

geophysics

Colorado School of Mines

Spring 2005



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On our Cover



From the Department Head



Terry Young

For some time now everyone's been talking about the impending "great crew change" — mass retirement of the "boomers" — looming just around the corner. It appears we've turned that corner, both internally and externally. Internally, we're experiencing faculty retirements — Phil Romig and Ken Lerner last summer, Hengren Xia last fall, and both Alex Kaufman and Max Peeters this spring. Really, though, Phil

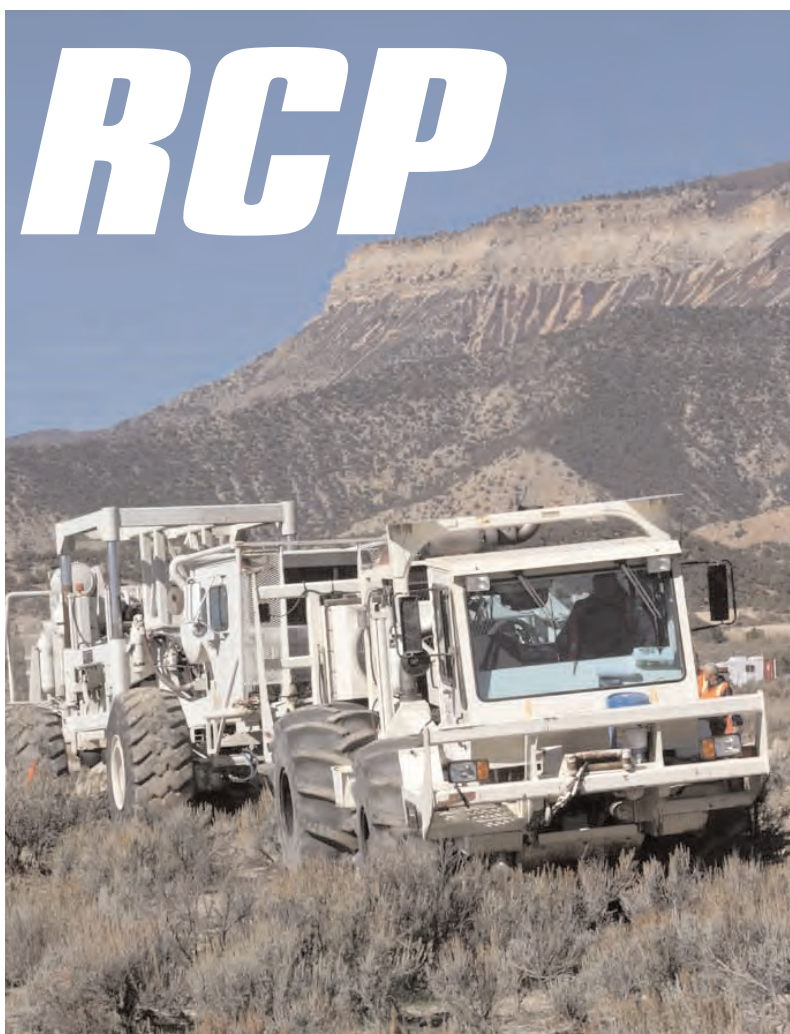
and Max are in transition for the next couple of years; Ken is still learning how to retire, so we haven't noticed a difference with him; and we'll just have to wait and see with Alex. Fortunately, we added Kasper van Wijk as a new research faculty member last spring. More recently, we are thrilled to have welcomed Dave Hale as the new Charles Henry Green Professor of Exploration Geophysics and Manika Prasad as our newest research faculty member. And we are excited about the new additions that will derive from the faculty search now underway.

Externally, companies, agencies, and universities who want to hire geophysicists have evidently turned the corner, too. We've been experiencing something just short of a "feeding frenzy" as recruiters come to campus seeking to hire our graduates. Across the U.S. in the past 20 years the number of students pursuing geophysics and related fields declined from 45,000 to 15,000. So there is a serious shortage of young people to fill the jobs available now and in the foreseeable future. We have enjoyed a strong, steady enrollment of 50 undergraduates and 50 graduates for years. This fall our enrollment jumped 20%!

A lot of good things are happening. And I don't have space here to say more. So read on and enjoy!

The photograph on our cover is a road cut through the Dakota Hogback along I-70, west of Denver and just over the hill from our campus in Golden, CO. The photographer is Lowell Georgia, photo editor for *Oil and Gas Investor* magazine and a freelance photographer. He was a co-founder and part owner of *Investor* in 1981, and has shot all but three of its cover stories. Georgia spent two years in Washington, D.C., as a National Geographic Society staff picture editor followed by 20 years of photographic assignments for the Society in various parts of the world. He has won numerous awards for his photographs including the National Press Photographer Association's Photographer of the Year. In addition to his involvement with Hart Energy, Georgia's work continues to be published in other international publications.

A second photograph taken by Georgia appears on page 3. We are grateful to Mr. Georgia for permission to use these photographs.



Equipment used by RCP, provided by Solid State, for the Rulison Field full-wave survey.

— Photo by Lowell Georgia

Reservoir Characterization Project *Celebrates* 20



Tom Davis

So, where's the breakthrough? Many of you have heard of high definition television. Well, to have high definition seismic imaging you need high sampling density, and to have high sampling density you need lots of receivers, not just any old receivers. We have smart digital receivers now and not just analog. As a result, we have higher dynamic range and greater fidelity to record the total wavefield. Moreover we can put out thousands of these sensors in patches and record day and night, using active full wavefield sources as well as passive recording during times that the sources aren't operating. It is obvious that the data volume and density is overwhelming, yet we as geophysicists have been pushing the limits of the computer industry for years and will continue to do so as Full Wavefield Imaging becomes more routine.

Where do students fit in? The answer is like the kids in Toys R Us, only it is Data R Us in RCP. It's fun seeing the unseen, utilizing medical imaging technologies over reservoirs. It makes you self-conscious — wondering what people see in you. In our case, new images help us understand what makes reservoirs tick and help us develop ways to keep them ticking, like the Energizer Bunny. The really good news is that armed with a better understanding of reservoirs, we can also find new ones using this technology. A new wave of exploration is starting to emerge at last.

Enhancing our Image

— Tom Davis

To some people image is everything. To students and faculty alike in the Reservoir Characterization Project (RCP) image is the *only* thing. Without a good image of our reservoirs we are leaving 70% of the oil in the ground, on average, and 50% of the gas. To enhance our image and to help increase our recovery factor, RCP is using Full Wavefield Imaging. This method is not new to RCP as we shot the first 3-D Full Wavefield survey in Silo Field near Cheyenne in 1987! We've come a long way.

As RCP prepares to celebrate its 20th anniversary we look back on how it grew from a fledgling idea of using shear waves to find fractured reservoirs to a whole new way of looking into the subsurface. For a blind man it is akin to seeing for the first time or for a person in need of glasses, clarity at last. Why the breakthrough and why has it taken so long? The answer is cost — the cost of developing any new technology, especially of this magnitude, is prohibitive if you are doing it yourself. The niche that RCP fills is that we bear the costs as an industry consortium. There is an old adage that you are only as good as those around you. Fortunately in this arena we *have* to be good considering the supporting cast that forms RCP.

TOP Year for Those on the Green Center's Bottom Floor

— John Scales

2004 was a great year for infrastructure modernization in the Physical Acoustics Lab (PAL), located on the “garden level” of the Green Center. PAL received two major grants for equipment from the National Science Foundation.

First, in collaboration with Manoja Weiss (CSM Engineering Division) we have been awarded a Major Research Instrumentation (MRI) grant to purchase a millimeter wave vector network analyzer from AB Millimetre in Paris.

This is a remarkable and unique instrument that is tunable from the microwave to the sub-millimeter wave regime. It will allow us to simultaneously measure the amplitude and phase of transmitted and reflected EM waves over an unprecedented range of frequencies.

There are only six of these instruments

PAL

Physical Acoustics Lab

<http://acoustics.mines.edu>

in the U.S. and a few more than 50 around the world. It's quite remarkable to be able to do quasi-optical experiments and yet have complete control of both the amplitude and phase of the EM wavefield for materials characterization and fundamental physical studies.

Secondly, we received a large Facilities and Infrastructure (F&I) grant to purchase state-of-the-art lasers for our studies in ultrasonic and seismic multiple scattering. One laser (a Quantronix pulsed Nd:YLF) will be used as an ultrasonic source (300 times faster than our

current source), while the other is a state-of-the-art externally stabilized, all fiber, femtosecond laser from Menlo Systems in Munich.

By going to a femtosecond-pulsed laser for our ultrasonic measurements, speckle from rough surfaces is eliminated. By stabilizing the laser with an external atomic clock we will be able to exploit recent advances in precision measurements via so-called optical combs.

With these grants our infrastructure has increased by \$500,000. We have well-equipped parallel laboratory efforts now in a wide range of optical and microwave/millimeter wave techniques applied to seismic and ultrasonic wave propagation and scattering.

Exploring New Acoustic Methods

In the Physical Acoustics Lab we are investigating a new acoustic method to detect buried landmines without having equipment touching the ground.

This project, sponsored by the Army Research Office, involves faculty members John Scales and Kasper van Wijk along with undergraduates Dylan Mikesell and Jared Peacock.



Dylan and Jared playing in the sand.

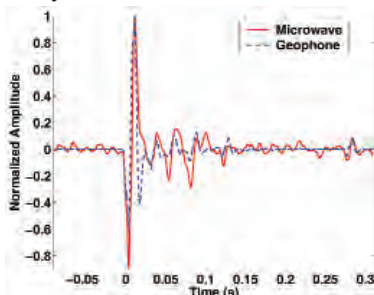


Fig. 1. Comparison between processed microwave and geophone data in grass. Reflections are seen in these data (for example at 0.28 s), which are likely caused by heterogeneity in the subsurface.

We have built an ultrasonic parametric array to focus an intense beam of sound on a spot on the surface of the ground. You can think of this tool as the acoustic equivalent of a flashlight.

This local energy is converted into the soil, where a non-contacting microwave detector (similar to a police radar) measures the motion of the soil in a region around the insonification spot. Using such a system, we hope to measure a unique reaction of the landmine to seismic waves.

To test the microwave receiver, we hit the ground with a hammer, and watch the (surface) waves come by with the micro-

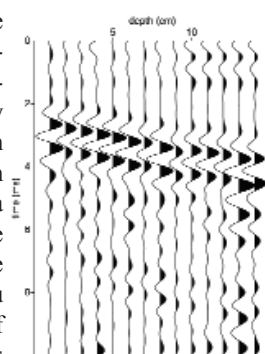


Fig. 2. Measurements with buried piezoelectric transducers of a compressional wave excited in air penetrating sand. Amplitude is well conserved with depth because the plane-wave character of this parametric array source limits geometric spreading of its energy.

wave detector a few meters away, even in a grass field (Fig. 1).

The parametric array has proven to excite seismic waves in a sandbox that Dylan and Jared built. After shining the sound at the box, we detect ground motion with sensors planted in the box (Fig. 2). These findings were published in *Geophysical Research Letters*, vol. 32, L01308, 2005.

Our next goal is to build a stronger parametric source and a more sensitive microwave detector, so that we will have a completely noncontacting landmine detection system!

— Kasper van Wijk

Welcome, Kasper!

As a Ph.D. student of John Scales, Kasper van Wijk gave one of the most outstanding and memorable thesis defenses in recent memory. Due to his prolific research output, John hired Kasper first as a post doc and then recommended him for a research faculty position. We are fortunate to have Kasper as a recent addition to our faculty.



SNIEDER TO COLLABORATE WITH SHELL ON GAMECHANGER* PROJECT

A research proposal by Professor Roel Snieder has been chosen as part of the Shell E & P GameChanger program. Shell has agreed to fund the three-year project “Virtual-source Imaging and Monitoring of Hydrocarbon Reservoirs,” a collaboration of Roel with Rodney Calvert and Jon Sheiman at Shell Research. The goal of this GameChanger Project is to further develop the use of incoherent sources (such as noise created by ships) for seismic imaging, which is important for permanent monitoring of hydrocarbon reservoirs because interferometric imaging does not rely on the availability of the active sources that are normally used in seismic surveys. A related interferometric project is described below.

Studying Hazards: Using Interferometric Imaging to Monitor Building Response

— Roel Snieder

Buildings may fail when they are shaken by a strong earthquake. The response of a building to a given ground motion depends on the resonant frequencies of the building, and on the attenuation of wave motion in the building. A stronger attenuation leads to a stronger damping of the wave motion in the building; this reduces the danger of structural failure.

Roel Snieder investigated this problem in collaboration with Erdal Safak of the US Geological Survey in Pasadena. They analyzed the wave motion recorded in the basement and ten floors of the Millikan Library on the Caltech campus during an earthquake (see left figure below).

Using the new technique of interferometric imaging,

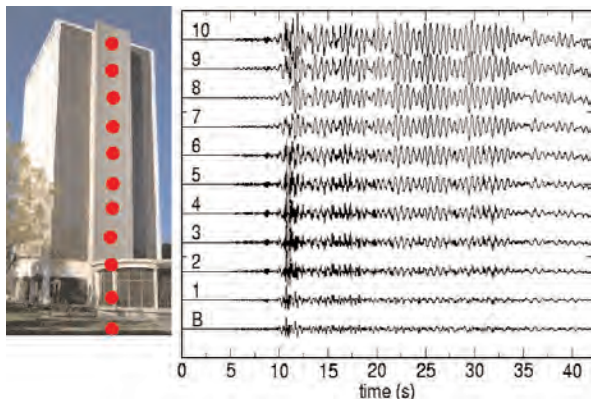


Roel Snieder

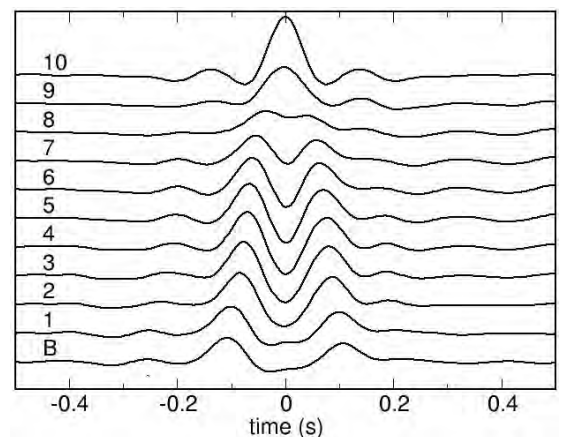
Snieder extracted from these data the response of the building at each floor (shown below in the figure on the right). In contrast to the wave motion during the earthquake, these processed data are very simple — consisting of one wave that travels up in the building and one wave that travels down.

The velocity of the upgoing and downgoing waves can easily be measured, giving information about the stiffness of the building. At every floor the amplitude of the downgoing wave is slightly lower than the amplitude of the upgoing wave. This property has been used to measure the attenuation of waves in the building, which provides valuable information to structural engineers about the strength of the building.

*GameChanger is an initiative within Shell E & P to support projects that have potential to improve profits or to open opportunities for growth. The proposals must contain new perspective on a problem, a new source of information, a new product or a new vision. Information about the GameChanger process is at <http://www.gamechanger.nl/>.



Left: The Millikan Library on the Caltech campus. Red dots indicate placement of seismometers. Right: Wave motion during an earthquake.



Response of the building using interferometric imaging.

Studying Space Dust

— Gary Olhoeft

Gary Olhoeft has joined with Masami Nakagawa (Department of Mining) to create a new center on campus whose goal is to study the “mitigation of dust and electrostatic accumulation for human and robotic systems for lunar and martian missions.”

The soils on the moon and Mars are so fine, they coat everything like paint. Not only does the dust coat surfaces, but it interferes with seals, degrades solar cells and bearings, and carries electrostatic charge, all of which may pose hazards to astronauts and equipment.

Astronauts and rovers disturb the dust as they move around, but there are also winds on Mars that mobilize and transport dust, and on the moon there are dust levitation and transport mechanisms that create dust storms at the lunar terminator visible to astronauts in lunar orbit.

Since his work on the Apollo program in 1970, Gary Olhoeft has been followed around by a large space simulation chamber, now in storage in the basement of the Green Center. When refurbished during the next year, the chamber will become the centerpiece of this new Dust

Center (yet to be named). It will be used both for experiments to character-

ize and understand the properties and processes related to dust, and to create lunar and martian simulants. Because the Green Center infrastructure cannot support operation of this facility, it will be housed in the new CSM research building.

On the Earth, activities that raise dust (such as mining and construction) com-

monly control dust by spraying water. On the moon and Mars, not only is water too rare to be used in this way, but temperatures are too cold. As the dusts have already evidenced the ability to be electrostatically charged, other methods of mitigation must be used,

very likely including electrostatic dust control, much like in a laser printer, only on much larger scales.

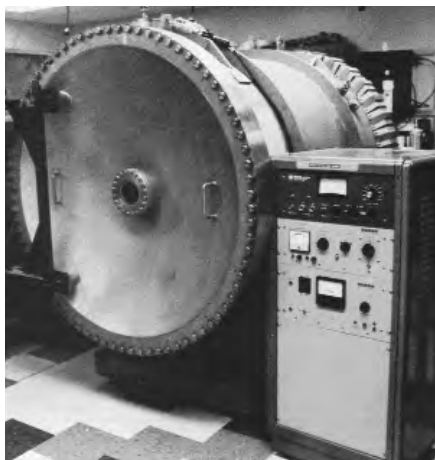
In addition, the nanophase iron on the moon and hematite on Mars are expected to exhibit unusual magnetic properties, including magnetic rheological processes that may explain the airbag imprints on the soil

at the Mars Exploration Rover Opportunity landing site. Nanophase hematite has important industrial applications on the Earth (such as disk drives) but magnetic rheology has not been previously recognized as an important geological process.

Measuring and understanding the properties and processes associated with these lunar and martian dusts will be the focus of the new Center, with a particular emphasis on determining methods to mitigate their impact on human activities, such as mining to construct habitats.



Apollo 17 astronaut Gene Cernan is to the left of the gnomon and is holding the geology hammer. Before their arrival at this Station, the replacement fender on the lunar rover vehicle began to fail and the astronauts were showered with dust. Image Credit: Nasa Johnson Space Center.



Space simulation chamber to be used for lunar and martian dust experiments at CSM. The chamber is capable of duplicating the pressure and temperature on the surfaces of the moon and Mars. It is one of the largest such chambers in any university in the U.S.



This color image shows the martian landscape at Meridiani Planum, where the Mars Exploration Rover Opportunity successfully landed. Note the “wet mud” look to the hematite soil, showing the imprint pattern of the landing airbags. Image credit: NASA/JPL/Cornell.

Remote Sensing

During the past several years there has been a growing interest on campus in the subject of geohazards, such as earthquakes, landslides and volcanoes. This is an interest we share with the Hazards Branch of the USGS, including the National Earthquake Information Center (NEIC), located right on our campus. Therefore, we've been grateful to have David Wald of the USGS/NEIC as an adjunct faculty member (see article on page 13).

Last year we offered a course on remote sensing for volcano monitoring in which we featured expert USGS volcanologists as guest lecturers. This year we expanded the concept. David Wald and Jill McCarthy, the Hazard Branch's Chief Scientist, joined with us to co-organize a course focusing on the use of InSAR (**I**Nterferometric **S**ynthetic **A**per-**R**ature **R**adar) for detecting surface deformation due to

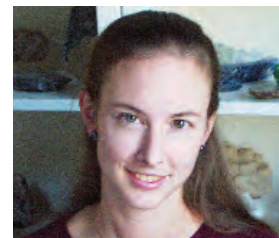
Learning to 'Look before you Leap'

earthquakes, volcanoes, landslides and subsidence. A satellite orbiting 600–800 km above the Earth, which reoccupies the same location relative to Earth's surface at two different times, can make a differential radar measurement that detects centimeter-scale deformation.

In addition to lectures by David Wald and our own Gary Olhoeft and Roel Snieder, we invited presentations from Chris Okubo (U. Nevada-Reno), Rowena Lohman (CalTech/Woods Hole), Nancy Glenn (Idaho State U.), Matt Pritchard (Cornell), Ingrid Johanson (Berkeley), and Brad Aagaard, Randy Jibson, and Gerald Bawden (all USGS). Also, one of our Ph.D. candidates, David Coulter, is an expert in remote sensing from nearly 20-years experience at Newmont Mining Corporation (see inset this page). David gave guest lectures to both last year's and this year's remote sensing classes.

Bringing in the Experts

*Thank you to our guest
lecturers, some of whom
are pictured here.*



Top row: Brad Aagaard, Chris Okubo, and Matt Pritchard.

Bottom row: Nancy Glenn and Rowena Lohman.

Student Profile: Dave Coulter

Dave Coulter is pursuing a mid-career Ph.D. in geophysics and geology through CSM's Integrated Interdisciplinary Graduate (IIG) studies program. His thesis research is on the use of visible-to-infrared remote sensing to map alteration associated with natural acid drainage near Independence Pass, Colorado.

Dave entered Mines in 2003 after an 18-year career at Newmont Mining Corporation. At Newmont he was responsible for the use of remote sensing in the company's worldwide gold exploration programs.



He was also involved in remote sensing and image processing research and development as a member of Newmont's Geophysical Department. He holds a B.S. in geology from Kent State University and an M.S. in geological engineering from the University of Arizona. In addition to attending Mines, he is a collaborative researcher on a Colorado Geological Survey study of natural and anthropogenic acid drainage in tributaries to the Upper Arkansas River.

Dave's motivations for returning to school are to refresh his technical and research skills and to recharge his enthusiasm. He is excited to be expanding his knowledge and sharing his practical experience in remote sensing and exploration.

UXO



Professor Yaoguo Li with GP students during the October field trip to Limestone Hill, Helena Valley, Montana, as part of an UXO detection and discrimination research project.

A new research program on UXO detection and discrimination has provided great opportunities for the CSM Department of Geophysics to contribute to the solution of a pressing environmental problem, while creating excellent educational opportunities for both graduate and undergraduate students.

Unexploded Ordnance Research

— Yaoguo Li

Unexploded ordnance (UXO) refers to munitions such as shells and other projectiles that did not explode upon impact and remain buried in the ground. They occur on or near the ground surface and can detonate when disturbed accidentally. Consequently, UXO poses a significant hazard to public safety in many parts of the world.

In the United States, it is estimated that nearly 11 million acres of land are contaminated with UXO, which is equivalent to Vermont and New Hampshire combined. The estimated cost of clearance is on the order of hundreds of billions of dollars. Thus, developing effective means to clear UXO is an important task for both economical and humanitarian reasons.

Because of the high contrast between physical properties of UXO and the surrounding soil, various geophysical methods have been the primary means of detection. In particular, electromagnetic (EM) induction and magnetic methods have emerged as the most important tools in UXO. It remains a great challenge, however, to discriminate between UXO and non-hazardous metallic objects. Current EM and magnetic data, and associated data analyses, do not always provide enough information for discrimination. Therefore, the UXO community has

been pursuing research to develop new instrumentation and new data techniques for data analysis.

Researchers of the Center for Gravity, Electrical, and Magnetic Studies (CGEM) in the Department of Geophysics at CSM have recently joined this effort with funding from the Strategic Environmental Research and Development Program (SERDP) and the US Army Engineer Research and Development Center (ERDC).

The team currently consists of faculty members Yaoguo Li, Misac Nabighian, and Gary Olhoeft; graduate students David Sinex, Vinicio Sanchez, Todd Meglich, and Whitney Goodrich; and undergraduate student Kris Davis. The team is growing, and we have been collaborating with researchers from other institutions and industry on four projects. The scope of research includes developing new instruments and data analysis techniques, and understanding physical properties associated with UXO clearance.

In a joint project with the USGS, we combine the expertise on instrumentation at USGS with that of processing and interpretation at CSM to

develop new instruments that acquire complementary data using both EM induction and magnetics. The goal is to simultaneously determine the size, conductivity, and magnetic susceptibility of a buried metallic target. The combination of these parameters can provide crucial information for discrimination.

In a project focused on discrimination algorithms, we investigate the statistical properties of multiple parameters of buried metallic objects obtained from inversion of EM and magnetic data. The results will be used to guide the development of statistical discrimination approaches based on active clearance results at UXO sites.

The presence, or lack, of remanent magnetization in UXO and metallic objects has emerged as an important diagnostic parameter in UXO discrimination. A collaborative project with



Undergraduate students Mike Palmieri and Dylan Mikesell looking over the inert UXO items that were wrapped for storage at Limestone Hill, Helena, MT.



Limestone Hill overlooking Helena Valley, Montana

Sky Research and the University of British Columbia aims to characterize this property in UXO and fragments through laboratory and field work. As a part of the project, Dr. Olhoeft's team is developing a mobile SQUID magnetometer system for measuring remanent magnetization of large UXO items.

In a major project that is led by CSM with collaboration from the University of British Columbia, Sky Research, and New Mexico Tech, we investigate the effect of magnetic susceptibility of soil on UXO discrimination. The objective is to understand the spatial variation and frequency-dependence of soil magnetism and their responses in magnetic and EM data. We will also develop processing techniques for identifying and removing such effects in order to improve discrimination capability in magnetic environment.

Four graduate students are currently working towards their graduate degrees in this area. In addition, the program has also provided research and field experiences for undergraduate students. Kris Davis, a senior majoring in geophysics, has carried out research to develop an algorithm for detecting potential UXO targets from magnetic data. That work has been accepted for presentation at the SAGEEP conference in April, 2005.

In October, 2004, five undergraduate students participated in the relocation and storage of inert UXO items in Helena, MT, as part of the research effort on understanding the remanent magnetization (see inset). A field trip taken by a junior geophysics class to the former Lowry Bombing and Gunnery Range enabled students to gain experience in the acquisition of ground magnetic data and appreciation of the issues involved with the practical applications of UXO clearance.

Sore Muscles and Sweat Yield Meaningful Student Experience

— Justin Rittgers

One of the many facets of the geophysics program at Mines that I have grown to appreciate is the wide range (or high bandwidth, as we geophysicists call it) of exciting and important research. UXO detection and discrimination is one such area of research in the Department in which I, and five other students, have been involved. Fall semester, we traveled to Montana with Professor Yaoguo Li, who is heading a project funded by SERDP. We worked with Dr. Cliff Youmans and his team from Montana Army National Guard and colleagues from Sky Research, to recover over 80 inert artillery shells for study in the ongoing project.



Naturally, we were excited when Professor Li asked for assistance in Montana, but we had no idea the saturation of hands-on experience we were about to endure. Despite hiking up and down Limestone Hill, wielding pickaxes and shovels onto gravel-riddled earth for several hours a day, we managed to have an educational and unforgettable experience — and a lot of fun — over the course of four days.

The two sites we visited were of comparable size to the city of Golden, a fact that impressed on us the magnitude of the UXO problem. This is such a small area compared to countries such as Sudan or Laos, where fence posts and even people's huts are actually made out of UXOs. People often die while scrapping metal from these objects or using primitive techniques to locate and destroy them. The current UXO threat is only one of many world-scale problems that geophysics can help mitigate.

On the drive back to Golden, we had the pleasure of watching the full lunar eclipse develop to the east while listening on the radio to the Red Sox finally break "the Curse." A nice ending to a great experience.



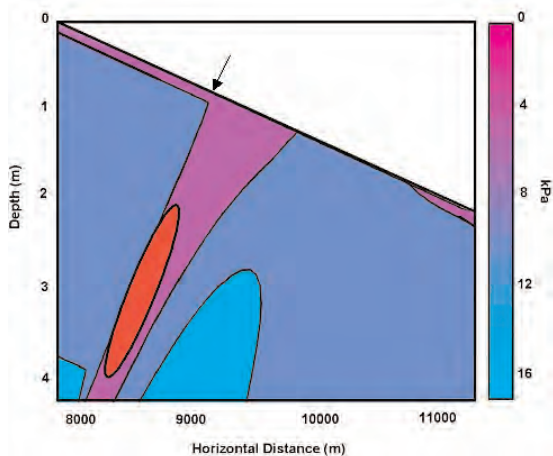
Undergraduate Ross Wagle (left) performing a magnetic survey at the Lowry Bombing Range. Jennifer Livermore (right) working in the field at Limestone Hill, Helena, MT.

In recent months, we have seen devastation due to natural hazards around the globe. One potential hazard takes place right in our backdoor — landslides. The landslides shown in these photos occurred in La Conchita, California. The first took place in March, 1995. Ten years later on January 11, 2005, a second landslide occurred in the same location, killing ten people and providing an eerie resemblance to its earlier failure due to massive rain storms.

Unfortunately, these are not the only types of landslides that could potentially threaten the Western U.S. Geophysics graduate students, Tamara Gippich and Wouter Kimman, are looking into this problem with Professor Roel Snieder. They are investigating a modeling method to research how earthquakes can trigger landslides. This project, which was presented at the American Geophysical Union (AGU) conference in December 2004, is in collaboration with Randy Jibson and Bill Savage of the USGS in Golden, CO, and is funded through the National Earthquake Hazards Reduction Program (NEHRP).

The dynamic stress generated by earthquakes is one of the triggering mechanisms for landslides. There are many methods that try to characterize the ground motion generated by earthquakes, but the role of dynamic effects in slope failure is not completely understood. We have developed a model to investigate the dynamic stress associated with ground motion and to show how this can be used to assess the role of shear and tensile failure in the initiation of slope instability.

The figure below is created using a Mohr-Coulomb analysis of shear stress. Principal stresses are calculated for the slope using the static and dynamic stresses produced and the Mohr circle is calculated at each location. The locations of failure due to the dynamic stress are shown in red while the remainder represents a distance until that location fails. This shows that the triggering of landslides by earthquakes is most likely to occur at a well defined shallow depth. Our model allows us to test for a variety of wave propagation scenarios and failure mechanisms to gain insight into the mode of failure of this potentially devastating hazard.



Example of Mohr Coulomb analysis of shear stress. The region indicated in red fails because of the stress generated by an earthquake.

Dynamic Triggering of Land Slides

— Tamara Gippich & Roel Snieder



La Conchita, California Landslides of 1995 (left) and 2005 (below) caused by massive rain storms.

— Courtesy of the USGS



Responding to the Tsunami Disaster

– Manika Prasad

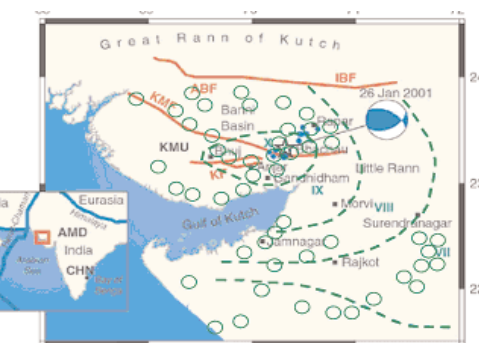


On December 26, 2004, a magnitude 9.0 earthquake occurred off the coast of Sumatra. A giant tsunami spawned off from this mega earthquake and wreaked great devastation in many countries around the Indian Ocean. What made this earthquake unique was not only its high magnitude but the deadly tsunami that it generated. It also drove home the necessity of installing a tsunami warning system and disaster training. While we cannot predict earthquakes, we can certainly map the path a tsunami can take. In the case of the Indian Ocean tsunami, the waves took about two hours to cross the Indian Ocean and reach Sri Lanka and Southern India. A warning system could have saved many lives.

The magnitude 9.0 Sumatra earthquake was one of the largest earthquakes in the past 40 years. Indeed, we have seen only two earthquakes of magnitude 9.0 or higher since 1900: the 1960 Chilean earthquake with a recomputed magnitude of 9.5 and the 2004 Sumatra earthquake with magnitude 9.0. Between 1800 and 1900, there were three events of similar magnitudes. However before 1800, we have indications of only one magnitude 9.0 earthquake in 1687. The

fact that such large earthquakes are rare makes it all the more difficult to study them. Our instrumental records go back only a few hundred years. So, if we wish to assess the seismicity of any area, we need to have data sources that pre-date our instruments.

A cross-dis-



Isoseismal lines of Mercalli Intensity VIII show the extent of the damage zone produced by the 26th Jan. 2001 earthquake (from Gupta et al., 2001) compared with location of Harappan archaeological sites. In this map, red lines mark the outline of major faults that are known today, the broken green lines are isoseismal lines of damage extent, and the green dots mark Harappan sites found in the area. Note that most archaeological sites lie in the zone of Mercalli Intensity VIII.

ciplinary study can provide new information and insights into historical seismicity of an area. For example, the western coastal region of India is not located on a seismic plate boundary and, until recently, was considered tectonically inactive. The January 26, 2001, Bhuj earthquake proved this is not true. Data compiled from current and historic seismicity, marine seismic surveys, and the geologic and tectonic features combined with archeological, historical, and scriptural evidence show signs of earthquake activity as far back as 2500 BC.

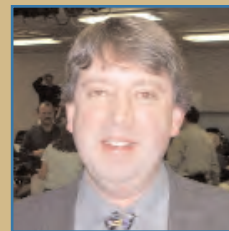
Welcome, Manika!

One of the highlights of our year has been the opportunity to welcome Manika Prasad as a new research faculty member. Mike Batzle, Gary Olhoeft, John Scales, and Kasper van Wijk, our experimental geophysicists on the “garden level” of the Green Center, were keen to invite Manika to join their efforts in fundamental rock properties research. Manika now lists herself as a member of Mike’s Center for Rock Abuse.



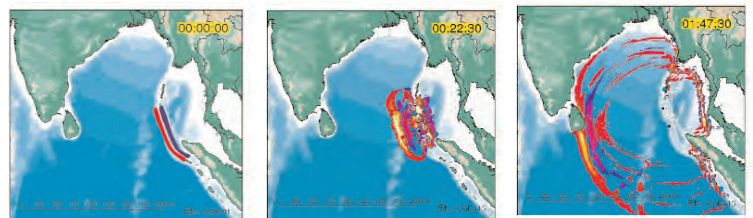
David Wald and Manika

Prior to her arrival at Mines, Manika spent eight years with the Stanford Rock Physics and Borehole Geophysics Project (SRB). She has also worked at the Indian Institute of Geomagnetism in Bombay, and the Mineral Physics Group at the University of Hawaii. Manika earned her B.Sc. (Honors) degree in geology at St. Xavier’s College, Bombay. She received her M.S. (Diplom) in geology and her Ph.D. in geophysics, both from the University of Kiel in Germany.



Eric Geist

Manika made a big impact soon after her arrival on campus by organizing a lecture for an overflow audience on the December 2004 earthquake in Sumatra and the associated, devastating tsunami. The featured speakers were David Wald and Eric Geist of the USGS. Manika was accompanied to Golden by her husband, Gunter Fuchs.



Snap-shots of simulation of tsunami propagation through the Indian Ocean at initiation, after 22 minutes and about 2 hours (images courtesy of Steve Ward).

Kaufman Awarded **SEG** Honor



Announces CSM Retirement

In our Spring 2002 newsletter there was an article entitled, "Professor Kaufman: A Perfect 10", celebrating the fact that Dr. Kaufman perennially teaches four core courses and that many students upon graduation comment on the life-changing experience it is to study under him. Although we are only halfway through the ski season now, Alex has already been to Loveland eleven times. So who would have guessed that young Dr. Kaufman (only 73 this year) would suddenly elect to retire?

Alex Kaufman was born in Moscow, Russia. He studied at the Moscow Institute of Geological Prospecting, where he received his engineer geophysicist degree in 1954 and, after a field experience, his Ph.D. degree in 1959.



Professor Alex Kaufman (left) presented the SEG Honorary Membership Award by President Peter Duncan, October 2004. The award marks "50 years of outstanding research." (Photo courtesy of Norm Bleistein.)

At that time Akademtown was being built near Novosibirsk with a new university and over 20 different research institutes in fields such as mathematics, physics, chemistry, and geosciences. Initially Alex became a senior scientist in the Institute of Geology and Geophysics, and at the same time associate professor in the University. The Institute's mission was to develop resources such as oil and minerals in Siberia.

In 1964, as a result of a book he wrote on induction logging and his other work in the electromag-

netics lab at the Institute, Professor Kaufman received the honorary degree of technical science. The following year, he was appointed as head of the Laboratory of Electromagnetic Fields and became head of the Department of Geophysics of Geology at the University.

In 1974, Alex moved to the Institute of Marine Ge-

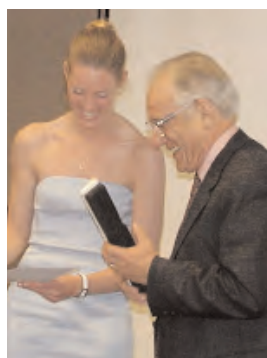
SEG Honorary Membership Award

Alexander Kaufman received the Honorary Membership Award from the Society of Exploration Geophysicists, October 2004. In the words of the accompanying citation, Alex received the award "for 50 years of outstanding research that resulted in numerous ground-breaking papers and a breakthrough patent on electromagnetic methods of exploration and induction techniques." In addition to being a premier educator, "he has made extraordinary contributions to virtually every aspect of the application of electromagnetic techniques to geologic mapping and mineral exploration. He is highly regarded for his leading role in the Geofizik Charity Fund, which he founded to provide health assistance to Russian geophysicists."

ology in Riga, Latvia, where he was invited to develop electromagnetic techniques for petroleum exploration in the marine environment. At that time, Alex and his wife Irina began thinking about emigration from Russia. They accepted an invitation to move to the Geological Survey of Germany in Hannover, where they lived almost one year before emigrating to Canada where Alex was offered a position as Head of Research at Scintrex Ltd. in Toronto. It was there that George Keller from CSM visited Alex and invited him to come to Golden. During the short time that Alex was in Canada, he met the president of Geonics Ltd., Duncan McNeill. Their cooperation and friendship continues today after more than 25 years.

After arriving at CSM, Alex was able to bring to Golden all members of his family, including his parents. Within a year he had his "green card", and a few years later, his U.S. citizenship. When first offered an appointment as a tenured full professor, Alex turned it down thinking he was preempting others who had been here longer and were not yet appointed to full rank. When it was explained to him that his appointment did not affect the chances of others, he did accept it.

Professor Kaufman has two important patents, one granted in 1958 related to time-domain EM, the other in 1989 related to the measurement of resistivity through casing. He has written four books with George Keller, and, just in the past decade, he has written an additional six books, published by Elsevier and Academic Press: a perfect 10!



Always a favorite, Professor Kaufman receiving an "award" during end-of-year festivities from 2003-04 Class President Vanessa Mitchell.

Charles Henry Green Professor of Exploration Geophysics Mines Welcomes Dave Hale

In January 2005, Dr. Dave Hale returned to Mines as the third Charles Henry Green Professor of Exploration Geophysics. Dave's predecessors in the Green Chair were Ed White and Ken Lerner. Dave's selection resulted from an international search conducted last year after Ken announced his intentions to retire. And it is clear from the outset that Dave's impact at Mines will be as different from Ken's, as Ken's was from Ed's.

Dave has a passion for computational science and the use of computer graphics in teaching and research. Just take a look at his webpage!

<http://www.mines.edu/~dhale/>.

His current teaching includes the computer science course Data Structures, and next spring he plans to teach Java to a section of geophysics undergraduates. Dave's research interests involve topics such as atomic meshing and global image segmentation. Of course, Dave also does geophysics.



Dave with grad student Matt Haney.

Currently he is teaching GPGN404 Digital Analysis, which he will teach again in the fall. The object of some of his research is a much tighter connection between the seismic interpretation historically done by geophysicists and geologists and the fluid flow simulation generally done by reservoir engineers.

In 1989, Professor Hale was awarded the Virgil Kauffman Gold Medal "for making an outstanding contribu-

tion to the advancement of the science of geophysical exploration during the previous five years." His contribution was his innovation to dip-moveout processing that facilitated its widespread use in seismic imaging.

Dave was previously on the Department of Geophysics faculty as an associate professor. Before that he worked both as a field seismologist and a research geophysicist at Western Geophysical and in R&D at Chevron. More recently he was a software developer and chief geophysicist at Advance Geophysical. Just prior to returning to CSM, Dave served as a senior research fellow for Landmark Graphics.

Welcome back, Dave!



David Wald

Adjunct Professor Strengthens USGS Collaborations

Some may remember the close connection that existed between the Department of Geophysics and the USGS earthquake group when Maurice Major was on the faculty. At that time the National Earthquake Information Center (NEIC) and the Department of Geophysics were both located in the Green Center.



Later, along came Tom Boyd from Columbia University, who has also been a catalyst for strong interaction between the two organizations. Most recently, Roel Snieder has fostered close interaction between our department and scientists at the USGS.

It takes people on both sides to build a strong link between two organizations, so we were delighted when NEIC's Dr. David Wald inquired about an adjunct appointment to the Department.

David has been very active in building strong relationships between NEIC and CSM. He has not only lectured in our classes and served on graduate committees, but he has also hired several undergraduates to work on important USGS projects.

Working on a part-time basis since last summer, sophomore Alicia Hotovec has already written software documentation and is now comparing ground motion in the Eastern and Western U.S., evaluating intensity attenuation as a function of distance and

magnitude. Junior Tanya Slota is working on the web pages and associated relational database for the USGS global Internet intensity ("Did You Feel It?") system. And Junior Matt Donnelly is working with both David and his colleague Paul Earle on global earthquake casualty and loss databases for implementing the Prompt Assessment of Global Earthquake Project (PAGER) system. In addition, CSM computer science students Marcus Strautman and Paul Krause are working part-time on programming databases and web interfaces for the USGS.

David is now an integral part of our faculty, and we appreciate his participation in the Department.

Mo Crous

Class of 1971

Life after the Oil Patch

Mo Crous fondly remembers his time at Mines. He had the great fortune to have been one of the last students of Prof. John Hollister, and to have completed his M.Sc. thesis under Prof. George Keller.

After graduation (M.Sc. Geophysical Engineering, 1971) he became a well-rounded E&P geophysicist in the oil patch, ending his career in 2002 as chief geoscientist for Talisman Energy in Calgary.

Mo's experience following retirement demonstrates how a Mines education prepares its alumni for the impossible! Mo spent two years at Daystar University, a small, private university in Kenya, East Africa. Mo served as Deputy Vice Chancellor for Finance, Administration and Planning



ty formed a task team assisted by an outside consultant, and by early October 2003, new structure and operating guidelines were approved. Staff count was reduced from 519 to 259, with associated reduction in overall cost, even after including the cost of outsourced services. Retrenched staff were treated very fairly

un-African, to say the least!

The University

mits that during his two years in Kenya, there was no need to recall those troublesome Hankel Transforms or Erdélyi's Higher Transcendental



Daystar University Graduation 2004.

Alumni Checking In

We love to keep in touch with former students and faculty. Here are recent messages from a few of our alumni. Let us hear from you: tkyoung@mines.edu.

(vice president, in North American terms). Imagine!

In 2002, Mo accepted the invitation from Daystar University Council to develop a sound financial planning and control system for the University. Little did he know that the financial concerns were mere symptoms of a great need for refocusing, cost cutting and "rightsizing"!

After about three months of analysis, a restructuring plan was approved to refocus the University on its core business — teaching and learning — and to outsource all non-core activities. Well, after his 16 years of doing these very things at Talisman, Mo was well equipped to take on this thankless task! His African Colleagues also graciously allowed him "to go fast!" — quite

and received severance packages similar to what is paid in the US and Canada.

By June 2004, Mo was pretty "burnt out", and completed his volunteer, unpaid tour of duty. The University now is on the path to recovery, and at year-end 2004 reported a modest operating surplus of KSh 20 million or about US\$ 270,000, compared to a shortfall of about KSh 80 million or more than US\$ 1 million the year before.

Mo jokingly ad-

Functions of 1971! The situation just called for utmost diplomacy to convince and guide his African colleagues through a most difficult time. Success was achieved and, he is certain, will be maintained and improved.

The future political and business leaders of East Africa are being educated at Daystar University — a very exciting and rewarding prospect to Mo. He fully expects to be invited to the inauguration of the President of Burundi, one day!



African sunset.

Jason Gumble

Class of 2000

Since graduating with a B.S. from Mines in 2000, I have been pursuing my Ph.D. and researching multi-component seismics with Dr. Robert Tatham in the Jackson School of Geosciences at the University of Texas at Austin. This research is currently funded under a Petroleum Research Fund Grant.

Later this year, I anticipate defending my thesis and entering “the industry” with **bp**. I have been fortunate throughout graduate school to have been able to continue a cooperative effort with Tom Davis and the Reservoir Characterization Project (RCP) at Mines.

Presentations of the multicomponent seismics research have taken me back to Denver (the SEG meeting) and Golden (the RCP meeting) and as far



as Paris, France, for the EAGE meeting. During this next year I’m anticipating presentations in Madrid, Spain, Pau, France, and hopefully Calcutta, India.

Three internships and a couple of extra-curricular projects have taken me to some far-off and not-so-far-off places; most recently, to Denver with WesternGeco working on a joint research project; to Houston, of course, working with both Marathon and **bp** on interpretation and seismic attributes; to Ankara, running a resistivity survey with AGI; and to the Cumberland Gap region working as my wife’s geologic field assistant.

Perhaps the most significant event in

my life since graduation was getting married and spending six weeks on the west and south coasts of Australia, playing guitar in wineries and wishing we could stay forever.



Jason as a Texas Longhorn

Alumni Checking In

David Rampton

Class of 1985, 1995

A CSM degree can really take you places! David Rampton earned a Bachelor’s degree in geophysical engineering in 1985 and re-



turned ten years later for a Master’s degree in 1995. Unfortunately, this

decade won’t see delivery of another CSM degree, since David is currently working for Shell International E&P in Aberdeen, Scotland, and will soon transfer to Stavanger, Norway. David has been fortunate (from his point of view) to enjoy the benefits of an international career, since the first job out of school was also in the North Sea working as a wireline engineer for Schlumberger, with postings in Scotland, Denmark, and the Netherlands.

David also worked for Amoco Trinidad in exploration for a few years before the opportunity to work internationally for Shell presented itself.

“A CSM degree can really take you places!”



David in Morocco.

Guy H. Towle

Former GP faculty member and CSM alumnus Guy Towle died February 2004. Guy received a BS at Mines in geophysical engineering in 1953 and returned for a PhD earned in 1978. In addition to his career in geophysics that included working at Halliburton, Welex, and PBT Inc., Guy was a life-long judo enthusiast, twice winning his age division in Masters competition. He is survived by his wife Ann and four children.

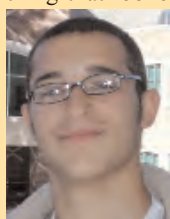
Trading Spaces

Sharing Cultures

United Kingdom – USA

Jason Fletcher

The idea of studying abroad, at first, was something that looked interesting to me, but was nothing to make a fuss over. However, nearing the time to leave the United Kingdom for a whole year made me realize what a fantastic opportunity studying abroad actually was. The chance to meet different people who live a different lifestyle, have a different cul-



ture and who have a completely different teaching system, is a unique experience. It is also an opportunity to make contacts around the world, which may prove to be useful in the future.

After one semester of studying abroad, I feel now as though I have adapted to the American way of living, have made new friends, and because it is a foreign atmosphere, I feel as though I have learned a lot more than I would have back at home. Because of the friendliness and excellence of the CSM Department of Geophysics, I am very happy with the way things are going. I strongly

encourage people to study abroad, simply because of the fantastic benefits and opportunities gained from being in a foreign environment.



Jason tackling Copper Mountain.

The Netherlands – USA

Wouter Kimman

This trip to the U.S. being my first out of Europe, my expectations were high. Especially taking into account the paperwork required prior to departure, I was really anxious to go. I arrived in San Francisco to start a tour with

others from Utrecht (pronounced like: Utre-'choking gchkggg'-t.). We saw parts of California, Arizona, Utah and Nevada (probably the "usual" road trip for



Americans), and I have to say my expectations were realized. I was amazed by the beauty of this country. Lots of geo-stuff



Wouter (second from left) sightseeing with other international GP friends: Joost, Sjoerd and Eldad.

to be seen of course, but I also liked sitting

back, relaxing and enjoying the scenery.

Following that trip, I was off to that mysterious little town between Denver and the foothills of the Rockies — Golden — home of that famous establishment, Coors Brewery. I arrived at a splendid brand new apartment in Mines Park.

Why did I choose Colorado School of Mines? In short, I've always wanted to go abroad and learn about other cultures. I had heard good stories about CSM from my advisor Roel Snieder and others. The enthusiasm that followed an email sent to Prof. Snieder made me ambitious to pursue the idea. His enthusiasm and enjoyment in teaching is important and inspiring, and you see it reflected throughout the GP faculty.

After meeting with my ad-

visor I was ready to go to work. Being in my last year of study in Utrecht my focus is on research of dynamic landslide triggering. During the first semester I made the simplest form of the model setting up failure criteria. I use a finite difference code for wave propagation, combining this with static situation (gravity) to compute and test the stresses for failure.

I almost don't need to mention the great Colorado outdoors. Whether you watch a sunset on the plains, come across elk in Rocky Mountain National Park or fall on your buttocks while snowboarding (started this season), these are all ways to become delirious — for which we Dutch are famous!

Trading Spaces

Sharing Cultures

USA – Japan

Katie Baker

Teaching in Japan

In Summer 2003 I arrived in Sendai, Japan to work as



an assistant language teacher for a junior high school.

My job was to advise teachers and junior high school students how to speak, read and write English. Twice a month I visited elementary schools and gave English lessons to younger students.

Sendai is a big enough city that when I got really homesick I could find English speakers and satisfy my appetite for western food with Starbucks, McDonald's — YES! — McDonald's, and a few Italian restaurants here and there. But the city is such that if you drive for 20 minutes in any direction you can find yourself in the countryside, in places where foreigners stick out like a sore thumb.

My school, Sakuragaoka Junior High, was right on the border of the transition zone between city and countryside so I was able to enjoy the sensation of being completely immersed in Japanese culture. Most of my colleagues, including

the English teachers, had very little experience speaking English, which forced me to use the little Japanese that I did know, which was challenging.

In my memories now I idealize many of the experiences I had living in Japan. I forget that I struggled with the culture and at some points I felt alienated due to the language barriers and misunderstandings between cultures and ways of doing things. I became frustrated with filling the kerosene heaters and the smell they gave off in the winter. I became annoyed by people pushing past me in the grocery store without saying excuse me. I became claustrophobic living on a narrow street in a small apartment with a kitchen having two feet of walking space. I was living in a completely different world, trying to get along with the language and to assimilate — as well as a blue-eyed girl can — into Japanese culture.

I think that my memories of Japan are so idealized because the experience pushed me to be more tolerant of others' opinions, it pushed me to learn to speak Japanese, it pushed me to be more conscious of the group men-



Street scene in Sendai, Japan.

tal, and it pushed me to look past the Japanese shell and see the person behind that shell. Ultimately I think that these things have made me a better and more compassionate person. For that reason, it is one of the most valuable experiences in my life.

In truth I think this article should be titled, "Learning in Japan." I learned so much about Japanese culture and language; I made lifelong friends; I lived through my first earthquake; I enjoyed the soothing mineral waters of the Onsen; I attended potato parties while enjoying beautiful colors of fall and mochi rice treats in the cold, cold winter; I relished in the beautiful cherry blossoms of the spring; and I realized that Japan-

ese people really do know how to have a good time and can be the most loyal of friends. I connected with children eager to learn and I built a pile of great memories that will last me a lifetime.

Experiencing Reality: *Shaping Lifetime Goals*

The Department encourages students to augment their studies by participating in internships. Here are the experiences of two undergraduates during Summer 2004.

Research on the Cape

Emily Roland



Two days after the 2004 GP field camp final presentation, I found myself on a plane to Massachusetts to begin a summer research fellowship at Woods Hole Oceanographic Institution (WHOI). Looking back, it is amazing how little I really knew about the sort of things that I would be encountering at the world class marine research facility; however, it was with nothing but excitement that I stepped off the bus into the little peninsula village of Woods Hole, a feeling that was only intensified by the view of the Nobska Lighthouse looming in the distance and the RV Atlantis docked in the harbor, Alvin somewhere on board. (Alvin is a famous deep submergence vehicle that can take two scientists and a pilot 4.5 kilometers under the sea.)



For a few days on the RV Tioga, I also had a chance to directly experience oceanographic data collection, cruising around Cape Cod taking conductivity, temperature and depth measurements and pulling up box corers full of seafloor mud.

For my research project, I worked with Jeff McGuire in the Ocean Bottom Seismometer lab studying oceanic transform seismicity patterns using a

dataset that had been collected of an earthquake swarm from a fault on the Galapagos Spreading Center. While at times the distraction of lunchtime swimming in the 70° Cape Cod waters and after-work sailing lessons from WHOI graduate students may have seemed to be an impediment to scientific progress, by the end of the summer I had learned more than I thought possible and had become completely engrossed in a new field of geophysics that I believe I may like to pursue in graduate school.

As a senior now, back at Mines, the experiences I had at Woods Hole are definitely contributing to my plans for how I would like to continue studying geophysics in my future and I can't help but hope to become a part of the community of scientists answering the inexhaustible number of questions that exist about earth processes, both on land and in the oceans.

Woods Hole is one of the largest marine research facilities in the world and at any one time has over 350 research projects underway on a full array of marine science topics relating to applied ocean physics and engineering, biology, marine chemistry and geochemistry, physical oceanography, geology, and marine geophysics.



As a Summer Student Fellow (a title that all permanent WHOI staff members seemed to delight in constantly using) I was one of 30 undergraduates who had been funded by the National Science Foundation to conduct research on a specific topic during the summer. During the fleeting 12 weeks, my fellow Fellows and I were kept busy not just working on our individual projects, but also attending biweekly talks from WHOI scientists. At these talks we were exposed to the complete spectrum of diverse fields being studied at Woods Hole that ranges from deep sea submersible robotics to the biodiversity of hydrothermal vents in the Arctic.



Life at the David A. Johnston Cascades Volcano Observatory

Sarah Thompson



When I reported to the Cascades Volcano Observatory (CVO) in my hometown of Vancouver, Washington, I had no idea what to expect. I never imagined what an amazing experience I would encounter, how many great friends I would make (who also share my passion for volcanoes), and

how much I would learn.

In the office, I spent most of my time processing Interferometric Synthetic Aperture Radar (InSAR) data for several volcanoes, hoping to see signs of deformation. I found a lot of atmospheric noise and lack of coherence, unfortunately, but I also learned a great deal about the fundamentals of RADAR and Remote Sensing. While geophysicists should expect to spend a lot of time in front of a computer screen, there is one time of the year to which almost everyone at CVO looks forward — fieldwork season.

During my first day of fieldwork at Mt. Shasta, CA, I found myself clinging onto a rock outcrop while scouting for a way up the cliff face. With gravitational forces acting on my 40-pound backpack full of GPS gear, all I could think was, “If only Dr. Young could see me now!” (just kidding). My partner and I found the benchmark, albeit a little treacherously, and made it back to the truck, just to set out for another arduous hike of a perilous scree field. And so the season of fieldwork began...

I participated in three weeks of geodetic field surveys at Mt. Shasta, Mt. Lassen, and Three Sisters (OR). Along with an elite team of geologists and geophysicists, I collected millimeter-precision GPS data in an effort to measure the rate of deformation occurring around the volcanoes. We discovered 14 cm of subsidence at Mt. Lassen since the last survey conducted in 1981, which is consistent with an Interferogram processed for the area. At South Sister, OR, we documented the inflation occurring in the area, first detected with InSAR prior to a related seismic swarm. Our data will be useful for modeling the volcanic processes responsible for such deformation.

At the end of the summer I had the opportunity of my lifetime: a trip into the crater of Mt. St. Helens. My partner and I were dropped off at three sites in the crater, including the lava dome, to collect GPS data for a photogrammetry study.



Helicopter landing at Sugar Bowl, NE side of Mt. St. Helens.

I was awestruck by the immensity of the crater, the beauty of the volcano, and the views of snowcapped Mt. Rainier and Mt. Adams sticking up above the clouds. Just as I was getting used to jumping in and out of helicopters, it was time to go back to Mines.

One month after my trip into the crater, Mt. St. Helens reawakened with hundreds of seismic events preceding the growth of a new lava dome. It was devastating to miss out on the eruption, but hopefully I will be able to investigate the new dome this coming summer. There is still much to learn from Mt. St. Helens, and I can only hope for more opportunities with the USGS Volcano Hazards Program.



Sarah on Mt. St. Helens northwest dome (Mt. Adams in the background).

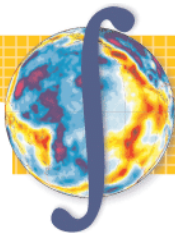


Estimating the uncertainty in Earth models was the focus of a ten-day summer school, "Mathematical Geophysics and Uncertainty in Earth Models" held on the CSM campus June 14-25, 2004. This school, directed and organized by CSM geophysics professor Roel Snieder, was financially supported by the program for Collaborations for Mathematical Geosciences (COG) of the National Science Foundation, and by Schlumberger.

Mines Hosts Summer School Event

Summer School

Mathematical Geophysics & Uncertainty in Earth Models



Others collaborating with Snieder to present the summer school were Luis Tenorio (Mathematical and Computer Sciences, CSM), Eldad Haber (Mathematics and Computer Science, Emory University), Alberto Malinverno (Schlumberger Doll Research), and Michael Ritzwoller (Physics, University of Colorado Boulder). The arrangements were professionally handled by the CSM

Special Programs and Continuing Education (SPACE).

Twenty speakers with a background either in geophysics or mathematics contributed to the school by giving lectures and by interacting with students. The 60 students who attended were from five different continents. Approximately twenty percent of those students are employed by industry.

Estimating uncertainty in Earth models is an important issue in geophysics, where images of the subsurface are analyzed for the production of resources such as hydrocarbons, for environmental purposes, for assessing geohazards, or for purely scientific reasons. In all situations the creation of the subsurface image, though not the endpoint, is a large component in the decision-making that may have large financial or environmental repercussions, or that may involve the safety of the public or the integrity of the science that is carried out with these models. The uncertainty in the Earth models is an important factor in this decision-making process.

The presentations during the School addressed methods to assess this uncertainty, and explored how to create a meaningful interface between the scientists who produce Earth models, and the decision-makers who ultimately use the Earth models. The estimation of the uncertainty in Earth models is difficult, because the relation between the recorded data and the Earth model is nonlinear, and because the construction of Earth models is a problem that often involves extremely large data sets and models that may contain millions of parameters.

It became apparent during the School that the estimation of uncertainty in Earth models has many open research questions, which will continue to challenge researchers in the geosciences and in mathematics. Faculty and students at CSM will continue to work on this challenge.



Geophysics on the Road

GP students and professors are often on the road attending conferences or partaking in research. We also love to have visitors. Here are just a few examples of our activity.



Yaping Zhu, Ilya Tsvankin, Andrey Bakulin (Shell International) and Pawan Dewangan.

Members of the Anisotropy team (A-team) attended the 11th International Workshop on Seismic Anisotropy in St. John's, Newfoundland. The A-team is a group from CWP and RCP doing research in seismic anisotropy guided by Professors Ilya Tsvankin and Ken Lerner.

Professor Roel Snieder and students Pawan Dewangan, Tamara Gippich, Matt Haney, Alison Malcolm, Emily Roland and Sarah Shearer attended the 2004 American Geophysical Union (AGU) meeting in San Francisco. At the AGU meeting, instead of oral presentations, the majority of participants give poster presentations. The CSM students who presented report gaining useful feedback from this interactive format. The diverse program allowed them to see what other universities are focusing on, as well as to hear how agencies such as the USGS and NASA are driving research in geophysics. The city of San Francisco is a wonderful place to attend such a conference!



Sarah Shearer and Tamara Gippich enjoy the San Francisco sunset while viewing the Golden Gate Bridge.



Geophysics alumnus Kandiah "Bala" Balachandran returned to Mines on sabbatical, participating in our summer field camp in New Mexico, then working with Mike Batzle on experimental research. Bala is on the faculty of the Kalamazoo Valley Community College in Michigan.

During the past three years, Ilya Tsvankin and Vladimir Grechka (Shell) have taught the SEG continuing education course "Seismic Anisotropy: Basic Theory and Applications in Exploration and Reservoir Characterization" at a number of locations throughout the United States and Canada. The course is designed for both graduate students and experi-



SEG short course partners: Ilya Tsvankin and Vladimir Grechka (Shell International).

enced geophysicists working in research, exploration or development. During Spring 2005, they will take the course further from home to Brazil and China.

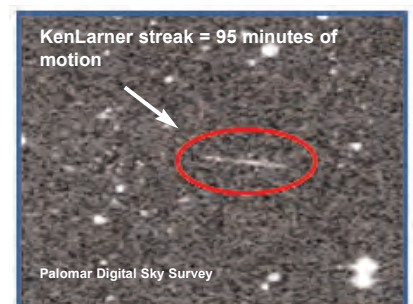


In August 2004, Yaoguo Li was invited by Geoscience Australia (GA), the counterpart to USGS, to give lectures on the processing and inversion of gravity and magnetic data. The visit was funded by a grant from the GA Staff Development Program, which was designed to bring outside researchers to interact with the colleagues there. Over the three-day period, Yaoguo gave a public seminar and a series of lectures on various aspects of data processing, 3D inversion, and their applications. GA is located in the capital city Canberra. Following the visit, he also attended the Australia SEG meeting in Sydney.

"The Sky is the Limit" for Ken Lerner

In 2001, geophysicist Joe Dellinger (BP) and fellow amateur astronomer William G. Dillon discovered an asteroid from the George Observatory, Brazos Bend State Park, Needville, Texas.

Joe and William's discovery, numbered 2001 SK10, is named KenLerner. Asteroid KenLerner joins another "chunk of rock" that Joe also discovered and named — asteroid Svenders, honoring geophysicists Sven Treitel and Enders Robinson.



SENIOR DESIGN PROJECTS

Waves Studied in Mine(r) Explosion

— Jason Fletcher

In the 1870s, the Edgar Mine in Idaho Springs, CO, produced high-grade silver, gold, lead and copper. Today it is known as the Colorado School of Mines Experimental Mine, an underground laboratory for faculty and students and the site for Jason Fletcher's senior design project.

The goal of Jason's project is to compare coda and transmitted waves before and after an explosion in a mining environment.

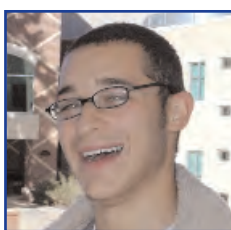
The method is to set off an explosion in a pillar in the Edgar Mine, designed to damage a small area of the pillar. The resulting damage area (approximately 40m long and 20m wide) will be studied using the coda (tail of a waveform after the P and S waves) to detect the wave changes after the explosion. Coda waves are very sensitive to small changes and so a noticeable variation is expected in these waves before and after the explosion.

With geophones and oscilloscopes recording the waves, the waves will be measured and compared using a sledgehammer (impulse source) and a sub-woofer (single-frequency source). The second part of the experiment is to find which source gives better results for looking at changes in the pillar.

Jason's plans were to obtain results during Fall semester and to analyze the results during Spring semester. Unfortunately, the geophones initially used were not sensitive enough to record the waves. This meant that obtaining results would have to be postponed until adjustments could be made.

These adjustments involve attaching amplifiers to each of the geophones so that the waves are recorded with visible results. It is this work that has attracted attention from a group trying to detect low frequency noise from a large fan belonging to an oil company that may be causing disturbance to nearby houses. By attaching these same amplifiers and geophones to the houses, the actual source of the noise will be determined along with possible corrective measures. Following the use of the equipment for this purpose, Jason will complete his project in the mine.

GP seniors select a "Senior Design Project" intended to give experience in the application of engineering design principles through individually chosen projects. These projects result in an engineering report or senior thesis and oral presentation.



Jason Fletcher



Drills inside the Edgar Mine, Idaho Springs, Colorado.



Kris Davis



Kris Davis (center) with the absolute gravimeter used to model water dispersion in the Leyden Mine.

Time-lapse Geophysics Studied in Mine Turned Reservoir

— Kris Davis

The lack of water in the Colorado Front Range is a rising issue. Every year many towns and cities declare drought. Water storage is becoming increasingly difficult and the space for reservoirs is decreasing rapidly due to newly built residential areas. One way to increase water storage is to transform existing underground facilities into subsurface reservoirs.

The City of Arvada, CO, has begun using the Leyden Mine (an abandoned century-old coal mine) as a subsurface water reservoir. The mine is 300 meters below the surface and approximately 16 square kilometers. However, because of mine collapse and the uncertainty of interconnection between the mine workings, the distribution of the stored water is poorly determined. In addition, there may be leakage of the water outside of the mined zones.

For a senior design project, geophysics student Kris Davis was awarded a grant from the City of Arvada and is currently working with the city to answer these questions using time-lapse geophysics. Kris is using time-lapse gravity measurements in order to see changes in water distribution over time. Four surveys will be completed over one year. Inversion and modeling of the gravity measurements will allow Kris to create a three-dimensional model of the water in the mine. Kris is also using electrical methods and inversion to complement the gravity measurements in the modeling process.

Preliminary results from the first two surveys show a positive anomaly of approximately 150 microgals, which has been interpreted as possible rubble zones in the mine. Background gravity measurements have also confirmed that there is no leakage outside of the mined area. Kris will conclude his senior design project in late April with a report and presentation to the City of Arvada.

Women In Geophysics

Women in Geophysics, v. 2.0

— Sarah Shearer & Tamara Gipprich

After a brief hiatus, the Women in Geophysics (WIG) program is back! A record number of Denver-area women geoscientists, including new arrival to CSM, Dr. Manika Prasad, have volunteered their time and energy to interact with the gals (and the occasional guy) from the GP Department during the 2004-2005 school year!



Mentor Jeanette Dubois and GP student Whitney Goodrich learning from one another.

Monthly meetings have covered a number of topics including a panel discussion focusing on the diverse backgrounds and experiences of our mentors, a geoscientists' survival guide to problem solving, a "Take Your Mentee to Work" day as well as career planning and interviewing and negotiation skills. WIG is not all work and no play however; this year's social activities have included Denver Geophysical Society (DGS) lunches, pottery painting and jewelry making.

With a newly updated brochure, the support of the Department of Geophysics, and financing from Dr. Phil Romig and ChevronTexaco, the women's mentoring program has been resurrected in style.

Become involved. Join us for next year's program!



A just-for-fun activity: pottery painting. Check out our website (<http://www.mines.edu/Academic/mentor/wgmp>).

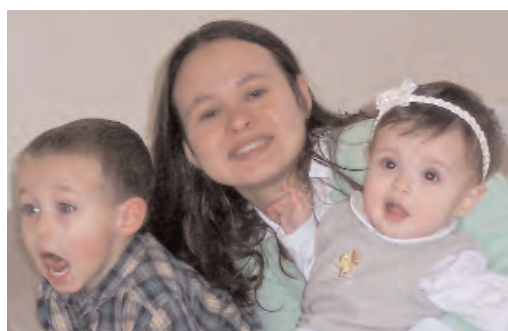
Studying GeoMom: ~~Working~~ Mother

— Gaby Briceno

I have been at the Colorado School of Mines since 2000, and during that time I have earned an MS in geophysical engineering, begun classes in the doctoral program, worked as a research and teaching associate, and filled an industry internship. And, oh yes, during that same period, my husband José Gago and I became the parents of two children: Mauricio (age 3) and Uxia (age 1 in June).

Combining the roles of student and mother means that when I get to school each morning, I am already exhausted after changing diapers, potty training, preparing bottles and breakfasts, and driving to daycare — all before finally getting to my research in petrophysics of tight gas sands. Juggling this schedule is demanding and challenging, but the rewards that I get from both school and family are extraordinary.

I have learned that quality time is more important than quantity; and also, that any single step requires a lot of planning, anticipating and prioritizing. There is no sure recipe for success, but I am fortunate to have three key ingredients as described by Bli Blu in her book *The Working Mother*:



Gaby Briceno with children Mauricio and Uxia.

1) a helping partner (both my husband who is also a Ph.D. student and my mother who is visiting from Venezuela; 2) an understanding employer, including my advisor Max Peeters (he even babysits occasionally); and 3) a good daycare service (CSM offers students a 10% discount in some daycare facilities). In addition, I have a mentor whom I met through the WIG program, Lesley Evans (Williams Production) who has ably modelled being a great geoscientist and mother.

Between breast feeding and studying there have been some long nights, but it is a most wonderful experience.

Gaby recently completed a three-month internship with Occidental Oil & Gas Company in Houston. Her project there was to analyze thin beds from turbidite sands to improve the oil-in-place determination. And yes, with some creative planning and the help of her mother, Gaby took the children along while husband José continued his research at CSM.

GOOD TIMES at MINES



Grad students "walk the plank" at annual retreat.



GP outing: white water rafting on the Arkansas River near Buena Vista, CO. Professor Max Peeters (right rear) is along for the ride!



Is it Halloween or a typical Friday night?



Celebration of Mines! Professors Davis and Li (left) help students spread the good word about GP.



Soccer is just one of CSM's intramural sports that attract GP teams.

Filling the
Green
Chair



Upon his retirement, students presented Professor Lerner with a lifetime supply of red ink!



GOOD TIMES at MINES



Head drum major of the CSM Marching Band and GP senior **John Chakalis** takes time out with buddy, **Marv the Miner** during a football game. Though Marv's alter-ego must remain anonymous, it is rumored that he often roams the halls of the Green Center. The CSM football team took the 2004 Rocky Mountain Athletic Conference Championship for the first time since 1958. The Mines band gained national recognition by appearing on ABC's "Extreme Makeover: Home Edition" in February.



The Mines Little Theatre acting troupe includes several GP thespians. Pictured here during a production of "Harvey" are **Justin Smith** (second from left) and **John Chakalis** (right). John served as director of "Harvey". GP grad student **Ivan Vasconcelos** directed "An Evening of One Acts" this season and the troupe also performed the musical "Guys and Dolls." Other GP participants are **Bryce Swinford** and **Paul Schwering**.



Spoofing the profs at the GP Day Banquet. Will the real Mike Batzle please come forward?



GP junior Andy Kass spends his study breaks as a patrolman at Loveland Ski Area. From Texas, he had never seen snow until he was in high school. Andy shared his enthusiasm by organizing a ski day and barbeque for GP students.



Tamara Gipprich and Justin Modroo prepare for volleyball. How hard can this be?



Field Camp 2004

Geophysics Summer Field Camp returned for the second year to the Estancia Basin of New Mexico to map the local aquifer and to study its recharge dynamics. Once again we are grateful to Vern Wood who provided accommodations and food on his ranch.



Class of 2004

Bachelor of Science

Neal Jordan Dimick
Fariz Fahmi
Amy Lorraine Hinkle
John Michael Jackson
Donald John Keighley
Douglas Lawrence Klepacki
Elizabeth Ann Labarre
Todd Matthew Meglich
Vanessa Renae Mitchell
Michael David Rumon
Tashi Tshering
Marc Charles Wennogle

Master of Science

Ludmila Adam Dvalishvili
Bethany Lynn Burton
Dongjie Cheng
Alisa Green
Cristian Hernando Malaver
(Geophysical Engineering)
Justin James Modroo
Carlos F. Pacheco
Theodore Leigh Royer
Hector Vinicio Sanchez-Rodriguez
Jonathan Andrew Woolley

Doctor of Philosophy

Tagir Edgartovich Galikeev
Alexandre Anatole Grêt
Martin Jordan Terrell

University Emeritus Professor

Kenneth L. Larner



Department Head Terry Young



Cristian Malaver (second from left) celebrates with family members.



The M.Sc. March: Ted Royer (left) and Ludmila Adam (far right).



Sara Summers congratulates Marty Terrell, Ph.D.



Jubilant Jordan Dimick.



December graduates (L to R) were Amy Hinkle, Justin Modroo and Liz Labarre.



Tashi Tshering will return to his homeland, the Kingdom of Bhutan.



Ken Larner, newly retired professor of geophysics, was honored during the December Convocation by the CSM Board of Trustees who conferred to him the title University Emeritus Professor. Larner is one of only five to hold that honor at CSM.



Class president Vanessa Mitchell plans to study abroad before beginning grad school.



Marc Wennogle (upper left), Don Keighley (upper right), John Jackson (lower left) and Doug Klepacki (lower right) accept congratulations during the GP celebration luncheon.

Graduate Student Retreat

Immersion in Friendship



The Department of Geophysics continues a recently established tradition to welcome new graduate students into the program by taking them “on retreat.” During this weekend together, the students (many of whom are first-time visitors to the United States) are exposed to the beauty of Colorado at the *The Nature Place* near Florissant, Colorado. There they explore hiking paths, view wildlife and enjoy the scenery of nearby Pike’s Peak, while getting to know one another. The 2004-05 retreat was led by graduate student Ludmila Adam.

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