need to reconcile religious testaments.” Look for this book in your local bookstore!

Tim Demko (PhD ’95)
In August of 2002, I resigned my position at ExxonMobil after 6 years in the oil patch. Working there was a great experience for me, and I was able to travel to many interesting places around the world to do both subsurface projects (North Sea, Canada, Alaska, Kuwait, Nigeria) and field work (Spain, Kuwait). However, I wanted to pursue my goal of teaching at the university level. After a few interviews, a position at the Univ. of Minnesota Duluth seemed like a great place for me to start an academic career. I was lucky enough to actually get an offer; so I loaded up the family in Duluth, Minnesota! This first school year has been very busy as I’ve been developing new courses and getting my research efforts geared up. I teach the sedimentology/stratigraphy courses, earth history, life and death of the dinosaurs, field camp (of course), and several upper level stratigraphy/basin analysis (sequence stratigraphy) courses, earth history, life and death of the dinosaurs, field camp (of course), and several upper level specialty courses (sequence stratigraphy/basin analysis type things). The bulk of my research continues to be on the Mesozoic rocks of the Colorado Plateau and Rocky Mountain regions. I have plans to start some local projects (looking at the Mid-continent rift succession, BIF’s, Paleozoic marginal marine sequences, and maybe some Quaternary sediments), and pursue some projects farther afield (IODP cruise to SE Asia, fluvial/lacustrine sequence stratigraphy in Spain). I will have two new grad students working with me next fall. One is working on the sequence stratigraphy of Gulf Coast strata. The other is looking at Triassic lacustrine deposits in Utah. Please stop and say hello if you are ever in the Duluth area!
~tdemko@d.umn.edu

2000s

Michael Henley (BS ’96)
After graduation, I worked for ASARCO Mission complex south of Tucson for a year as an Assayer. The copper industry began to plummet, and I decided to pursue a MS Degree in Geological and Geophysical Engineering at the UA. After graduation in 2001, I worked for Zonge Engineering for a year before finding a happy home as a geophysicist with Hydro-Geophysics Inc., in Tucson. I am currently married, and we are eagerly awaiting the birth of our daughter in April.
~mhenleyaz@comcast.net

Gregg Garfin (PhD ’98)
I was married on October 2002, to Roberta Brack of Tucson. I currently work for the Institute for the Study of Planet Earth’s (ISPE) Climate Assessment for the Southwest (CLIMAS) project as Assistant Staff Scientist. I am responsible for outreach to stakeholder groups in Arizona and New Mexico on issues of climate variability, drought, and fire.
~ggarfin@email.arizona.edu

2000s

Melissa Giovanni (MS ’02)
I have begun my PhD at UCLA under Brian Horton. My project will consist of structural reconstruction, basin analysis, and thermochronology of the Cordillera Blanca normal fault and the Marañon fold-thrust belt in central Peru. My next field season will be this summer.
~giovanni@ess.ucla.edu

Delores Robinson (PhD ’02)
Delores and Jeff Herndon are happy to announce the birth of their daughter Hannah Faith Herndon on March 8th, 2003.

Hannah was born at 10:47 am
She weighed 6 lbs 10 ozs, and was 20 inches long with green eyes and blond hair. Everything about little Hannah is perfect except for our picture taking ability. Here is one of our attempts to capture her best qualities. Jeff and I have enjoyed this rite of passage and look forward to the next 18 years.
~dmr@geo.arizona.edu

Other News

Birth

Retirement
Cyndy Christopoulos retired in April after 30 years of service at the UA and almost 20 years with Geosciences. Cyndy plans to join the Arizona Gold Prospector’s Club, become more involved at the Tucson Botanical Gardens, and volunteer at her Veterinarian’s office one-day-a-week. She is also working on her house and planning a vacation to New York. We wish her well in all of her new activities!

Memorial
William Price, BS ’46, MS ’48, PhD ’72, died August 11, 2001, in Tucson. Bill first studied Geology under E.D. McKee in 1944. John Harshbarger had been a friend from Graduate School when Bill signed up for courses in John’s new Department of Hydrology in 1963. Bill eventually received one of the first PhD’s in Hydrology. After he retired from the USGS, Water Resources Division, he moved back to Tucson and his first love, the geology of the Southwest.

Mark Your Calendar
GeoDaze 2004 will be held on Thursday and Friday, April 1st and 2nd at the University of Arizona in Tucson. As always, there will be a field trip scheduled on Saturday, April 3rd. Please mark your calendars now, and plan to join us next spring.

Alumni Drawing Winner
ax Baumeister (BS ’76) from Albuquerque, New Mexico, won a eosciences T-Shirt for sending in his updated contact information.
Please update your contact information!

We are especially interested in your **E-mail address** as we hope to produce electronic news bulletins in the future.

Name ________________________________

(Circle the address that you prefer as a mailing address.)

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New job? Kids? Back in school? Retired? Attend national meetings? See a classmate? Take a trip? Send us your news for future newsletters (please include a photo that will be returned).

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