geophysics

Colorado School of Mines

Spring 2014

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Thank you to ConocoPhillips, ExxonMobil and Marathon Oil

for providing funding for the 2014 Geophysics magazine and to all of our sponsors for their continued support of the department!

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SEG DENVER
26-31 OCTOBER 2014
Society of Exploration Geophysicists International Exposition and 84th Annual Meeting
Colorado Convention Center • Denver, Colorado USA • www.seg.org

Look for Us at SEG!

As of this printing, we are still finalizing the details of the annual department alumni luncheon at SEG Denver scheduled for Oct. 28th. Please see Michelle Szobody at the CSM booth in the exhibit hall, or contact her at *mszobody@mines.edu*.

On the front cover:
Brennan Malcom, Class of 2014, takes a turn operating the vibroseis truck at the 2013 field camp in Pagosa Springs, Colorado.

From the Department Head

Hearty greetings from CSM! We are glad this newsletter has found its way into your hands. We hope it conveys successfully the spirit, people, and activities of the Department of Geophysics. Enjoy!

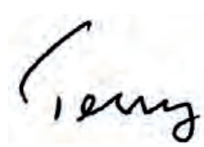
We are bursting at the seams with continued growth in our undergraduate enrollment. With a total of about 140 students in our BS program in Geophysical Engineering, enrollment in some classes is almost 50, which challenges us to create additional sections, particularly in the hands-on lab courses, to maintain instructional excellence.

Our graduate research program is also enjoying robust health. Within the department we have the Center for Wave Phenomena (CWP), the Reservoir Characterization Project (RCP), the Center for Gravity, Electrical, and Magnetic Studies (CGEM), Rock Physics, Hydrogeophysics and Porous Media, the Planetary Geophysics Lab, and Earthquakes and Active Tectonics. Both CWP and RCP are celebrating 30-year anniversaries!

In the context of our relationship with USGS, particularly the USGS Hazards Science Center which is right here on campus, it is a pleasure to celebrate the honor bestowed on Dr. Gavin Hayes, a Research Geophysicist at the USGS National Earthquake Information Center (NEIC), and an adjunct faculty member in our department. Gavin received the Presidential Early Career Award for Scientists and Engineers (PECASE) for his contributions to our fundamental understanding of earthquake processes.

In the coming months we will be engaged in faculty searches to find successors for both Dave Hale (C.H. Green Professor of Exploration Geophysics), who is retiring in summer 2015, and Tom Davis (Professor and Director, Reservoir Characterization Project), who is retiring in summer 2016. If you know of good candidates, please send them our way!

Warm regards from Geophysics,



Congratulations to Geophysics graduate students and faculty whose papers were named among the Top 30 at the 2013 SEG International Exposition and 83rd Annual Meeting in Houston:




Farhad Bazargani and Prof. Roel Snieder, Center for Wave Phenomena: "Optimal wave focusing for imaging and microseismic event location"

Luiz Martins and Prof. Tom Davis, Reservoir Characterization Project: "From OBC seismic to porosity volume: a pre-stack PP and PS analysis of a turbidite reservoir, deepwater Campos Basin, Brazil"

Adel Zohdy (February 15, 1935 - March 23, 2014) was a distinguished senior scientist in the Department of Geophysics Dr. Zohdy had a varied and successful career as a geophysicist with the USGS, eventually rising to the position of Branch Chief. After his retirement from the USGS after 30 years of service, Dr. Zohdy joined the faculty of the Geophysics Department at CSM. He enjoyed his interactions with students--- teaching geophysical electrical methods and groundwater geophysics.

Adel was born in Alexandria, Egypt and graduated from the University of Alexandria with a B.Sc. in geology. Upon graduation, he taught chemistry and physics at Victoria College, Alexandria. The following year he became a teaching assistant in geology at the University of Alexandria and also taught physics and chemistry at the British Boys School. He received a scholarship and, in September 1959, he came with his wife and 5-month-old daughter to the University of California at Berkeley to study geophysics. He worked as a lab assistant making induced polarization measurements on core samples. One summer, he was hired by the University of Illinois, Humboldt River Project, as a geophysical field assistant for groundwater work near Winnemucca, Nevada. He received his Master's degree in geophysics in 1962 from UC-Berkeley and transferred to Stanford University to pursue an interest in exploration geophysics. During that time at Stanford, the Ph.D. comprehensive exam was a grueling five-hour oral exam. His committee was composed of two geophysicists, a hydrologist, a mining engineer, and yes, a paleontologist. Switching from deriving Poisson's second relation to identifying a Triassic index fossil was fun. and he did very well and passed. He successfully completed and defended his thesis - “Resistivity and seismic refraction studies in the Santa Clara Valley, CA” - and graduated in 1964.

To quote John Stockwell: “He was a kind gentleman who is missed by all who knew him.” We continue to value Adel’s wife, Sohair, and their two children as members of the Geophysics family.

*Biography courtesy of **wiki.seg.org**.*

Congratulations to Professor Dave Hale, Center for Wave Phenomena, named 2014 Fall SEG/AAPG Distinguished Lecturer

More information about Dr. Hale's lecture, "3D Seismic Image Processing for Interpretation of Faults and Horizons", including abstract and tour schedule, can be found at ***www.seg.org/education/lectures-courses***.

Congratulations to Dr. Gavin Hayes, Adjunct Assistant Professor & USGS NEIC Research Seismologist, recipient of the *Presidential Early Career Award for Scientists and Engineers.* This is the highest honor awarded by the United States government for outstanding scientists and professionals in the early stages of their independent research careers. Dr. Hayes' research is helping to transform our understanding of earthquake processes and advance real-time response activities when major earthquakes occur. The award presentation took place on April 14 in Washington, DC. The full press release can be found at ***www.whitehouse.gov***.

Marvin R. Hewitt, age 87 died February 9, 2014. He and his wife, Jene, have been good friends of the CSM Geophysics department for many years. He graduated from the Colorado School of Mines in 1950 with a degree in Geophysical Engineering. and joined Stanolind Oil and Gas Company, now Amoco Production Company. He served as district geophysicist in the company's Calgary, Edmonton, Midland, Fort Worth, and Houston offices. In 1972 he was transferred to Amoco's Tulsa Research Center as a research group supervisor, specializing in applied research. In 1979, he was promoted to senior research associate, responsible for geophysical liaison with Amoco's world-wide geophysical departments and for long-range geophysical research planning.

Marvin presented papers at numerous technical meetings, both domestic and international; he was published in GEOPHYSICS and The LEADING EDGE, including the geophysical Delphi forecast. Marvin served as Second Vice President of the Permian Basin Geophysical Society, First Vice President and President of the Fort Worth Geophysical Society, and First Vice-President and President of the Geophysical Society of Tulsa.ln 1983 he was awarded Honorary Membership in the GST. He was been a member of the Society of Exploration Geophysicists for 35 years and served as President from 1985-1986. He served the Society as Second Vice-President in 1981-82, was General Chairman of the 54th Annual Meeting held in 1984 in Atlanta. He was also a member of the Geophysical Society of Tulsa, Tulsa Geological Society, AAPG. and EAGE.

*Biography and photograph courtesy of **wiki.seg.org**.*

Class of 2013

Doctor of Philosophy Geophysics

May 2013:

Prof. Andre Revil (advisor); Dr. Kristopher MacLennan; Dr. Terry Young, Department Head; Dr. Tongning Yang; Prof. Paul Sava (advisor)

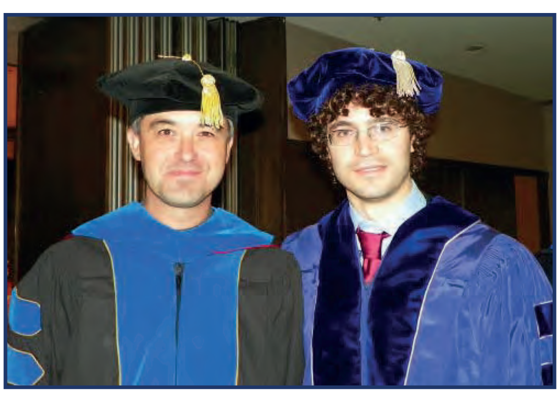
December 2013:

Left: Prof. Roel Snieder (advisor); Dr. Filippo Broggini

Right: Prof. Mike Batzle (advisor); Dr. Farnoush Forghani-Arani

Below, L-R: Prof. Paul Sava (advisor); Dr. Francesco Perrone; Prof. Ilya Tsvankin; Dr. Steven Smith

Not pictured: Dr. Norimitsu Nakata



December 2013 *cont'd*:

Left: Prof. Yaoguo Li (advisor);
Dr. Trevor Irons

Right: Dr. Aaron Wandler;
Prof Tom Davis (advisor);
Dr.Paritosh Singh

Left: Dr. Allan Haas;
Prof. Andre Revil (advisor);
Dr. Scott Ikard (Geophysical Engineering);
Dr. Harry Mahardika

Master of Science Geophysics

May 2013:

Mohamed Abdulla; Pengfei Cai; Christopher Steinhoff

Not pictured: John Bishop, Jr.; Husni Lubis

Professional Master Petroleum Reservoir Systems

Karoline Bohlen; Aikhan Sadykov

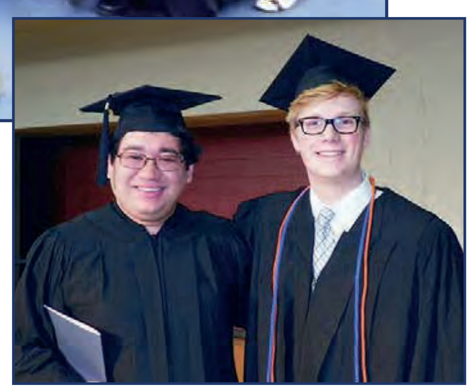
Master of Science Geophysics

December 2013:

Rachel Vest Woolf; Carla Carvajal Meneses; Luiz Martins; Imad Atshan (Geophysical Engineering) Not pictured: Guillaume Barnier; Mariana Carvalho; Lillian Comegys; Brian Davis; Ezgi Karsozen; Jae Kwon; Kathryn Martin; Indah Putri; Kelsey Schiltz; Loren Ziegler

Bachelor of Science Geophysical Engineering

May 2013: Back: Michelle Szobody (B.Sc. Engineering Mechanical Specialty); Loralee Wheeler; Lindsay Patterson; Aranxia Gallastegui; Georgianna Zelenak; Thomas Rapstine; Elizabeth Maag; Jasmine Lambert; Alexandra Grazulis; Karen Moll; Daniel Shannon; Heather Johnson; Abdulhamid Almumtin; Hala AlQatari; Front: Detchi Ittharat; Matthew Doyle, Jr.; Stephen cuttler; Elias Arias; Matthew Emmett; Gabriel Martinez; Christopher Graziano James Gayer; Russell Mah

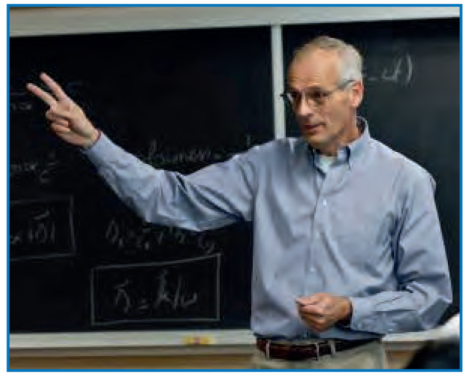


December 2013:
Thomas Blitz; Johannes Douma

Failure of Levees

Roel Snieder, Professor

W.M. Keck Foundation Distinguished Chair in Exploration Science



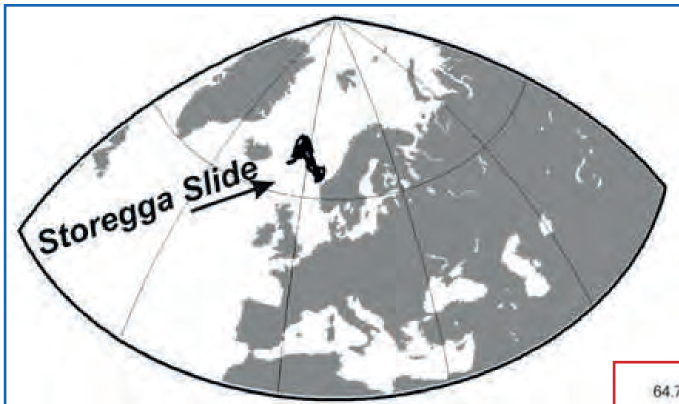
In collaboration with Mike Mooney from Civil Engineering, I am engaged in a project on monitoring internal erosion of dykes and levees. Levees keep large tracts of lands dry, not only in the Netherlands, but also in the United States. Levees can fail because they are eroded from the inside out by water that washes material away. At some point this can lead to a complete failure of the levee and flooding of the land. Mike and I, along with postdoc Thomas Planès, are studying the internal erosion of levees with seismic methods.

The image shows the IJkdijk in the Netherlands. This is an instrumented levee that was deliberately induced to fail. By studying the seismic waves propagating through the levee as it is weakened by the internal erosion, it may be possible to develop monitoring systems that can be used to diagnose the integrity of levees.

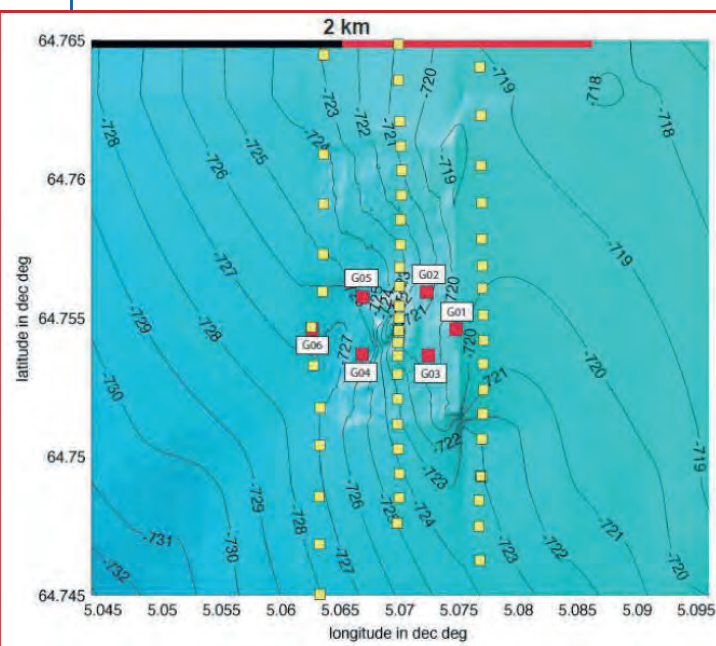
First Results from an Electromagnetic Survey of a Gas Hydrate Vent Offshore Mid-Norway

Andrei Swidinsky, Assistant Professor

The continental shelf offshore mid-Norway hosts several well known hydrocarbon provinces. Numerous geophysical surveys have been carried out in the area for conventional hydrocarbon exploration, as well as for more recent near surface investigations of gas hydrate deposits. One well known feature in this part of the shelf is the famous Storegga Slide. The slide took place 8150 years ago and is one of the largest known submarine landslides, resulting in a large tsumani arriving on the coasts of Norway and Scotland. The seafloor instability leading to the slide is hypothesized to have been caused by hydrate disassociation during periods of low sea level and is an extreme example of the potential marine geohazard associated with hydrates. Together with the Helmholtz Centre for Ocean Research Kiel, Germany (Geomar), I helped design and carry out a novel electromagnetic survey to image the resistivity structure of the hydrate vent CNE03, which should be electrically resistive in comparison with the surrounding water-saturated host sediment. The vent is located approximately 10km north of the Storegga Slide sidewall, extends from the very shallow seafloor to a depth of a few hundred meters, and is over 200m in diameter at its base. With its high gas hydrate content, such a vent could be a significant non-conventional energy source, but also a potential geohazard if sea levels fall.

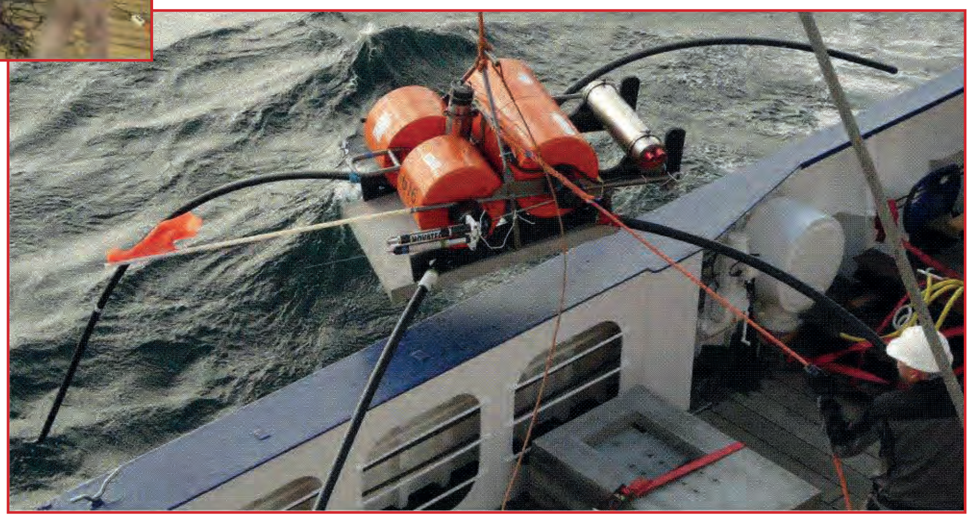


Left: The geographic location of the Storegga Slide and working area, offshore mid-Norway.



Right: The marine electromagnetic acquisition geometry above vent CNE03. Yellow squares are transmission positions while red squares are receiver positions. The vent and corresponding seafloor pockmark are centred at the ring of receivers. Contour lines are water depth in meters.

Left: "Sputnik", the electromagnetic transmitter. When the device comes into contact with the seafloor, the 10m-long dipole arms open in a cross pattern. The metallic spheres are designed to maximize the amount of current that can be transmitted into the earth.



Right: An electromagnetic receiver that measures the two horizontal components of the electric field on the seafloor

The electromagnetic survey consists of a transmitter which mechanically unfolds two orthogonal 10m-long electric dipole arms when the device touches the ocean floor. Such an instrument is suitable for a detailed investigation of a small scale seafloor target like a gas hydrate vent. Standard electromagnetic receivers are dropped from the survey vessel and measure the two orthogonal components of the electric fields on the seafloor. The resulting apparent resistivity pseudosections from CNE03 show a resistive anomaly near the centre of the ring of receivers and which may indicate the presence of hydrates. P-wave velocity slices were also created from previous ocean bottom seismometer (OBS) measurements at the same intervals as the apparent resistivity pseudosections. We think that the high velocity zone corresponds to an accumulation of hydrates in the sediment, and it is interesting that its location is near the high resistivity anomaly.

The electromagnetic instrumentation was designed at, and is operated by Geomar. Data analysis is now routinely carried out by my electromagnetics group at the Colorado School of Mines. New datasets are frequently collected worldwide over small-scale targets such as marine mud volcanoes, fluid flow features, gas hydrate reservoirs and seafloor mineral deposits (the last two research cruises were offshore Taiwan and in the Black Sea). Ongoing research and development continues to leverage the data from this unique marine geophysical experiment.

Guiding Image Inversion of Resistivity Data from Pagosa Springs

André Revil and Jieyi Zhou

The last field camp (May 2013) gave us the opportunity to collect an amazing DC resistivity profile crossing a set of faults near the hot springs of Pagosa Springs in southern Colorado. This work was the continuation of the work undertaken in 2012 in the same area to determine the plumbing system of the hot springs of Pagosa. This profile was cutting a rough topography in some places and the "cherry on the pie" (as we say in French, "la cerise sur le gateau") was to cross the San Juan river. This profile, 6.38 km long (4 miles), was performed with our 1.26 km cable using a roll along of the electrodes. The result of the inversion shown in Figure 1 was pretty spectacular. It was possible to recognize the different geological units and to improve the geological model shown in Figure 1a used as the guiding image. The next step will be to combine the self-potential data with this resistivity image and the use of some attributes to localize where the flow of the hot water is located in this profile.

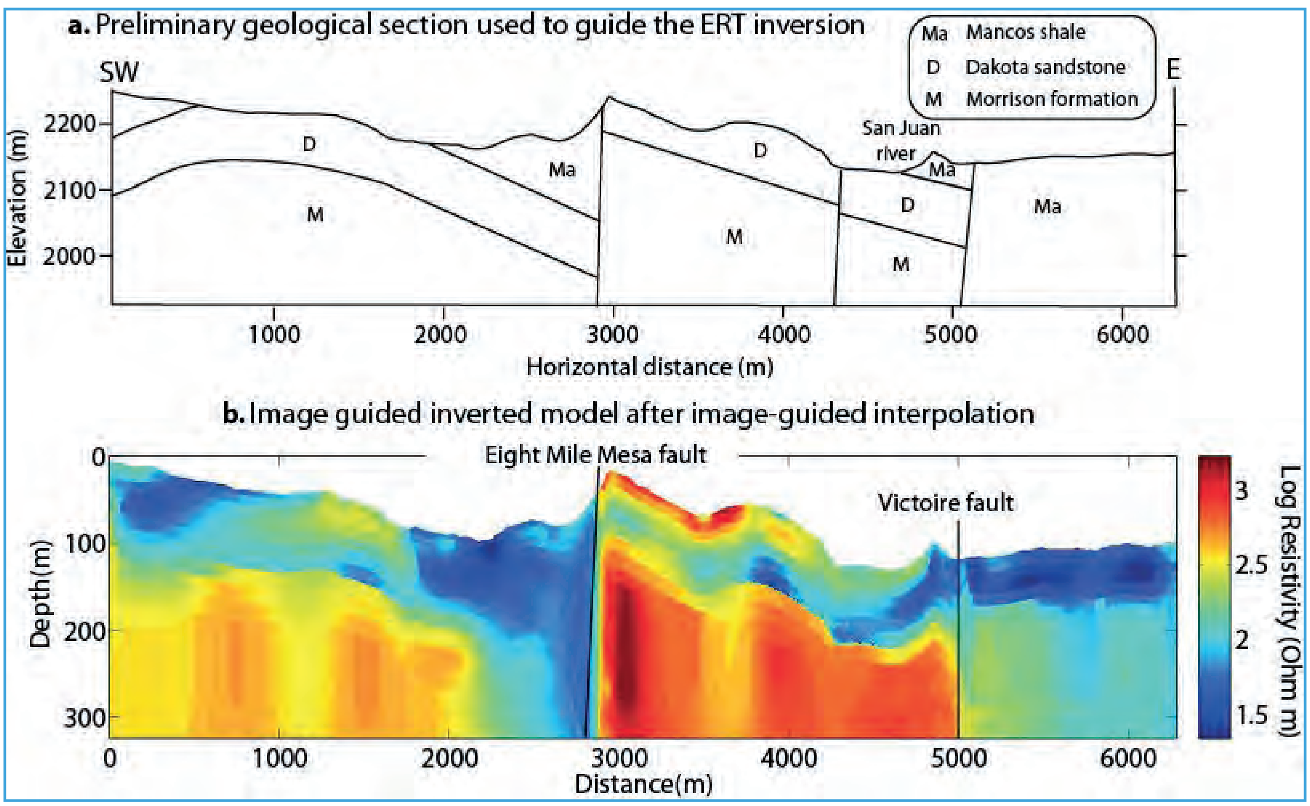


Figure 1. Guiding image and image guided inverted resistivity model after image-guided interpolation. a. Preliminary geological section used to guide the inversion of the electrical resistivity data. The sketch shows the position of the Stinking Springs anticline on the West, the eight Mile Mesa fault in the center, and two other faults in the East. b. Result of the image guided inverted model after image-guided interpolation. Interestingly, the position of the Victoire Fault is now associated with the position of a dike that is outcropping. This dike seems associated with a slightly higher resistivity in the first one hundred meters below the ground surface. The Mancos shale appears as a very conductive material (10-50 Ohm m) because of the presence of smectite. At the opposite, the Dakota sandstone is very resistive (>500-1000 Ohm m) in some areas because of silica precipitation in the pore space and cracks.

Stringing DC resistivity cable across the San Juan River near Pagosa Springs, Colorado

André Revil publishes new book: *The Self-Potential Method: Theory and Applications in Environmental Geophysics*

André Revil and Abderrahim Jardani

The self-potential method is a simple yet innovative process, enabling non-intrusive assessment and imaging of disturbances in electrical currents of conductive subsurface materials, by measuring the electrical response at the ground's surface or in boreholes. It has an increasing number of applications, from mapping fluid flow in the subsurface of the Earth, to understanding the plumbing systems of geothermal fields, and detecting preferential flow paths in earth dams and embankments.

This book provides the first full overview of the fundamental concepts of this method and its applications in the field. It begins with a historical perspective, provides a full explanation of the fundamental theory, laboratory investigations undertaken, and the inverse problem, and concludes with chapters on seismoelectric coupling and the application of the self-potential method to geohazards, water resources and hydrothermal systems.

Datasets and analytical software are made available online for the reader to put the theory in practice, and analyse their own data. This book is a key reference for academic researchers and professionals working in the areas of geophysics, environmental science, hydrogeology, hydrology, environmental engineering and geotechnical engineering. It will also be valuable reading for related graduate courses.

Hunting an Ancient Fault Scarp in Western Turkey

Ezgi Karasozen, PhD student

About a year ago, I started my PhD journey in the earthquake group with Dr. Edwin Nissen. Studying earthquakes is a lot of fun and particularly interesting and important to me because earthquakes are a very serious hazard in my home country. For example, the Izmit earthquake (magnitude 7.4 on August 17, 1999) caused massive damage near Istanbul on the North Anatolian fault (NAF) system. The NAF is one of the best studied fault zones in the world and is very similar to the San Andreas fault. Likewise, western Turkey, a highly active continental extension zone, resembles the Basin and Range province a lot. However, active faults in this area are at best poorly characterized, and at worst not mapped at all. Another important aspect of this area is that it is an industrialized and densely populated region with many large cities situated on, or very close to, active faults (e.g. Bursa, Izmir, Denizli, Antalya).

My PhD research focuses on these active normal faults in western Turkey. We started by investigating a recent Mw=5.8 earthquake in Simav (Kutahya) region. This area is particularly interesting because it experienced a series of destructive normal faulting earthquakes in the 1960s and 1970s, including the largest ever recorded instrumentally in western Turkey (the Mw 7.0 Gediz earthquake, 28 March 1970). This earthquake destroyed the town of Old-Gediz, killing ~1000 people.

Last summer we travelled to western Turkey to investigate these earthquakes. We spent 10 days in the field and mainly searched for the fault scarps. The Simav earthquake fault scarp was a difficult one because either we were searching in a densely vegetated area or it was modified by humans or in most cases it was both. Although this earthquake happened 3 years ago, we were unable to identify the fault scarps. Gediz earthquake, on the other hand, happened 43 years ago, again in a densely vegetated mountainous region. After 3 days of scarp hunting for this earthquake, we found our 43 year old fault scarp in the middle of a steep valley. It was an amazing find and the turning point of the field trip for me. I realized that the fault scarps that I thought I'd seen until then were not fault scarps at all! After seeing this huge scarp, I now know what to expect and what to look for. Apart from searching for the scarps, we studied the geology and the geomorphology of the area. This is particularly important because it provides a link between the landscape and the tectonics of the region. We traveled to every village in this mountainous topography and saw how the geomorphology changes with normal faulting. During our trip, we talked with local people a lot. They guided us with their earthquake memories and were thankful to us for pointing out the importance of seismicity in their home towns.

Using LiDAR to Map the Degradation of the 1959 Hebgen Lake Rupture

Kendra Johnson, PhD student

During recent years, increasing coverage of the Earth by Light Detection and Ranging (LiDAR) data – which uses airplane or tripod-based laser return times to map topography – has facilitated a wide range of scientific studies. LiDAR data offers a much higher ground resolution (several points per square meter) than satellite-based terrain mapping methods, and can also "see through" vegetation to the Earth's surface by filtering out all but the last returns of each laser pulse. In light of the potential applications of LiDAR, the National Center for Airborne Laser Mapping (NCALM) surveys a few sites each year proposed by graduate students seeking LiDAR data. This year, my proposal titled "Degradation of the 1959 Hebgen Lake rupture (Montana) and application of diffusion coefficients to undated scarps in the N Rocky Mountains and Mongolia" was among the few approved submissions. I will work with my PhD advisor, Dr. Edwin Nissen, and a colleague from University of Montana, Dr. Rebecca Bendick, to complete this project.

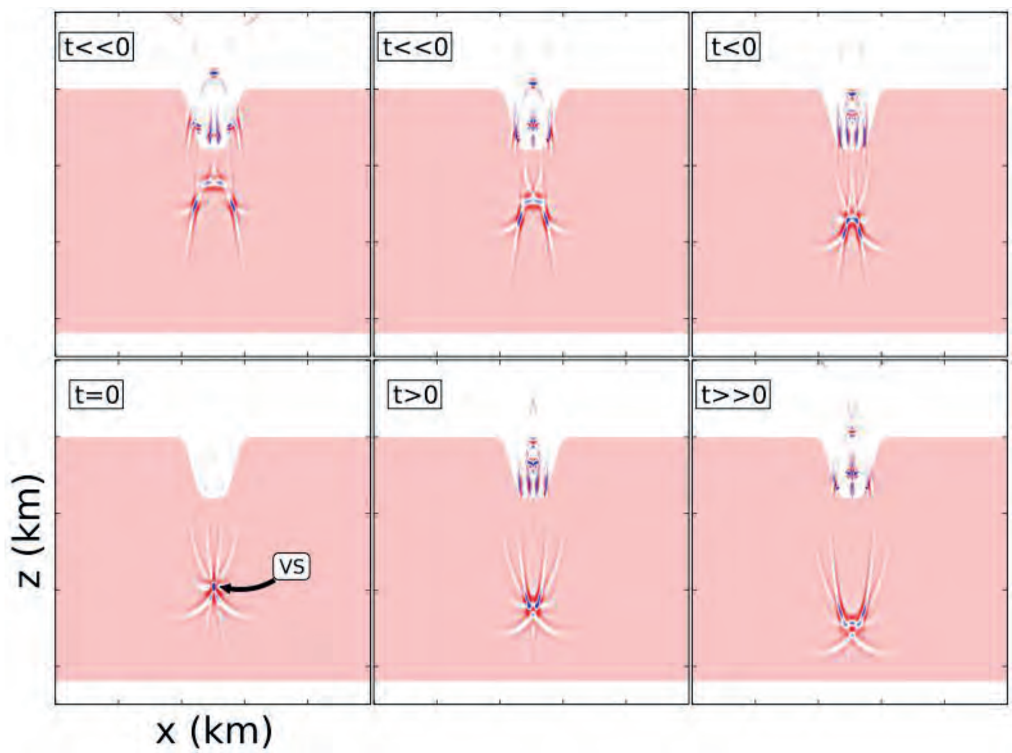
The Mw 7.3 1959 Hebgen Lake earthquake is tied for the largest historical or instrumentally-recorded earthquake in the Rocky Mountains, and the deadliest at 28 fatalities. The rupture scarred the landscape with a scarp that reaches several meters high for much of its ~70 km extent. Like other scarps in the region, the Hebgen Lake scarp will persist for hundreds, and most likely thousands of years, slowly degrading via sediment diffusion processes. In the case of Hebgen Lake, we have the opportunity to observe the extent of degradation after just a few decades, allowing us to identify the rate at which the scarp erodes in this cold, intramontane climate. On the other hand, scarps that formed prehistorically have degraded further, and we can use the extent of erosion along these features to estimate when surface rupturing earthquakes occurred. The approximate dates of prehistoric events have important implications for seismic hazard, as they help us infer the interval at which earthquakes on a certain fault recur (tens, hundreds, or thousands of years).

The LiDAR data, once filtered to remove vegetation, will provide a dense set of topographic profiles crossing the Hebgen Lake scarp, which we will use with the known age of the scarp to compute regional scarp diffusion coefficients for a variety of lithologies. We will apply the diffusion coefficients to several clear, but undated fault scarps of western Montana, eastern Idaho, and northwestern Wyoming. We will obtain topographic profiles for these scarps from Digital Elevation Models we produce this summer using Structure from Motion, which builds upon traditional photogrammetry to produce subdecimeter resolution topography data of sparsely vegetated field sites from a set of converging, low altitude aerial photographs. We will complement our topographic and age data with estimates of fault dip derived from shallow geophysical data (i.e. hammer seismic and resistivity) to determine slip and extension rates across the target faults. We will compare the computed extension rates to those derived from Dr. Bendick's GPS network in order to assess how our target faults accommodate deformation in the northern Rocky Mountains. Our results will have the capacity to further constrain regional seismic hazard assessments.

Autofocusing of Waves

Prof. Roel Snieder and Dr. Filippo Broggini

A lens can focus light onto a point. When one has a complicated medium, such as frosted glass, it is in principle possible to focus light at a point in the glass, but it appears one must know the detailed properties of the frosted glass. This is the basic conundrum in seismic imaging: to create the image one must focus the seismic waves, but to obtain the focus one needs to know the medium. Graduate student Filippo Broggini and Roel Snieder showed that inverse scattering theory, as developed originally in quantum mechanics, can be used to focus waves in an unknown medium. In order to do this they need the reflected waves and an estimate of the velocity structure.



The figure shows snapshots of waves that propagate through a complicated subsurface structure. As a result, the wavefield is also complicated. Yet at time t=0 (lower left panel) the wavefield is concentrated in a small part of space, this is a focused wavefield. These focused wavefields can be used for imaging under complicated structures in the earth, such as salt bodies or basalt. This work is carried in collaboration with Delft University of Technology where Filippo carried out part of his research. Filippo now is a postdoctoral fellow at the Swiss Federal Institute for Science and Technology (ETH).

Horizon Volumes with Constraints

Xinming Wu, PhD student

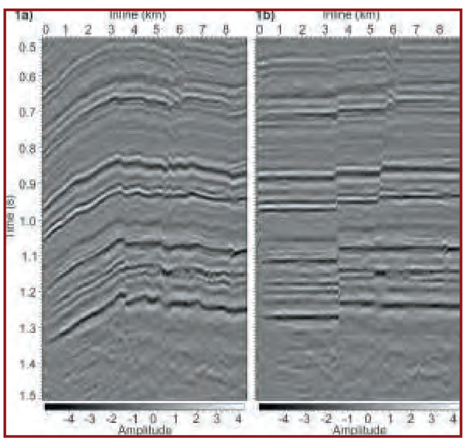
Extracting horizons from seismic images is a common and important process in seismic interpretation. Methods have been proposed to automatically flatten seismic images and therefore identify all seismic horizons at once. However, completely automatic methods may be inadequate for images complicated by faults, as shown in Figures 1 and 3. In cases such as these, interpreted constraints may be helpful in accurately extracting horizons.

We have developed a method in which the interpreter may specify, perhaps interactively, a small number of control points (green markers in Figures 2 and 3) that may be located anywhere within a 3D seismic image.

In the 2D example shown in Figures 1 and 2, an automatic method without constraints cannot correctly flatten the image, especially at faults. Using 3 pairs of control points, our method accurately flattens the image.

In the 3D example shown in Figure 3, with 3 sets of control points interpreted on 3 horizons, our method accurately flattens the entire 3D image and generates a complete horizon volume. Figure 4 shows a cutaway view of some of the horizons.

1)



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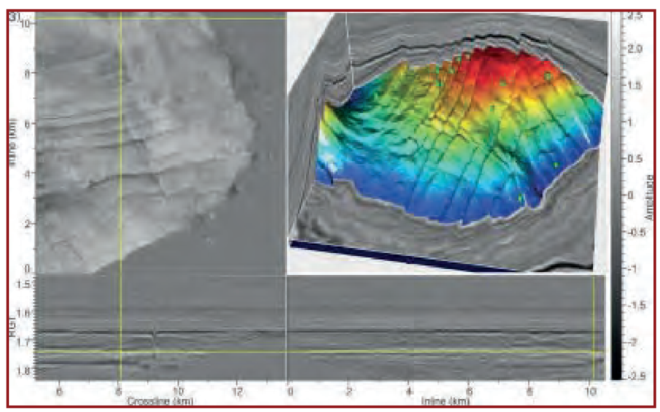

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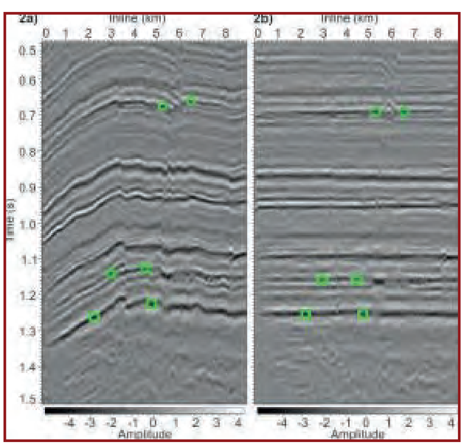

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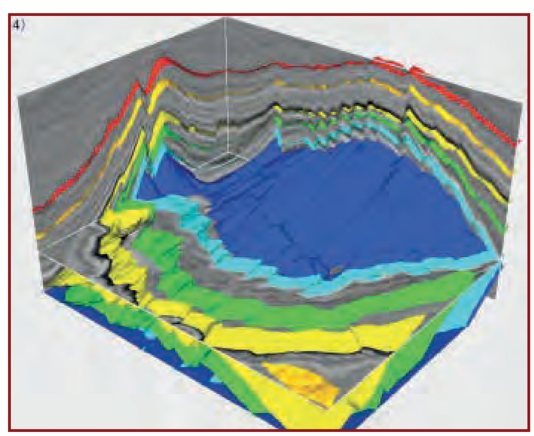


CWP

Reservoir Characterization Project

Integrated Reservoir Characterization

Travis Pitcher, MS student

When I decided to leave the government sector and return to graduate school, I had only one destination in mind - the Reservoir Characterization Project (RCP) at the Colorado School of Mines. When looking at different programs, RCP stands out in many ways, including its well-known academic rigor, real-world applicability, and industry reputation. Luckily for me, I was accepted into the program as a graduate student working on the newest phase of the project - Phase XV - Wattenberg. This project is very exciting as it is literally located in our backyard - just north of Denver - and focused around the Niobrara Formation. Beyond the large dataset provided to us by Anadarko Petroleum Corporation, this project stands to be one of the best yet as we have a large, diverse, interdisciplinary team working on its development. I cannot imagine a better group of colleagues to work with on this integrated project.

Currently in the second semester of my master's program, I am just beginning to truly delve into my research. The first semester was consumed with coursework, working as a teaching assistant, and an in-depth literature review. With much of this work complete, I am on to new tasks. Within the Wattenberg project, I will be specializing in the microseismic dataset, attempting to answer a variety of questions. The microseismic dataset just recently arrived within RCP, and was in fact only loaded today. Having briefly looked at the data, I am quite impressed with the quality and magnitude of the data.

At this point, based upon the data we have, as well as my literature review, I plan to look into the following research topics:

1. Is there an existing fracture network within the Niobrara study area that will aid the flow of hydrocarbons into the wellbore?
2. If there is an existing fracture network, is the hydraulic fracturing actually opening new fractures, or is some energy stimulating the already existent fractures?
3. In coordination with the geomechanics study for the Wattenberg Field, are the hydraulic fractures propagating in a manner that we expect to see?
4. Is there any communication between the Niobrara and Codell Formation evident in the microseismic data?
5. Can we determine the lateral extent of the hydraulic fractures in order to optimize well-spacing?

RCP has meant a great deal to me over the last six months, and I am very excited to see which avenues my colleagues and I choose for our graduate research. With the direction we receive from the RCP directors, as well as the many alumni and advisors that work closely with us, we will surely succeed in our individual challenges. While each of us will choose a different portion of the project to turn into a thesis, the project as a whole is an integrated one. Each of us contributes our piece, or pieces, to the puzzle, and makes it possible to build the project into what this consortium has always been about - integrated reservoir characterization.

Center for Gravity, Electrical and Magnetic Studies

CGEM

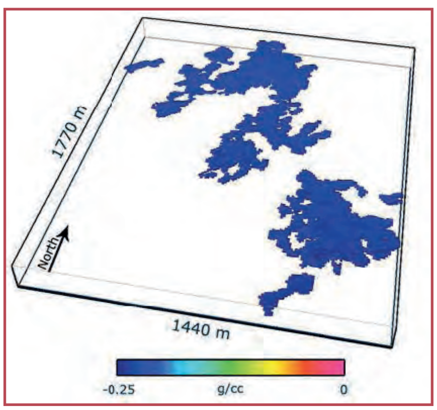
Time-lapse Gravity Gradiometry for Reservoir Monitoring

Anya Reitz, MS Candidate

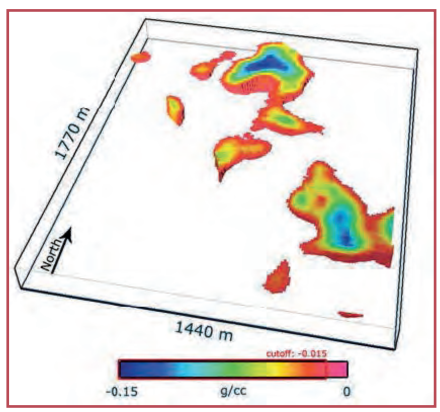
Time-lapse reservoir monitoring has become an important part of the hydrocarbon industry. Historically, this has been a seismic-dominated field. However, due to the high cost of seismic acquisition, there is motivation to explore additional methods that can provide complimentary information in-between the more expensive seismic surveys. One such alternative we are investigating is time-lapse gravity gradiometry with the consideration of recent and anticipated future advancements in instrumentation. This research is part of a major on-going effort on time-lapse gravity monitoring within the Center for Gravity, Electrical, and Magnetic Studies

To determine whether or not gravity gradiometry could be a suitable time-lapse method, I have conducted significant feasibility tests for various reservoirs types, both conventional and unconventional. The results demonstrated that while some reservoirs are more appropriate than others, it is ultimately a site-dependent problem determined by the combination of reservoir properties such as depth, thickness, porosity, saturations and time-lapse density change. I have also found that while it is effective to generalize reservoir geometries and parameters when necessary, the results are greatly improved by incorporating advanced information from multiple available sources such as reservoir property models and seismic data.

1a)



1b)



A good example is a sub-section of my results evaluating the feasibility of time-lapse gravity gradiometry for Steam Assisted Gravity Drainage (SAGD) reservoirs. The high density contrast created by steam replacing heavy oil, in combination with the relatively shallow depths of these reservoirs, provides an excellent gradiometry target. Figures 1a and 1b show the true and recovered model, respectively, for time-lapse steam bodies at an Athabasca SAGD site over a 9-year period. I created the steam body density model shown here in collaboration with Kelsey Schiltz [recent MS Graduate] and the Reservoir Characterization Project, who recovered the spatial boundaries of the steam chambers from time-lapse seismic data. The excellent recovery of steam chamber geometry in Figure 1b demonstrates the potential of the time-lapse gravity gradiometry method for monitoring at this particular SAGD site.

Planetary Geophysics Lab

Sinkholes in Florida:

An Analog for Lakes on Saturn's Moon Titan

David Horvath, PhD student

My research on Saturn's moon, Titan, continues to challenge and intrigue. Approaching it's 10th year in the Saturnian system, the Cassini spacecraft still provides planetary scientists with a wealth of data, particularly on the surface of Saturn's moon Titan. Titan is the only body in the Solar System, beyond the Earth, where stable liquid is observed on the surface. But at 95 K, water on Titan's surface is only stable as ice and composes the majority of the crust. Hydrocarbons (methane and ethane) on the other hand, are stable as liquids on the surface, and participate in a hydrocarbon based hydrological cycle on Titan. Of particular interest are the lakes of liquid methane that are found in the north polar region, which appear morphologically similar to lakes and seas on Earth.

This research on Saturn's icy moon Titan has taken me to a surprising analog location: warm and sunny Florida. Data from Cassini revealed a number of features on Titan that looked similar to karst-related features on Earth. Karst on Earth includes caves, sinkholes, and a variety of other features that form when liquid water dissolves carbonate rocks such as limestone. On Titan, the role of the carbonates is likely played by solid organic material that is soluble in the methane flowing on and beneath the surface. Despite obvious differences in temperature and composition, features on Titan look very much like karst features seen in Florida. Last February, I took part in a Titan surface workshop in central Florida with members of the Cassini spacecraft science team. Besides the chance to pick the brains of some of the top scientists in the field, central Florida also offered me the opportunity to investigate karst features that make up a large area of Florida in order to try to learn more about karst on Titan.

Our first stop on this one-day field trip was a region just east of the Florida gulf coast, where extensive cave systems cut through limestone layers that make up the Floridian aquifer. The Florida peninsula is the surface expression of a large carbonate platform that was deposited during the Miocene and has since been reworked by fluctuations in the sea level. During times of high sea and ground water levels, dissolution erodes the limestone to make subsurface cave systems. As the water level recedes, hydrostatic pressure no longer supports the cave systems and collapse begins to occur.

Geophysics graduate student David Horvath (far right) and members of the Cassini spacecraft science team explore karst landscapes in Florida that resemble those on Titan.

This was observed in multiple caves around this area, where collapse exposed the caves to the surface allowing us to explore the cave system. Features within these caves indicative of high discharge suggest they played an important role in transporting water across the region. These caves and their subsequent collapse have had a profound effect on the landscape of Florida. On Titan, numerous small lakes and giant seas are observed in the north polar region. In some cases, the lakes are not fed by fluvial channels suggesting that they receive liquid methane from flow in the subsurface. If dissolution processes are occurring on Titan, underground cave systems could rapidly move liquid methane between these lakes.

Gator sink (left), home to a 10 ft alligator, appears morphologically similar to small lakes on Titan (right).

A direct observation of cave systems on Titan would be difficult, but the observed morphology of small lakes can be compared to similar lakes on Earth. Some Titan lakes have rounded, steep-sided shorelines, similar in morphology to karst sinkholes on Earth. Once a cave system develops and the water table subsides, overburden on top of the aquifer can cause collapse in the form of rounded depressions. This is the case in central Florida and was the next stop on our field trip. The Gator sink (home to a 10 foot long alligator) is a small, rounded, ~ 30 m deep steep-sided depression that formed during a time of extreme drought when hydrostatic pressure from the water table could no longer support the overlying sedimentary layer. The sides of the sink showed evidence for recent fluctuations in lake level due to changes in the water table. Similar to other sinks in the area, this karst lake is fed by a subsurface spring during dry periods and overflow from a nearby creek following heavy precipitation events. This morphology resembles lakes in Titan's north polar region and may indicate similar dissolution processes in a subsurface aquifer on Titan. The nature of this dissolution is still not understood on Titan and is an active area of investigation.

Of all the surfaces in the Solar System, only the surface of Titan has a diverse hydrocarbon-based hydrological cycle, similar to the water cycle on Earth. My research is aimed at understanding this hydrocarbon-based hydrological cycle on Titan. This trip to Florida has convinced me that karst-like processes may have a significant impact on Titan's hydrology. For my continued research on this topic, I plan to model dissolution processes with a subsurface hydrological model to investigate the aquifer characteristics that fit the observed morphologies of Titan lakes.

Although evidence for a 140 foot long gator on Titan has yet to be found, the morphology of lakes are analogous to dissolution morphologies that make up karst lakes in central Florida. But how far can we take this analogy? Well, retirees and vacationers beware: if a person were to take a dip in one of Titan's lakes, they would sink like a stone because of the low density of liquid methane and freeze to their core in a matter of minutes!

2013 Geophysics Field Camp - Pagosa Springs, Colorado

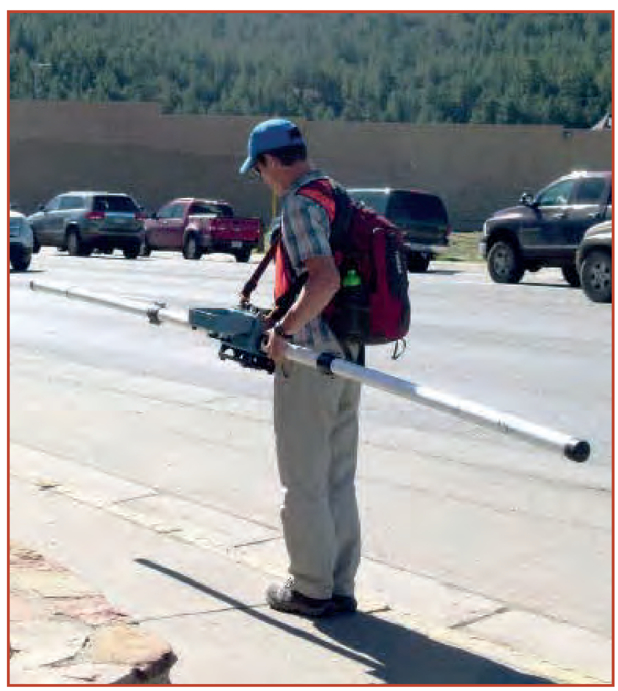
Thu Thao Bui, Class of 2014

My name is Thu Thao Bui and I'm a senior in Geophysical Engineering. Last summer, I participated in our department's field camp. Through this experience, I have learned a lot both in the academic and personal improvement aspects. Field camp 2013 was conducted at Pagosa Springs, Archuletta County, Colorado with the goal of characterizing the geothermal potential of the local area. During this four weeks intensive course we designed surveys, collected data, interpreted the data, compiled a technical report and presented our findings to the public,including CSM staff and other scientists.

The first two weeks of the course were spent in the field. First, we learned about the geology of the region and made maps in order to define and locate our targets. Next, we designed our surveys. Then, we conducted these surveys using electromagnetics (EM), electrical, ground penetrating radar, self potential, DC resistivity, hammer seismic, deep seismic, remote sensing, gravity, and magnetic methods. to collect our data. Lastly, we processed and interpreted the data for two weeks back at CSM.

This field camp was an amazing opportunity to introduce ourselves to new geophysical methods. However, the most important knowledge we've learned is to incorporate all of the information we got from these methods into the big picture for assessing the geothermal potential of Pagosa Springs. In addition, by living and working with each other for four weeks, we got to know our classmates and staff better. We've also stepped out of our comfort zones and academically mingled with the students from the Imperial College of London, adopting each other's strengths and improving on them.

Last but not least, I had the opportunity to observe my admirable professors and friends working and socializing. From that I was able to recognize, improve and correct my own techniques. Now I study more efficiently and I feel that the geophysics department is where I belong. I am that much closer to achieving my goal of becoming a respected professional and an inspiring individual, all thanks to our field camp.



Break-ups are the Worst:The Life of a Fault Scarp

Steven Plescia, AJ Yanke, Paul Geimer, Class of 2014

A fault scarp is a surface expression that is created when a fault ruptures. They are often distinguished by a vertical displacement and a change in the topography's slope. When the fault first ruptures, the edge that was displaced is sharp and the slope is very steep. However, over time, the material from the top of the fault scarp erodes and begins to fill in the bottom. This makes the edges round out and the slope begins to flatten out. After an incredibly long time, if there are no more fault ruptures, the scarp will eventually be completely flat and indistinguishable from the surrounding topography.

If you saw a fault scarp today, it would almost certainly be between the completely vertical and completely horizontal stages. Our task was to attempt to determine the age of one of these scarps that is in the in-between state.

We first set out to create an accurate cross-section of the fault scarp we wanted to model. We did this by taking aerial photos of the scarp. We rigged a camera that was hacked to record GPS measurements and take pictures at regular intervals to a "heli-kite," something that is a cross between a helium balloon and a kite. We then flew this "heli-kite" all along the fault scarp and surrounding area collecting pictures. We took these pictures with the GPS data and loaded it into a program that overlapped the images and used the GPS to create a Digital Elevation Model or DEM for short. The DEM is a 3D aerial image of the area we took pictures of and it allowed us to make our cross-sections. We then used forward modeling of the slope diffusion equation to create a theoretical erosion situation for a hypothetical initial fault scarp. As time progresses, the initial fault scarp erodes, and our model produces a scarp that begins to round out and get flatter. Since we know the amount of time it took our model to produce this hypothetical fault scarp, if we can find one that matches our cross-section, then we can determine the age of our fault scarp.

However, faults tend to rupture more than just once. Multiple displacement events can occur before the first event has had time to fully heal. This would create a more complicated system and is much harder to model. In fact, on our DEM, it was impossible to distinguish multiple events and therefore we were only able to model the most recent displacement event.

My Experience as an International Student

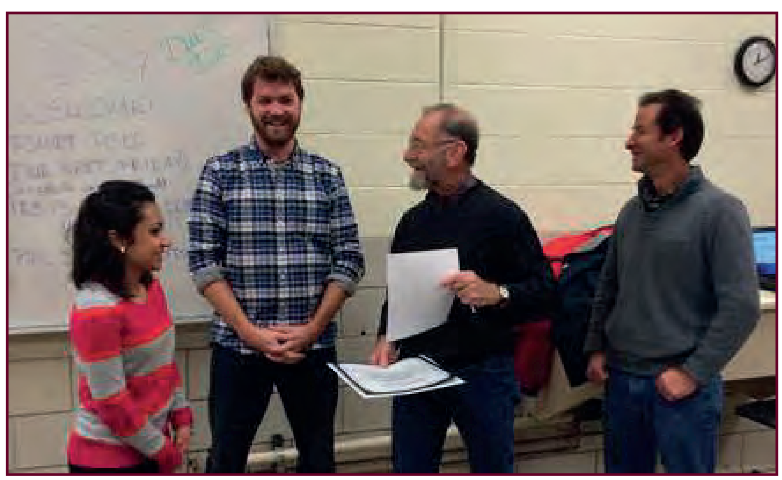
Deema Albeesh, Class of 2014

As a senior who has completed three quarters of my degree, I am looking back at the past three years and I realize that I have had a very rich experience as an international student. Being from Saudi Arabia means being roughly 7600 miles away from home. Not only am I distant from family, but the 9 to 10 hour time difference makes it difficult to communicate with my loved ones. Nonetheless, being here at CSM helped me grow in different ways. My sense of persistence has been reinforced, and it continues to grow everyday. I have spent countless hours completing homework problems and long late nights studying for tests and completing projects.However, all of the hard work I have been putting in only made me more passionate about what I study. One of my favorite tasks so far is being able to experience hands on geophysics during field camp. There is no better learning method than two continuous weeks of working outdoors with different geophysical equipment and analyzing that data with all of its challenges.

Being at CSM has also granted me the opportunity to make diverse friends from different parts of the world. I have learned so much about different cultures. Even though I will be returning home after graduation, I believe I have made some unforgettable life-long friends.

The unique nature of Colorado has given me the chance to try numerous adventurous outdoor activities including skydiving, zip lining, rafting and many others, all of which I have not tried before. I never considered myself as an outdoors person, but I have learned to love all of these activities and I am always eager to try new ones. I have come to the Colorado School of Mines seeking a degree in geophysics, but have gained much more than an excellent education. The past three years made my family proud of me and made me feel at home even though I'm very far away from home.

Congratulations to Deema Albeesh, the first-ever recipient of the *Ken Larner Prize for Exemplary Writing.*



This prize is awarded annually by the faculty of the Introduction to Geophysics course (GPGN200), in recognition of the importance of communicating ideas well, to a student whose writing in this course was exceptional. Deema is pictured with Dr. Gavin Hayes, Adjunct Assistant Professor & USGS NEIC Research Seismologist; Professor Emeritus Ken Larner; and Dr. David Wald, Adjunct Associate Professor & Supervisory Research Geophysicist, U.S. Geological Survey.

Modeling Seismic Anisotropy at Los Alamos National Laboratory

Ian Stone, Class of 2014

As a Mines geophysics student, you will have the opportunity to work and research at some of the country's foremost research institutions. During the past four years, my education has taken me all over the country, though my most valuable experience yet has been researching at Los Alamos National Laboratory.

After receiving a Science Undergraduate Laboratory Internship (SULI) grant in my sophomore year, I was paired with the Earth and Environmental Sciences research group at Los Alamos National Laboratory. There, I have had the distinct pleasure of working with the geophysics subgroup for the past two summers, researching and building code to model seismic anisotropy at the Nevada National Security Site, as well as predicting ground motion from injection-induced earthquakes at carbon dioxide sequestration sites.

This experience has given me a unique perspective on how research is conducted at national laboratories, and I credit my Mines education with preparing me for the rigorous standards of work expected there. Because of the quality of the work I have conducted and the connections I have made, I will be returning to the lab for a year long, Post-Baccalaureate research position, which will further allow me to hone my research skills and prepare me for my graduate education.

Geophysics, Koalas and Cricket: An Internship Down Under

Cici Martinez, PhD Candidate

Center for Gravity, Electrical and Magnetic Studies

Where on Earth can you cuddle a koala? The great Down Under of course! I was fortunate enough to have spent a few of Colorado's colder months experiencing an Aussie summer in Fall 2013. While many believe I was on vacation (and it really felt like it!), my trip to Australia was more of a working holiday. I had the opportunity to intern with the England-based company BG Group at their QGC office in Brisbane. Afterwards, I spent another two weeks visiting Perth and Western Australia.

While in Brisbane, I spent six weeks working with the software CGEMaestro (developed by my research group here at Mines) applied to exploration projects at QGC. This was a unique opportunity in that I was helping to develop a workflow to incorporate potential field interpretation (specifically algorithms developed by CGEM) into existing exploration efforts. While this is and will be an ongoing process, it was an excellent learning experience to be a part of the initial stages of such an endeavor.

Geophysics aside, working with a foreign-based company was in itself an experience. As an England-based company, there were just as many English as there were Australians. While the addiction to coffee remains constant, there were some things I could not have experienced anywhere else in the world. It just so happened that I was in Brisbane during a festive six weeks with the Melbourne Cup and The Ashes taking place. The Ashes is a popular cricket rivalry between Australia and England that was hosted in cities throughout Australia in 2013. It made for an entertaining time in the office with an almost equal mix of cheering and booing banter. I had to look up both Aussie and English slang on more than one occasion. Having never seen a cricket match, I found myself intrigued by the sport, though I don't think I would ever be able to sit through a whole match. My time in Brisbane rounded out with my first ever lawn bowling outing with the exploration team. After golf, I think I've found my second favorite leisurely sport.

When my short internship ended, I traveled to Western Australia. In the interest of space, I'll summarize my time in Perth and Western Australia through a short poem (thanks to Brent Putman for his assistance).

Dolphins swimming with sky scrapers above,

Margaret River vines and glasses of wine,

Reflecting sunsets on sandy beaches,

stromatolites and pinnacles o my!

Sad truth: Roos are road-kill. Red meat kebabs.

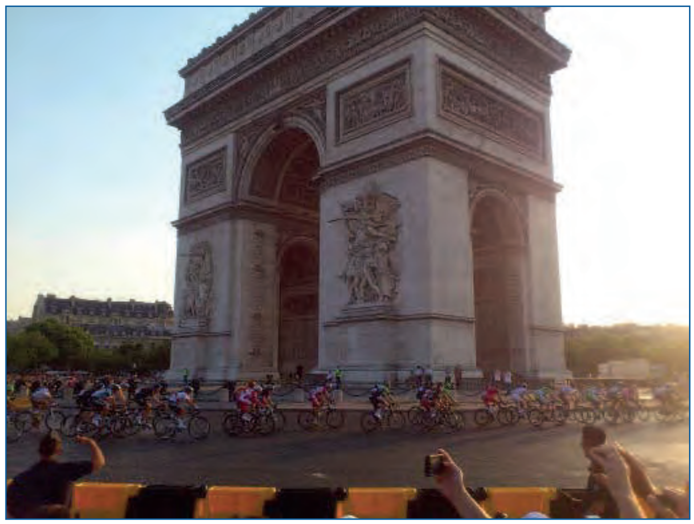
Cold beer, mangoes, lamb chops like nowhere else

Satisfied, yet not enough time; or wine.

Geophysics WORLDWIDE Elijah Thomas, Class of 2014

Last summer I had the opportunity to intern abroad with CGG in Massy, France. The most important thing about geophysics, I've come to find, is the many opportunities you are afforded. One may think, “Oh geophysics? I've heard a bit. You are those people that help to find oil.” That is part of what we do. However, there are so many more opportunities. We live in a diverse world full interesting, challenging geologic environments and issues. We as a society are constantly confronted with an Earth that we do not fully understand, even as we make important decisions, explain complex phenomena and move forward to make the world a better place. Now let me tell you about my internship!

It all began in early May of 2013. Roel Snieder told me of an opportunity with CGG aimed at creating a closer connection with Colorado School of Mines. I contacted CGG, applied for the internship, obtained a French visa, and traveled to Massy, a suburb of Paris. To describe this as a dream come true is right on target. I've never had the opportunity to leave the United States, and to have such an opportunity while being paid, fed, and housed was beyond anything I might have imagined for myself. Upon arrival at the airport in France, I realized what kind of situation I was getting myself into -- carrying three bags of luggage, and figuring out a fairly complicated metro system in another language. Let's just say that I was lost for a bit, bought the wrong ticket, but finally wound up at my hotel/apartment.



At CGG, I worked in their research and development department. With my prior experience in alternative methods, and CGG's recent acquisition of Fugro (with its diversity of geophysical applications), I was invited to do research in gravity and gravity gradiometry surveying. The geophysics department at Mines prepared me very well for my work. I was able to contribute to research into pros and cons for different surveying, inversion, and interpretation techniques. I also modeled sensitivities pertaining to using different equipment for surveying areas with targets of variable densities, depths, and volumes. The fun did not stop there!

I was also presented with an opportunity to visit a seismic exploration site near Pau, France. This project was designed to fully understand a produced reservoir being used for gas storage. What made it particularly interesting was CGG's implementation of a new wireless geophone system. I helped collect data, while learning about the challenges of doing fieldwork in a location with many farms, vineyards, and some forested areas filled with brambles and tree branches that threatened to snag you -- I would love to go back!

It's a unique life path when one chooses geophysics, and its a decision that I do not expect to regret, but rather cherish as I grow and age. I am thankful for the students and faculty in this department, and thankful for the companies that seek out geophysicists. Without them, I might have never had the opportunity to work in France and enjoy every minute of it. If you're interested in hearing more about my less work-related adventures in France, please feel free to peruse my public journal that I kept: iamelijah.tumblr.com/. À bientôt!

"Never Satisfied, Always Improving"

AJ Yanke, Class of 2014

The very first words I read walking into the doors of Statoil, Houston were "Never satisfied, always improving," a phrase that I have reminisced ever since my internship with the company's Prospect Maturation and Evaluation (PME) group during summer 2013. Having experienced the Statoil initiatives first hand, I can confirm that this simple affirmation vitalizes the legacy that Statoil strives to leave behind in each of its endeavors. Throughout the summer, I received mentorship in combining 3D seismic interpretation, well log analysis, facies correlation, and stochastic modeling to estimate resource volumes and their associated risks within a deep-water Gulf of Mexico prospect. My project culminated in a formal presentation to coworkers and management where I advised on the prospect's potential and proposed future work. The project challenged me to tune my academic skills and knowledge to an applied setting (i.e. in the workplace).

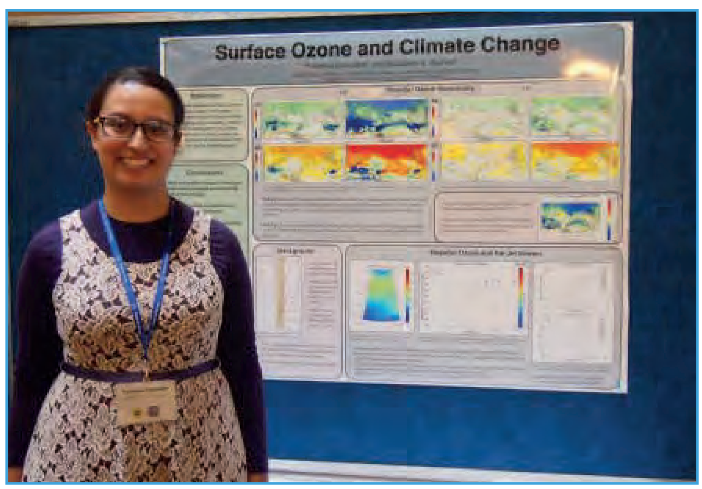
Along with the project, the Statoil workplace constituted an experience that should be pursued by any geoscience intern. The workplace, itself, has an open ambience where colleagues are easily accessible and responsive to any of your requests or questions. One of the best experiences as an intern at Statoil was that other employees did not treat me as an intern; they treated me as a colleague with whom they can discuss live projects that affect corporate decisions. This involvement was extremely enticing for me since I felt that I could constructively contribute to others' work as much as they could to mine—so long we were always improving. The whole experience was one of constructive learning and feedback on both ends of workforce spectrum: the Statoil employees and all the interns. Consequently, the Statoil experience was invaluable with respect to the project objectives and the constructive environment through which the entire Statoil team, including interns, collaborated in pursuit of their ambitious goals.

Reaching for the Sky: An Undergrad's Summer Research Experience in Fort Collins

Katerina Gonzales, Class of 2015

I have been a cloudgazer for much of my life, and my love of earth science transcends beyond the solid. Nearing the completion of my sophomore year, I thought it would be good to see if atmospheric science would be an interesting future for me and I was accepted to the REU at the Center for Multiscale Modeling of Atmospheric Processes (CMMAP) at Colorado State University in Fort Collins. Some students get a brief exposure to atmospheric and climate science in GEO101, but for the most part the uppermost layer is a mystery to CSM geoscience majors. As a result, I was slightly nervous coming into the program where most of the other thirteen interns were atmospheric science majors. However, upon opening MATLAB at my desk, the uncertainty began to melt away. I realized how well the Geophysics department had prepared us, especially with EPICSII and other programming classes.

Doing research was a blast, and it was really interesting to see where the project took me as I investigated surface ozone and its influence from climate change. I worked with coupled chemistry climate model data from IPCC's Coupled Model Intercomparison Project Phase 5. Basically, I had grids upon grids of surface ozone data as well as wind speed data from 2006 to 2100. My project focused on the seasonality of surface ozone and the connection to the wind circulation. At the end, we all got to present orally and in poster. CMMAP even sends the interns to the AMS conference or AGU Fall Meeting to present their research.



This ten week experience was very instrumental in realizing that research is fun and going to graduate school after Mines will be the next step for me. It was such a pleasure to work with CSU Atmospheric Science professor Dr. Libby Barnes, as she understood the challenges not coming from an atmospheric science background. The program really did a good job to see that every intern was mentored, both by faculty and grad students there. This experience wasn't all science, though. The internship includes activities such as a USGS Ice Core Lab tour, tour of NCAR, ropes challenge course, lunch seminars, and more. Interns grew very close and also did many fun things such as hiking, trivia night, rafting, biking to work, and many more adventures.

I definitely learned a lot that summer and highly recommend applying for the CMMAP internship. Even if you are uncertain of what aspects of earth science interest you the most, this is a great taste of atmospheric science and grad school. Or perhaps you want to try something new. As we like to say at CMMAP, reach for the sky!

"An Experimental Analysis of CO2 Sublimation and Martian Gully Morphology"

Rosie Leone, Class of 2016

Last summer I had the opportunity of being a research intern at the University of Arkansas at the Center for Space and Planetary Sciences. My project was entitled "An Experimental Analysis of CO2 Sublimation and Martian Gully Morphology." The main goal of the project was to see what happened when dry ice sublimed on Martian regoloith simulant in a test section.

For the first part of the summer I learned how to use ArcGIS and photogrammetry software tools. Since we were going to be analyzing the test section using a Digital Elevation Model (DEM) I had to learn to create a DEM using the photogrammetry tools and then analyze it with ArcGIS. I created a python script that analyzed the slope, elevation change, direction of slope movement, and curvature of each DEM. I also learned how to create the DEM's by importing snap shots of the test section over several time intervals. After this, I spent about two weeks in a cold room doing the experiment. The rest of the summer I spent analyzing the video from the webcam that ran during the experiment, creating snap shots of when an important event happened, and then making these snap shots into DEM's which I then analyzed with ArcGIS.

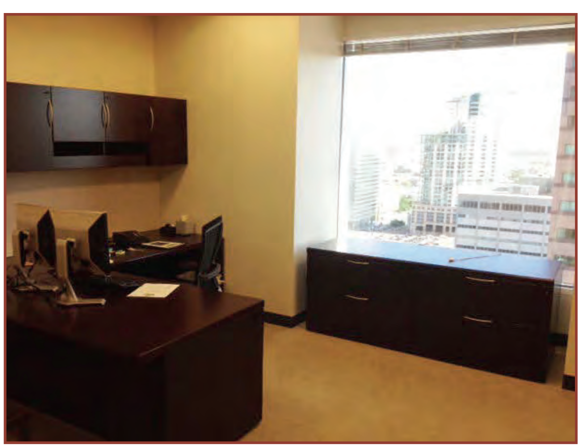
The highlight of my time with the University of Arkansas was when they let us take a week off to go to Houston where we got a V.I.P. tour of the NASA Johnson Space Center. Here I got to see exclusive sights such as the Neutral Buoyancy Lab where astronauts train underwater for when they have to go to space, as well as the Apollo 13 room. Normally you just get to see this room behind glass but we had the opportunity to actually go inside of the room which is something I will never forget.

Overall, this internship not only allowed me to see what grad school may be like someday but it also allowed me to gain friendships with students from other colleges interested in going into planetary science. I am still in contact with many of the other students and this spring I will have the opportunity to go to the Lunar and Planetary Science Conference (LPSC) to present the poster of my work as well as network with professionals in the field. This was an amazing experience and it felt good to actually be able to use the skills I learned in the classroom to a real life research project.

Balancing Research with an Internship

Jarred Eppeheimer, Class of 2014

After field session ended in early June, I began working as a research assistant on a project with CSM Professor Andre Revil. As I had worked with Dr. Revil last summer as well, I had experience with the equipment and lab procedures required for this project. The goal was to document the complex conductivity properties of several volcanic shale samples, as this information is absent in geophysical literature. I had already worked with the SIP equipment (used to measure complex conductivity), so I was able to work independently while recording these data. However, before I could even start taking measurements, I had to manually cut and shape each sample with various rock saws and sanding belts—this was a very tedious and lengthy process. Following the preparation of the samples, they had to be pressure saturated at 1000 psi for several weeks due to their extremely low porosity. Graduate student Matt Wisniewski and Professor Mike Batzle were a huge help to me in these parts of the project, as I had never worked with diamond saws, pressure chambers, or automated pump systems before. I also had to create specialized current and potential electrodes to fit each sample so that complex conductivity could be measured. Graduate student Bill Woodruff helped me greatly with this process, showing me how to properly cut the electrode pads, solder electrode connections, etc. This project is still continuing, but I was able to complete the first round of complex conductivity measurements for Dr. Revil.

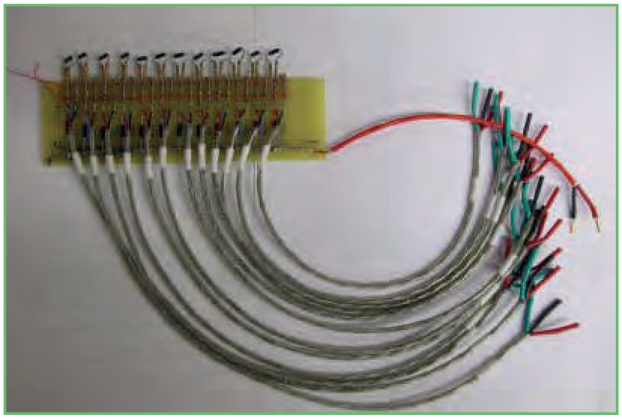


What made my summer really interesting is the fact that I also worked part time for Cimarex Energy Co. in downtown Denver. I received this offer about a week after starting to work for Dr. Revil, and immediately began working on several small projects for Cimarex the next week. My days usually consisted of spending the mornings in downtown Denver, and rushing back to CSM in the afternoon to continue with my project for Dr. Revil. The radical shift in atmosphere—from a corporate office to a dusty basement—was interesting to say the least. I had to change out of my office clothes between jobs, as I would routinely become covered in rock dust, grease, and miscellaneous gunk in the Green Center basement. My hectic days were well worth it, however, as I learned great deal this summer about the geophysical industry, and also added quite a few new research skills to my toolkit.

My Summer Romance with P and S Waveforms

Spencer Haich, Class of 2014

Last summer I had the privilege of working on a research project under the supervision of George Radziszewski and Mike Batzle. The overall goal of the project was to set up a system that enabled us to measure P and S wave velocities in core samples, from companies, at a range of temperatures and pressures. We used a vacuumized pressure chamber connected to a computer-operated custom controller box and oscilloscope. We would first connect piezoelectric crystals (crystals that vibrate in certain ways when subjected to a voltage dierential) to the sample and make sure that these were coupled well. Then we would test the sample outside of the pressure chamber to see what sort of response we would expect. The sample was placed inside the pressure chamber and then connected through a wiring system to the controller box and oscilloscope, which were in turn connected to the computer. After running more tests on all of these connections we would then proceed to vacuumize the pressure chamber and run even more tests to see how well-sealed the chamber was. After all of this, one sample is ready to run once. A single run takes several hours and produces thousands of waveforms at varying temperatures. We take this data and analyze it, picking P and S wave times in each waveform. After certain corrections we are able to obtain a P and S wave arrvial time versus temperature plot. This data is useful to the company sending the samples because they are able to much more accurately predict the velocity of the subsurface from their cores. Setting up the system required basic knowledge of almost every science and was a huge challenge in itself; it helped me to hone and expand my skillset in unexpected ways. During the course of the project, I learned about soldering methods, piezoelectric crystals, remote operating of oscilloscopes, picking P and S arrival times, and much more. Being given the opportunity to serve as a summer research assistant in the Colorado School of Mines geophysics program was incredibly rewarding.



A Freshman Work Experience in the Rock Physics Lab

Hanna Flamme, Class of 2018

As a freshman, I am glad to have been given the opportunity to work in Professor Batzle's lab. I have learned a great deal in a short amount of time, and the experience has proved to be quite valuable. Every day my work in the lab proves to be even more interesting than the previous days, and I look forward to the time I spend there. During my first few weeks my main duties consisted of cleaning and organizing the lab area. However, as my skills increased the difficulty level of my duties also increased. My first project included designing a heating and cooling system for a pressure vessel in the lab. Professor Batzle jokes that I've learned enough about pipe fittings and couplings from building the cooling system that I could become a plumber if Geophysics doesn't work out. Additionally, I have learned how to calculate porosity based on Archimedes' Principle, solder, and make thermocouples and extension cords. My previous project was a chemical inventory, including the name, manufacturer, and location of chemicals in the various Geophysics labs.

Currently, I am creating a Wheatstone bridge under the direction of another Geophysics Department employee, Weiping Wang. The Wheatstone bridge will be incorporated into a project for the Chinese. I hope to become more involved in this project so that I may have the opportunity to travel to China in the future. I also desire to increase my skills so that I may be more involved in the preparation and collection of data from rock samples. Specifically, I hope that I can test rock samples using the heating and cooling system of the pressure vessel that I worked on. The hands-on experience in the lab has afforded me new skills and contacts in the department as well as the ability to be part of the lab and its projects. I look forward to more challenges and experiences in Geophysics!

CSM, Take #2

Craig Markey, MS Student, Center for Rock Abuse

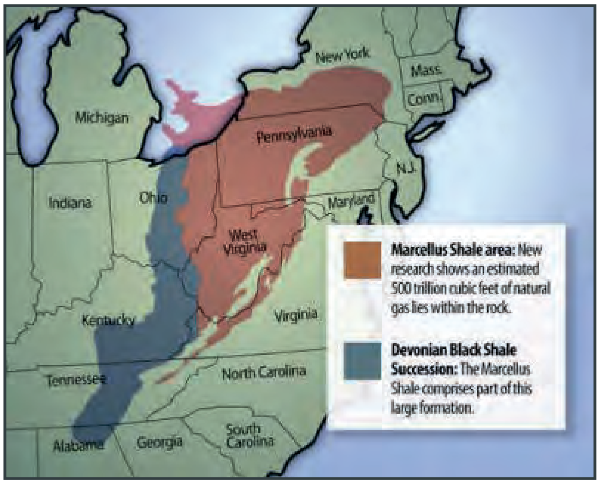
When first coming to Mines for undergrad in 2005, I thought getting into math and science was going to be my ticket out of having to deal with poor writing skills… But, as I have found through my experience in becoming a professional, there are many ways that expectations will be confronted with reality (for better or worse). In fact, I originally came to CSM to pursue a degree in mechanical engineering, never expecting I would become fascinated with earth sciences and applied geophysics. As I followed these interests to a full time position at a small geophysical consulting company I was eager to use my shiny new Mines degree and begin my career path in geophysics. I was met with a steep and exciting learning curve getting exposure to the world of planning, collecting, processing, and reporting on problems within the field of geotechnical and exploration geophysics. Some projects involved new and exciting techniques in unique places while others required repetitive laborious tasks in adverse climates. When joining this company I had no idea I would get a chance to do Vp, Vs surveys on an atoll in the Marshall Islands. Or, conversely, have to spend the hottest months of a Texas summer dragging instruments mile after mile to map utilities along transects. And, to my surprise most of the difficulties and challenges faced throughout these three years were not usually those related to complex geophysical problems or theories, rather the dynamics of handling an adverse situation. To me these experiences were invaluable, but eventually my desire to build my understanding in geophysics brought me back to graduate school.

I am excited to be back in school and to be able to focus on furthering my education in geophysics. I chose Mines not only because of its great faculty and comprehensive program, but also because I attended undergraduate here and thought it would be a manageable transition from being away from academia for the past 3 years. As I have gained more experience and involvement in geosciences I have realized that I am driven by solving problems in exploration. I returned to Mines to become a better equipped geophysicist and a more valuable professional in exploration

geophysics. Regardless of these expectations I am confident that attending graduate school here at Mines will continue to make exciting opportunities possible as I move forward in my career path.

Interest in Marcellus Shale

Andrew Cooper, Class of 2017



Growing up in Cleveland, OH, I observed year after year the hardships of a troubled economy affect local and corporate business in a devastating way. Ever since the steel industry of Ohio, Pennsylvania, and New York has been lost to countries like China and Japan, hundreds of thousands of people have moved away from a seemingly hopeless area of the United States. However, in the past decade new technology and research have given hope to the area, as the process of hydraulic fracturing has been established.

The Marcellus Shale itself for a while had very little interest in the minds of corporate oil companies, as crude oil had been extinct in the area for many years. When scientists and engineers perfected extracting natural gas from shale, the Marcellus Shale became the hottest spot to purchase land rights in the entire country. Literally, the area has around 500 trillion cubic feet of natural gas, or enough fuel to power our country for hundreds of years. This new economic market has sparked new life, as employment has soared and numerous on site drilling jobs are now in high demand.

All of the research and time put into developing the Marcellus Shale has seemed to pay off, as the United States could use this reservoir to move away from foreign oil dependency and instead provide for itself once again. Unfortunately, politics have caused hardships when oil corporations moved into the area looking to help extract energy for the country. Drilling regulations and restrictions have made it essentially impossible to drill in most areas of New York, while Pennsylvania and Ohio are following in the same path. Do we not have faith in our engineers and scientists to extract the natural gas in a safe and controlled manner? The United States would benefit immensely from the natural gas, but in order to see results a little trust must exist between government and the energy industry.

The future could be extremely bright for states resting on the Marcellus Shale, and as a native of Cleveland, OH it is comforting to think I could return home to work in oil exploration as a geophysicist and find a secure job.

Old Fogey, Scary School....................Brandon Williams, Class of 2018

I am 28 years young. I know that is not entirely too old by most people's standards, but comparatively at Colorado School of Mines it is on the older side. I am fine being the old fogey in my opinion. I can say I have made few trips around the pool. I own my own place, I have a dog and I am ecstatic that I have the opportunity to be part of this school. I have been to four different universities and I must say the faculty and students at Mines are easily the most friendliest. Not to take away anything from my prior schools, but I get a sense mutual respect throughout the campus. I think everyone knows since they are here, they are smart, motivated and should be taken seriously. I find when I meet someone new on campus it is easy to be very friendly and quickly become friends with whomever I am talking with. This is just my first semester here, so I might be a little naive, but that is what I got from this school so far, or maybe everyone is just respecting their elders (me).

Also, I am veteran. I could go on and on about how proud I am to serve my country in such a patriotic manner, but I'll spare you. I am glad I served four years in the Marine Corps, but also I am happy I got out too. So after four years of honorable service Uncle Sam literally gives you a blank check to any public institution in the country. This program was first introduced in 2008, and the time I first caught wind of it I quickly decided getting out and going to Colorado School of Mines was in my future. Growing up in Colorado Springs I only knew two people, one out of my graduating class, that got accepted to School of Mines. To say the least, it is a pretty hard school not only to graduate, but also to get in to.

When I got my acceptance letter to the school I immediately got excited, but a slow insidious anxiety started to set in, "Crap, now I have to go to scary School of Mines". My girlfriend will tell you that I am smart and I am being a big baby, but I know, just like everyone else at this school, brains do not get you here. Strenuous hard work gets you here. In the words of Theodore Roosevelt on the strenuous life, "In the last analysis a healthy state can exist only when the men and women who make it up lead clean, vigorous, healthy lives; when the children are so trained that they shall endeavor, not to shirk difficulties, but to overcome them; not to seek ease, but to know how to wrest triumph from toil and risk. " This is a fitting quote for this school and a successful and fulfilling life. I trust I have much work to do.

As far as Geophysics goes, my best explanation for the major is that it's like a really good spring roll from your favorite Japanese Restaurant; it's got everything you want all rolled up in one delicious fried treat. Maybe not fried, but definitely a cornucopia of everything that is cool about math and science. In my short exposure to the major I only get more and more excited about it. "So you mean I get to do a little bit of all the sciences and still not get stuck in a lab for the majority of my career? Sign me up!" I am just a Sophomore and only having one class in the field, I can not tell you it is the exact and perfect match. I don't know that, I can only guess Geophysics is pretty close to everything I wanted to learn and do in my life and career. So I trust I will be very fulfilled in the field, even for a scared old fogey.

Geophysics: The Perfect Area of Study for Someone Who Can't Decide

Joni Sanborn, Class of 2016

When I first got to Mines I was shocked by how everyone seemed to have their lives planned out and how they knew exactly what they were going to do and how they were going to do it. I'm a planner, so it seriously stressed me out that I didn't know what I wanted to major in. Sure, I was good at math and I thought I would like engineering, but I wanted that four-year plan sitting in front of me. I ended up printing out a list of all the degrees offered and spent an afternoon researching and crossing off nearly everything on it but geophysics (and honestly, that's probably because I just enjoy the way it sounds when you say it).

A few days later I happened upon an upperclassman who described being a geophysicist as "a pirate searching for treasure" and after that I was determined to learn more. I made an appointment to talk with Dr. Young and he made geophysics sound even better by relating his playground analogy. Not only does everyone's inner child love playgrounds, but the facts behind the metaphor worked for me. I love having a broad knowledge of a lot of things rather than specializing in just one area, and I don't want to spend my entire life studying just geology, physics or math—so geophysics seems the perfect fit!

A Trip to Paris

Chris Graziano, MS Student, Center for Wave Phenomena

For someone who has never left the United States, a trip to Paris, France can seem overwhelming. This was me when my girlfriend's sister told me about her birthday present for my wonderful girlfriend, Demi Anderson. The overwhelming part was I was invited. Knowing Demi, who has 15 pictures of the Eiffel Tower in her apartment, I knew she would love it, but I had no idea what it would be like to step into a country where the primary language was not English.

After I agreed to the trip, time flew by and before I knew it Demi and I were on a 9 hour flight to Paris with Demi's sister, and her sister's husband, who both knew how to speak French. After getting through customs, we were on our way to our apartment, which was right next to Notre Dame and the Seine River. At this point in the trip, I had calmed down from the anxieties of being in another country and started enjoying the trip.

I usually judge a place by the overall taste of the food and I have to tell you, my first bite into a freshly baked baguette smothered in cheese told me that the rest of my trip was going to be a blast. My favorite dish was smoked salmon on toast. It seems so simple, but it was so delicious! For dessert we always went by a little shop where I got two scoops of coconut gelato on a warm Belgian waffle. Oh boy was that amazing!

Besides the food, the architecture combined with the history of France was unbelievable. It was amazing to see Notre Dame in person from the outside and from the inside. You really do get a feeling of insignificance when you are inside. The Eiffel tower was a sight to see in person and it was great to see Demi actually see the building she has been dreaming about forever .

Of course, all of the museums were spectacular! I think I could have stared at one painting or sculpture for 30 minutes before I was satisfied. This would have meant I would have had to spend the rest of my life in the Louvre. It was amazing to see paintings that were bigger than a semi truck.

Despite of everything that I ate and saw, nothing could compare to the moment when Demi and I locked our rust and bullet proof lock on the Pont des Arts and threw our keys into the Seine. It was probably the best moment of the trip to know that a piece of Demi and me would always be in Paris.

After the trip was all said and done, I had a fantastic time in Paris. Will I go back, yes! I can't seem to find a store in Golden that has coconut gelato on a warm Belgian waffle and I need to finish analyzing that one painting in the Louvre.

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Visiting Scholar at Delft

Dr. Filippo Broggini, Class of 2013

From August to October 2013, I had the opportunity to visit Professor Kees Wapenaar and his group at Delft University of Technology (TU Delft) in the Netherlands. My visit was an excellent and rewarding opportunity to work in a lively and world-renowned environment, which contributed to expand my horizons as a researcher. During my time at TU Delft, I shared an office with a group of talented young researchers who shared my passion for seismic wave theory and chocolate chip cookies. Discussions with the colleagues in my office and researchers from other groups always led to new and stimulating research questions. Many seminars gave me excellent opportunities to discuss my research in detail, hear about other fellow scholars and researchers and their fields of study, and exchange views and experience. This three-month visit was indeed an intellectually challenging and productive period and it allowed me to get additional energy to help me to carry on with my research. Besides spending time in the office, I had the chance to appreciate the delicatessen of the Dutch cuisine, such as kroketten, kaassouffles, and the great varieties of peanut butter. Additionally, Delft was a perfect starting point to visit the Netherlands because of its location between Rotterdam, Den Haag, and Amsterdam. The time spent at TU Delft as a visiting scholar has been one of the most rewarding experiences of my career as a student. I can only thank everyone I met for the great time I had there.