THE UNIVERSITY OF OKLAHOMA

ConocoPhillips School of Geology and Geophysics

EARTH Scientist

2010 Issue

Wright Valley, Antarctica

3rd Place Winner – Jefferson Chang

About this photo: *The image is a night silhouette of the towering iron eagle sculpture that watches over the entrance to the new OU Field Camp in Cañon, Colorado. It was taken with a Canon EF 16-35mm f/2.8 L II USM Lens, mounted on a Canon 40D body. The image is a composite of two shots with 30-second and 90-minute exposures, with the lens stepped down to f/4.5, and the ISO set at 400. The background illumination, to create the silhouette, is from the town behind the mountains.*

ABOUT THE COVER: Allison Stumpf and Kristen Marra taking water samples from the melt water stream from Clark Glacier (in the background), Wright Valley, Antarctica. This was one of the coldest days in the Dry Valleys. The photo was taken by Dr. Lynn Soreghan and submitted to the ES cover photo contest by Allison Stumpf. This photo won 1st Place in the contest and, therefore, has the honor to grace the front cover of the Earth Scientist this year.

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2nd Place Winner – Professor Lynn Soreghan

About the photo: *Dr. Lynn Soreghan (left), M.S. student Allison Stumpf (middle), and Ph.D. student Kristen Marra (right) display their Sooner Spirit in Wright Valley, Antarctica (latitude 77 degrees south), with a respectful nod to the great Sir Ernest Shackleton's "Farthest South" Expedition. This photo was submitted by Dr. Soreghan and won 2nd Place.*

Earth Scientist

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DIRECTOR'S BRIEF
State-of-the-School

The ConocoPhillips School of Geology and Geophysics (CPSGG) continued to make progress during the 2009-2010 academic year. The new "Bartell Field Camp" is in the construction phase and should be finished in the summer of 2011. You can check my field camp blog for updates, http://faculty-staff.ou.edu/E/Richard.D.Elmore-1/blog/, or go to our Web site and click on the blog under *News and Events.* In addition to the geology camp, we will replace our current geophysics capstone (independent study) with a three-week field course at the Cañon City camp in 2011.

Building our own camp has produced some challenges. In December of 2009, I went to Cañon City to attend a county commissioners meeting and request approval for the new camp. Ron Conner, the builder, and the engineer who we hired to develop the plan, did not think there would be any problems, but when we arrived at the meeting, the engineer informed us that the county was going to require a fire plan since the area is not covered by the Cañon City Fire Department. Ron was surprised because he did not realize that the fire department would not come to his house, which is near the new camp. The com-missioners asked some hard questions, but I informed them that we take the safety of our students and faculty very seriously and would do whatever it takes to meet their requirements. We developed a plan which included contracting with the Cañon City Fire Department to come to the camp and put out fires, installing a 15,000-gallon water tank and fire hydrant just for fire suppression, and fulfilling a number of other requirements in terms of accessibility. The plan was approved.

The funding for the camp is proceeding. As of late in the summer, we have generated over $2.7 million. Buying and building the camp will cost about $1.2 million which will leave approximately $1.5 million endowment, the interest from which will be used to run the camp. We still have some naming opportunities which range from faculty cabins and bathhouses ($50,000 each) to rocking chairs ($1,000 each). We appreciate all the donations.

As many of you know, Roger Young died suddenly last fall. This was a major loss to the school. Roger was a valued colleague and an important contributor to the geophysics program, and particularly to the exploration program.

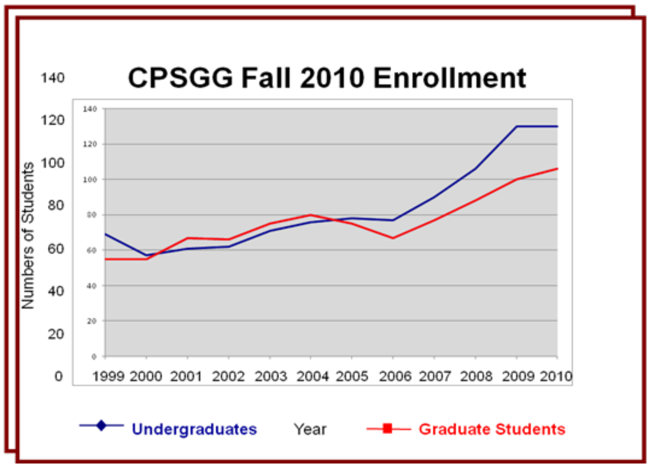
Jim Forgotson retired in May of 2010. Jim was an important and appreciated member of the faculty. He had been involved in administration as Director, contributed to our research mission, taught several important courses such as Petroleum Geology sections for our majors as well as for the engineers and business majors, and supervised/mentored many students. He will be missed.

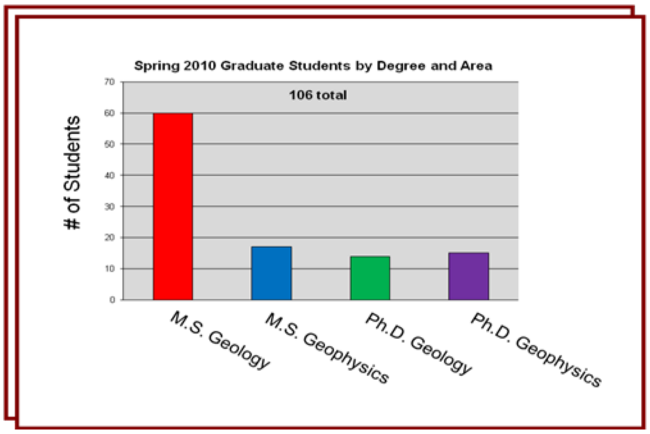
Our graduate and undergraduate enrollments continue to increase. We now have over 105 graduate students and over 140 undergraduate majors. We had to renovate one of our classrooms to accommodate the over 50 students we have in mineralogy in the fall of 2010. The number of undergraduate scholarships is up, and we continued with our increased scholarship amounts from last year.

Other noteworthy news:

- ✓ The AAPG student Chapter won the outstanding chapter award at the 2010 AAPG Meeting in New Orleans.
- ✓ Five students placed second in the regional Imperial Barrel Competition. Team members included: Elisheva Patterson, John Deng, Matt Totten, Chris Althoff, and Bora Yalcin. Their advisor was John Pigott with help from Larry Grillot and Doug Elmore.
- ✓ Last fall, we had 25 companies interview on campus and this fall we expect about 30. Our students continue to get jobs. The AAPG/SEG Spring Break Student Expo event was successful with 198 students from around the country. Jefferson Chang and Evan Staples won first place at the regional SEG Challenge Bowl competition and will represent the School in the SEG meeting in October.
- ✓ Katie Hulsey received the Outstanding Student award from the Tulsa Geological Society.
- ✓ Neil Suneson, Rick Andrews, and Dan Boyd from the OGS continued to offer the undergraduate Subsurface Methods course. This is an excellent course, and grad students are now taking it. They had 15 students last year.
- ✓ In addition to the courses we teach for our majors, the CPSGG faculty members continue to teach over 1,500 students in introductory general education courses as well as courses for MPGE and the Price College of Business.
- ✓ We added some important new research equipment last year. This includes a new x-ray diffractometer which was funded by Devon Energy and is housed in the new Devon Nano lab. Andy Madden is in charge of the lab. Ze'ev Reches finished his new Earthquake Friction Apparatus, and Mike Engel bought a new mass spectrometer. Both were funded by NSF. Andy Madden and Megan Elwood Madden also continued to upgrade our low temperature geochemistry lab by adding an Atomic Absorption Spectrophotometer.
- ✓ In the Spring, Barry Weaver, Gail Holloway, and I ran the freshman field trip again to New Mexico and Colorado. We had 20 students, and it was a big success.
- ✓ Research expenditures in the school were above $2 million last year.

Construction update – inside of Dining Hall, facing the front porch





Funding

Scholarships

- Increased numbers by ~ 50% in the past year
- Increased amounts awarded by up to 50%
  - Typical amounts per semester:
    $1800-3000 Freshman/Sophomores
    $5000-6000 Juniors/Seniors
- Also working with students with 2.75 – 3.0 GPAs who need help because of a financial problem

> $25,000 in scholarships to ~18 students who went to field camp last summer

Successes & Challenges

- ♥ New OU field camp – ready in Summer 2011!
- ♥ Undergraduate numbers are up significantly – some concern about lab space
- ♥ Good Progress on grad recruiting – Competing well
  - Lost funds for TAs in budget cuts but we have good endowments and 100k from the Graduate School
- ♥ New emphasis on research at OU (Aspire 2020)
  - Need to increase scholarship and maintain/increase research funding to support grad students
- ♥ Budget Problems – University/State of Oklahoma
  - Underwater funds

R. Douglas Elmore

ALUMNI BRIEF

Michael A. Pollok
Chair 2009 – 2011

Greetings from the Alumni Advisory Council of the CP School of Geology and Geophysics. I have enjoyed serving as the AAC Chairman and am looking forward to serving this next year also. (That would be one of the changes to have taken place since I have been in office. It was decided, in November, that the AAC officers would all serve two-year terms instead of the one-year term served previously.) We have had quite an exciting year.

In November 2009, Doug Elmore, Director of the ConocoPhillips School of Geology and Geophysics, said that land had been chosen for the new Field Camp to be built near Cañon City, Colorado. In April 2010, he reported that 71 acres of land had been purchased and that the "Bartell Field Camp" (named after Denny Bartell and family who have made a large donation to the camp) was under construction! The subdivision landowner is the builder and comes with very good references. The camp will be secure, with only one way in and gated. Roads are being built, land cleared and construction has begun. The first building on site is the "water" cabin which contains the well and water supply controls. Log trusses for the dining hall are being built as everything goes forward toward completion. Doug shared stories of his trials as he got each permit and license to begin construction. We are all so grateful for his efforts.

Dr. Elmore also reported that enrollment continues to increase for both undergraduates and graduate students. The Spring 2009 freshman trip had 15 students and there is an expected 20+ students for 2010. The AAPG student chapter won the outstanding chapter award at the 2010 AAPG meeting in New Orleans. New lab equipment has been added at the school that will benefit many of the students. Doug was also proud to announce that scholarship numbers have increased by 50% in the last year.

When I first came into office, I challenged all of the AAC members to submit their biography of how they made a living with their Geology and Geophysics degrees. My vision was to compile these bios into a book to be given to each of the graduates from the School of Geology and Geophysics. After a mass mail out and several phone calls, I have received 30 stories, and they are now being published in book form, as the vision becomes a reality. I would like to extend my thanks to each of the members who took the time to prepare their story and send them on to me. The finished product will be available for all of the AAC members to view at the November 2010 meeting.

Dean Larry Grillot spoke to the group in April concerning the donations made to the school by alumni. Because of the economic changes taking place around us, there was need for some restructuring of the way that funds are handled. Dean Grillot explained that some donations might fall below 75% of their original amount and that the interest needs to be put back into the account until it is back up to at least 75%. There is an assumed or allowed 25% drop due to the economy lately. He stated that the intent is to support the students and also honor each donor's wishes.

Work continues to be done on the website. The webmaster is working toward creating a login for each alum on the Council.

In April 2010, we welcomed several new members to the Council and three new Directors to the Executive Council. A system of keeping track of terms and expiration of terms, along with use of previously developed letters, was presented to help members know what term they were serving and when their terms expired.

We're moving forward! *Boomer Sooner*

MEWBOURNE COLLEGE OF EARTH AND ENERGY

Dean Larry R. Grillot

I am pleased to be able to report that as we begin our fifth full academic year, we continue to make good progress in the Mewbourne College of Earth and Energy.

One area of primary focus this year is to complete the major remodeling activities for the Sarkeys Energy Center Tower, along with the completion of our major teaching labs. You will see more about the new geology field camp throughout the magazine, so I won't discuss that here, except to say that it will be an outstanding facility for the school, college and university. Our new National Oilwell Varco (NOV) Drilling Simulator is complete, and many of our seniors were able to get some "hands on" exposure to drilling during the last spring semester. We will also be using the newly remodeled space on level 10 of the Energy Center tower for the Crustal Imaging Facility this fall. As I write this note, we have remodeling activity underway for the Youngblood Energy Library, the Plaza Level (the Gene Van Dyke Plaza), and levels 10-15 in the tower. The college administrative offices have already moved to level 15, which will be named the "James C. and Teresa K. Day Suite." We will be having numerous "dedication" events for these and other areas of the Energy Center to recognize the generous support of our alumni, industry and other supporters. I again want to take this opportunity to thank all of our supporters for their help in making this happen.

Our students continue to perform in an outstanding manner, and many have received recognition for their work. Our faculty have also continued to provide strong research and teaching. Selected student and faculty activities and achievements are highlighted throughout the *Earth Scientist.* We also continue to add to our faculty and have several active searches underway in both CPSGG and MPGE.

The Fall, 2010 semester should be very active and interesting for the college. In addition to normal college programs and activities, we are looking forward to the second Distinguished Alumni and Distinguished Service Awards Banquet to be held on Friday, November 12, where we will recognize another outstanding group of alumni and key supporters. More information about this event will be communicated in the near future. Also, we are starting a college tailgate before each home football game to be held by the Guffey Fountain on the Energy Center (O'Brien) Plaza. The first tailgate will be before the first home game against Utah State on September 4, 2010. This will provide an opportunity for alumni and friends to meet and visit before the game, share stories and discuss the upcoming Sooner victory. Thanks to Curtis Mewbourne, new landscaping for the plaza is almost complete, which will enhance the tailgate experience.

I hope you enjoy the 2010 edition of the *Earth Scientist.*

Ameil Shadid
Director of Development

In the ever-changing world of higher education, planning for the future can be very challenging. Will our number of students increase? How will our faculty needs fluctuate with increased or decreasing enrollments? Will our classrooms and laboratories provide our students and faculty the facilities they need for continued success?

As many of you know, the University of Oklahoma is receiving less than 20 percent of its annual budget from the State of Oklahoma. I'm proud to say that our alumni have stepped up and, to date, we have raised more than $80 million since the start of the campaign in 2006. Thank you to those who have helped us during the campaign…as we plan for the future.

Back to planning for the future. Campus wide, the number of applicants who want to join the Sooner Family is up. Prospective students are seeing the exciting educational opportunities our current students have, and they want to be Sooners. The ConocoPhillips School of Geology and Geophysics has seen an increase in the number of freshmen interested in CPSGG and continues to recruit top faculty to provide the hands on, laboratory-based education that many of our alumni say has contributed greatly to the success they have had in industry.

I am often asked the question, "How can I help?" Getting involved is easier than you might think. We need financial support and always will; but you can become involved through giving your time and talent as well. Are you in a position to hire our students, provide mentoring, or lead a field trip to an area that would be of interest to our students and faculty? Being involved can be very rewarding, just ask Mike Pollock, Chris Cheatwood, Mica Feinstein, or Jon Withrow.

If you would like to get involved and help us plan for the future, please contact me at 405-325-3821 or by email at shadid@ou.edu. If you are already involved and supporting CPSGG, thank you. Your leadership and support are essential to our success.

FACULTY 2010

R. DOUGLAS ELMORE
Director, CPSGG
Eberly Chair Professor and Associate Provost

My research centers on using an integrated paleomagnetic/geochemical/petrographic approach to investigate the timing and origin of fluid flow and burial diagenetic events. My students and I are currently working on diagenetic studies of the Barnett Shale and Ellenburger Formation, the Marcellus Shale, the Phosphoria Formation, Carboniferous carbonates in the Canadian Cordillera, and the Alamo Breccia. I teach undergraduate Sedimentology and Sedimentary Petrology and Native Science and Earth Systems of North America. My graduate courses include Diageneisis, Paleomagnetism, and Clastic Facies.

YOUNANE ABOUSLEIMANN
Director, PoroMechanics Institute
Larry Brummett/ONEOK Chair
Professor

My research is in general mechanics applied to reservoir characterization in geology and geophysics. However, I conduct applied research related to petroleum engineering, civil engineering and biomechanics. I also direct the PoroMechanics Institute in the Mewbourne College of Earth and Energy at the University of Oklahoma (www.pmi.ou.edu). I act as the director of the Rock Mechanics Consortium and the GeoGenome™ Industry Consortium. These industry consortia are composed of seventeen member companies in oil and gas. The research focuses on wellbore drilling mechanics, flow/stress in naturally fractured reservoirs, soft sediment mechanics, and shale chemomechanics activities when exposed to fluids. In 2005 the nano poromechanics of gas shale was undertaken in the GeoGenome™ Industry Consortium that is going on through 2013. I teach Introduction to Reservoir Characterization and Advanced Reservoir Characterization with Professor Roger Slatt, and the Mechanics of Materials in petroleum engineering.

NEW GRANTS IN 2010 (Continued on following pages)

Detachment faulting and geothermal resources – An innovative integrated geological and geophysical investigation (Katie Keranen and R. Keller, DOE, $125,000)

Powe Research Award (Andy Madden, ORAU, $10,000)

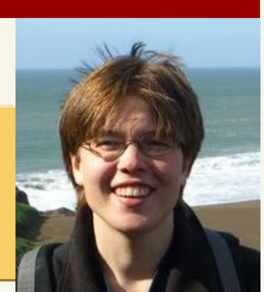
New XRD and clay mineral analysis (Elmore and Andy Madden, Devon, $200,000)

MICHAEL H. ENGEL
Clyde Becker, Sr. Chair Professor

My research focuses on the origin and distribution of organic matter in terrestrial and extraterrestrial materials during the early stages of the formation of the solar system. I have also been investigating global changes in the stable carbon and sulfur isotope compositions of marine crude oils and fossil proteins to reconstruct secular changes in ocean water chemistry. I teach undergraduate courses in physical geology and oceanography and graduate courses in organic and stable isotope geochemistry.

G. RANDY KELLER
Director, Oklahoma Geological Survey
Edward Lamb McCullough Chair
Professor of Geophysics

My research stresses the geological applications of geophysics and span a variety of techniques at a variety of scales. My main interest is in integrated studies of the structure and evolution of the crust using gravity, magnetic, remote sensing, seismic measurements, and geological data. However, I also regularly use geophysical methods to study issues such as ground water resources, earthquake hazards, basin analysis, and site characterization. My main international research focus is presently China.



KATHLEEN KERANEN
Assistant Professor

My research group studies the tectonics and geodynamics of the lithosphere, typically focusing on actively deforming regions and large earthquake seismogenesis. We use land and marine controlled-source reflection and refraction seismology, passive seismological analyses (shear-wave splitting, receiver-function analysis), and potential field data as necessary to address the chosen problems. Recent and ongoing areas of investigation are the western Basin and Range, the Pacific Northwest, the Aleutian Islands, global subduction systems, and the East African Rift system.

DAVID LONDON
Norman R. Gelphman Professor

In 2010, I was awarded the Hawley Medal of the Mineralogical Association of Canada for the best paper in Canadian Mineralogist for 2009 for "The origin of primary textures in granitic pegmatites." I made two domestic and one international speaking tours as one of the three Mineralogical Society of America Distinguished Lecturers.I received an NSF grant, "Garnet-Biotite-Tourmaline Thermometry at High Mn Content", $263,356.

RICHARD LUPIA
Assistant Professor
Assistant Curator, Sam Noble
Oklahoma Museum of Natural History

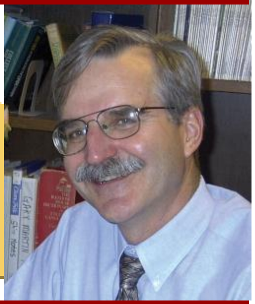
My research addresses large-scale evolutionary patterns in the fossil record of terrestrial plants in order to understand the taxonomic and ecological frameworks of major ecosystem changes. I am currently investigating the pollen and spore record of vegetation change during the Late Pennsylvanian and Early Permian. I am working on cores extending from the Wabunsee through Sumner Groups. I also study the diversification of water ferns and lycopsids during the Cretaceous terrestrial revolution. I teach undergraduate non-major courses in physical geology and the history of life and evolution and a graduate course in paleobotany. I am jointly appointed in The Sam Noble Museum as Associate Curator of Paleobotany and Palynology.

ANDREW S. MADDEN
Assistant Professor

My research focuses on low temperature geochemistry and nanoscale characterization of materials. Projects this last year in our lab included investigations of size-dependent hematite reactivity, the fate of uranium during biological magnetite formation (ORAU), the precipitation of uranyl phosphate minerals, prospecting for nano-diamonds (NSF, with Lee Bement, Brian Carter and Alex Simms), nanoscale transformation products of jarosite dissolution (NASA, with Megan Elwood Madden and Don Rimstidt), and quantitative bulk and clay fraction shale mineralogy with powder X-ray diffraction (Devon Energy). Additionally, our group has recently collaborated with researchers from Baylor, Brigham Young University, Harvard, and Oak Ridge National Laboratory on topics relating to geological nanomaterials. I'm excited that the NSF-funded "Nano2Earth" secondary school curriculum I have been working as part of a team with for several years is set for publication by the National Science Teachers Association Press. I teach undergraduate courses in physical and environmental geology; my graduate courses to date are Minerals and the Environment and Clay Mineralogy.

MEGAN ELWOOD MADDEN
Assistant Professor

I am a planetary geochemist- I investigate the thermodynamics and kinetics of fluid-rock interactions, alteration assemblages, and gas hydrate systems on Earth and other planets. My students and I use laboratory experiments, geochemical modeling, and field work to to study how rocks weather in extreme climates (pg. 51), determine how fast gas hydrates form and decompose (pgs. 40 & 75) and constrain the duration of liquid water at Meridiani Planum, Mars (pg. 60).



KURT J. MARFURT
Frank and Henry Schultz Chair
Professor of Geophysics

My primary research interest is in the development and calibration of new seismic attributes to aid in seismic processing, seismic interpretation, and reservoir characterization. Recent work has focused on applying coherence, spectral decomposition, structure-oriented filtering, and volumetric curvature to mapping fractures and karst as well as attribute-assisted processing.

SHANKAR MITRA
Victor E. Monnett Chair, Earth Resources
Monnett Professor, Energy Resources

My research has focused on the use of scaled experimental models to understand the geometry and evolution of macroscopic and prospect-scale structures. This year, we have developed a new technique of laser scanning to accurately depict the topology of experimentally modeled structures. This approach allows us to develop quantitative 3- D models of structures and compare them to the geometry of mapped surface and subsurface structures. Analysis of the analog models allows us to better interpret unconstrained subsurface structures and to understand the controls of major parameters relating to structural geometry and fault density and orientation. We have applied this approach to model a complete suite of map-scale structures observed in basement-involved compressional structures in the Rocky Mountain foreland. We have also used it to study structures related to transfer zones in salt-cored growth faults in the offshore Louisiana part of the Gulf of Mexico.

Diagenesis of the Marcellus Shale (Elmore, Devon, $100,000)

Geophysics of the Barnett (Marfurt, Devon, $100,000)

AASPI Consortium (Marfurt, 15 companies, $420,000)

PoroMechanics Consortium next phase 2010-2012 (Abousleiman, $1,200,000)

R. PAUL PHILIP

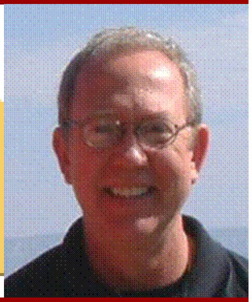
Joe and Robert Klabzuba Professor
George Lynn Cross Research Professor

The past year has seen a number of developments in the areas of petroleum and environmental geochemistry. We have continued our work in collaboration with Devon on the Barnett Shale. For the past year we have focused primarily on obtaining kinetic parameters that can be used in basin modeling studies of the Barnett. This has required numerous maturation experiments in the laboratory to obtain quantitative information that can be used to determine kinetic parameters such as activation energy and frequency factors for use in the basin models. In related areas we have also been investigating the use of a group of compounds known as diamondoids to expand the use of these compounds as potential maturity parameters in these mature shales.

In terms of our environmental geochemistry, we have continued to develop applications involving stable isotopes in environmental studies. In particular we can now determine the stable chlorine composition of common groundwater contaminants such as perchlor oethylene, a common ground water contaminant used as a dry cleaning fluid and degreaser. The use of chlorine isotopes along with carbon isotopes provides a powerful combination that can be used to study the origin and fate of this compound in the environment. In a related area we are also developing a new area of investigation, namely vapor intrusion studies. Indoor air quality is a major environmental issue at the present time. This is a particular problem in areas where the underlying groundwater is contaminated with organic compounds that may be diffusing into the indoor air. The problem is to differentiate the contaminants originating from the subsurface versus those from indoor products, many of which contain volatile organic compounds. We are developing methods based on the carbon and chlorine isotope compositions as one tool to differentiate these products.

JOHN D. PIGOTT

Associate Professor



My research studies integrate geology, geophysics, and geochemistry into the evaluation of the tectonic evolution and hydrocarbon potential of sedimentary basins worldwide.

A particularly exciting and new development in my basin research is the recent work in the Middle East. Presently, under the auspices of the United Nations - World Bank, I am supervising the processing and interpretation of some 100o km of seismic data from the Red Sea - Gulf of Aden, a program of research and technology transfer with member nations funded by a consortium of international oil companies.

In the South China Sea and Gulf of Thailand co-workers and I are unraveling the history of basin response to propagative extrusion tectonics using an inventory of reflection seismic and well borehole data and state-of-the-art basin modeling software.

ZE'EV RECHES

Professor of Geology

Research projects include earthquakes and faults, dynamic fracturing of rocks, seismic vibration and localized earthquake damage, 3D geotechnical mapping of the Jerusalem region, and PC software for structural analysis.

ROGER M. SLATT

Gungoll Chair Professor
Director, Institute of Reservoir Characterization

For the past several years, I have been conducting studies of deep--water (submarine fan) sandstone gas reservoirs using a combination of subsurface reservoir data and analog outcrops. The main emphasis has been on the Pennsylvanian Jackfork Group of Arkansas (currently gas is produced from the Jackfork in eastern Oklahoma) and the Cretaceous Lewis Shale of Wyoming.

In Arkansas, studies are moving westward from Arkansas into eastern Oklahoma where there is a major, active gas play in the Lynn Mountain Syncline/Potato Hills area. Work is being focused more into the subsurface, utilizing the outcrop investigations previously completed in Arkansas to evaluate subsurface stratigraphy, architecture, and reservoir quality.

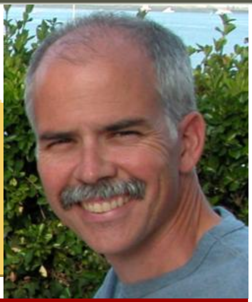
In Wyoming, there is a significant Lewis Shale gas play evolving in the Greater Green River Basin. In this area, sedimentologic criteria have been recognized from outcrop studies to differentiate deep-water sheet from channel sandstones; these criteria have been identified on borehole image logs.

G.S. "LYNN" SOREGHAN

Brandt Professorship

I use the sedimentary record to investigate climate and tectonics and am particularly intrigued with the late Paleozoic (300 million years ago) owing to its dynamic climatic and tectonic behavior. Current research topics include: (1) investigating hypotheses of tropical glaciation and mountain collapse in tropical Pangaea, (2) atmospheric dust as an archive and agent of climate change (3) high-frequency, glacial-interglacial climate change, and (4) the use of rock weathering as a climate indicator. I teach courses in Depositional Systems and Stratigraphy, Earth's Past Climate (with Meteorology Professor Susan Postawko), Paleozoic Carbonates and Sequence Stratigraphy, Honors Introductory Geology, and Sedimentology/Stratigraphy seminars.

Cooperating Faculty



MICHAEL SOREGHAN
Assistant Professor

My research centers on the broad theme of delineating the controls of sedimentation in continental settings. Recent work involves reading long-term climatic signals from eolian siltstones and rift-lake sediments and sedimentary rocks. I am primarily a field-oriented geologist, however, I have increasingly employed geochemistry, computer imaging and modeling to supplement the field data. Field areas include the southwestern U.S. and East Africa--both great places to work! I teach undergraduate courses in Physical Geology and Earth Science, Earth System History for majors, and a graduate course in Rift Basins with Dr. Keller. I also have a strong interest in outreach education and led a science camp for middle-school students for the last several summers.

BARRY WEAVER
Associate Professor
Associate Dean, Mewbourne College of Earth and Energy

My research interests include the application of x-ray fluorescence and instrumental neutron activation techniques to the analysis of geological materials, and the interpretation of these data in terms of the origin and evolution of igneous and metamorphic rock suites. On a broader level this research leads to a consideration of trace element models for the composition and growth of the continental crust, and for the evolution of the crust-mantle system.

STEVE WESTROP
Willard L. Miller Professorship
Curator, Sam Noble Oklahoma Museum of Natural History

My research interests lie at the intersection of paleontology, ecology and evolutionary biology. Patterns and processes of mass extinction, with special reference to Lower Paleozoic trilobite faunas of North America, have been a primary focus for several years. More recently, I have expanded my studies to deal with evolutionary radiations following mass extinctions and with the changing role of trilobites in Paleozoic marine communities. I have also published extensively on trilobite systematics and biostratigraphy. Other areas of research include taphonomy of shell beds, particularly in storm-influenced depositional systems, stratigraphy and sedimentary facies analysis.

National Geothermal Data System - Oklahoma Contributions (Keller, DOE, $290,088)

National Geological CO2 Sequestration Assessment (Keller, USGS, $50,000)

RICHARD CIFELLI
Associate Professor, Dept. of Zoology
Adjunct Professor, School of Geology and Geophysics

I am Associate Curator of Vertebrate paleontology at the Oklahoma Museum of Natural History, Associate Professor in the Department of Zoology, and cooperating faculty member in the School of Geology and Geophysics. My research interests are in the paleobiology, systematics, and evolution of mammals. I conduct research on fossil mammals of South America which, because of the continent's isolation during most of the Tertiary, represent a **natural environment** in zoogeography and evolution. At the same time, I have been developing a sequence of early mammal faunas from the Cretaceous of the southwest U.S. These assemblages document a long and poorly understood interval in mammalian history, during which they were relatively small, rare taxa living in the interstices of a world dominated by dinosaurs. Most of my research programs are field-based, with activities currently being conducted in Colombia, Argentina, Texas, and Utah. I have collaborated extensively with geophysicists in developing an absolute temporal framework for mammalian evolution.

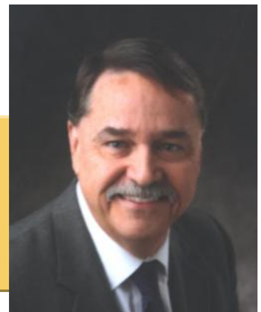
GEORGE MORGAN
Adjunct Professor
Research Scientist II, Electron Microprobe Lab

I am responsible for operation of the electron microprobe laboratory, and consider a modern electron microprobe to be ***the*** most useful tool for characterizing multi-component solid materials. One of the joys of working with such a versatile analytical platform is exposure to materials problems from a great variety of scientific disciplines including not only samples from numerous geological settings, but also diverse materials problems spanning the gamut from identifying the constituents of human kidney stones to investigating the nature or failure of fabricated metallic or electronic components.

NEIL SUNESON
Adjunct Professor, Geologist IV
Oklahoma Geological Survey

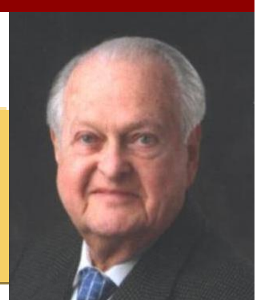
My research interests include all aspects of Oklahoma geology, with an emphasis on the stratigraphy, structural geology, and resource evaluation of the Arkoma Basin and Ouachita fold-and-thrust belt. Teaching interests focus on geologic mapping and field techniques.

Emeritus Faculty



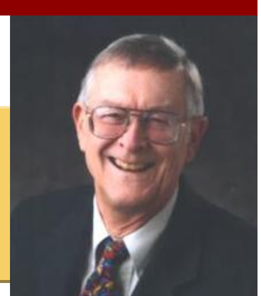
JUDSON AHERN
Emeritus Professor

Geomechanics, Gravity and Magnetics, Environmental Geophysics



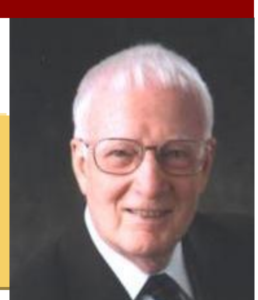
JAMES FORGOTSON, JR.
Emeritus Professor

Petroleum Geology and Basin Analysis



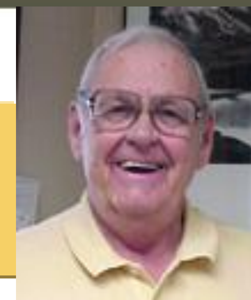
M. CHARLES GILBERT
Emeritus Professor

Igneous and Metamorphic Rock Systems



CHARLES HARPER
Emeritus Professor

Paleontology



DAVID STEARNS
Emeritus Professor

Structural Geology and Tectonophysics

Administrative Staff

Standing: *(L to R) Teresa Hackney, Donna Mullins, Stephen Holloway, Nancy Leonard.* ***Seated:*** *(L to R) Robert Turner, Adrianne Fox, Gail Holloway, Niki Chapin*

Garnet-Biotite-Tourmaline Thermometry at high Mn content (Dave London, NSF, $263,356)

Integrated Stable Isotope (Philp, DOD, $212,636)

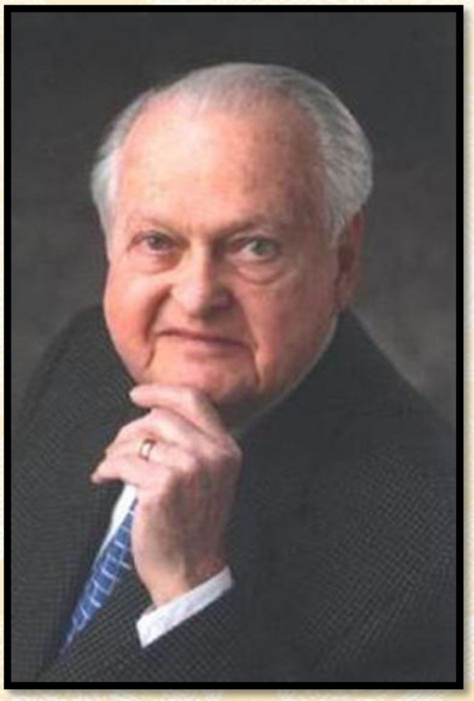
Assessing Geomorphologic, Paleoclimatic and Tectonic Aspects of Unaweep Canyon and the Uncompahgre Plateau through Detailed Geologic Mapping (L. Soreghan, USGS, $26,497)

Potential Impacts of Anthropogenic Change on Shell Beds of Lake Tanganyika Grant-in-Aid of Research (Mike Soreghan, M.J., National Geographic Society, $15,860).

Research Planning Visit: Investigating high-latitude climate change recorded in upper Paleozoic non-marine strata of East Africa (Mike Soreghan, M.J., NSF, $20,398)

Jim Forgotson

Years of Service
1986 – 2010



Dr. James Forgotson, Jr., retired in May, 2010, after 24 years of service to the university. Jim came onboard in 1986 as director of the school and stepped down in 1989 to focus on his professorship in Petroleum Geology and Basin Analysis.

Jim was a dedicated former school director, faculty member, and scholar in the School of Geology and Geophysics, and the co-recipient of research grants to study horizontal drilling and petroleum geology of the Red Sea. He proudly held the seat of vice-president of the AAPG in 1986-87 and was invited to be an AAPG Distinguished Lecturer on computer applications in geology. His roles as an educator and mentor have influenced the lives of countless students and inspired them to pursue their dreams.

Retirement Party, April 23, 2010

In Memory of
Roger Adams Young

Last October 13, 2009, the School was devastated by the sudden and unexpected death of geophysics Professor Roger A. Young. Roger, who was 66, had been at OU since 1990 and had contributed much to the School's geophysics program through active and involved teaching. His legacy at OU includes the instigation of a week long geophysics field program conducted during summer field camp in Colorado; insightful teaching of core graduate and undergraduate seismology courses; service as thesis director for geophysics graduate students and faculty advisor for the student chapter of SEG; and Director of OU's Shell Crustal Image Facility.

Roger was born in Massachusetts and had received degrees from Wesleyan (Connecticut), B.S. in Geology; from Stanford, M.S. in Geophysics; and from Toronto, Ph.D. in Geophysics. Roger had served in the U.S. Army Corps of Engineers, had worked for Mobil Oil and later for Phillips Petroleum. He had been a Senior Research Fellow at Curtin University in Perth, Western Australia, before coming to the University of Oklahoma. Some of his OU students had worked on the Frontal Fault Zone of the Wichita Mountains system, and in recent years on problems in near-surface geophysics. Roger worked hard to connect OU geophysics students with the Oklahoma City Society of Exploration Geophysicists.

In 2008, Dr. Young received the Stubbeman-Drace Presidential Professorship. Presidential Professorships are "given to outstanding faculty selected on the basis of teaching, willingness to mentor and dedication to research, creative activity and service". This description perfectly summarizes Dr. Young's career at OU. In recent years, Roger became best known for his work in near-surface geophysics, and many graduate students completed their degrees under his direction.

Articles / Abstracts

Meeting of the Americas

Foz do Iguaçu, Brazil

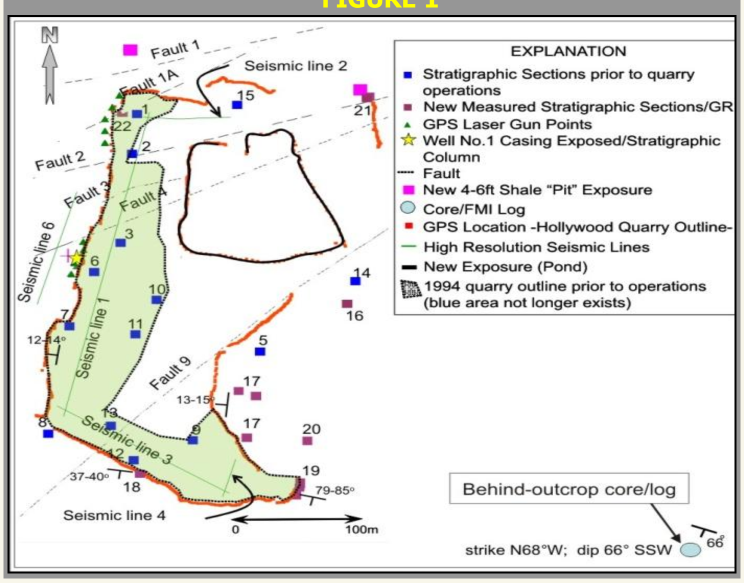
Left to right: Stacey Evans, John Deng, Shannon Dulin, Dr. Doug Elmore, Matt Zechmeister, and Earl Manning.

In August 2010, Doug Elmore and five students attended the American Geophysical Union Meeting of the Americas in Foz do Iguaçu, Brazil. Three current OU G&G students gave presentations at the meeting, two of which were oral presentations (Stacey Evans and John Deng) while the third was a poster session (Earl Manning). A recent graduate, Matt Zechmeister, similarly presented a poster over his PhD work. Doug Elmore also presented an invited talk and co-chaired a session on Hydrocarbons and Magnetizations. Shannon Dulin, a new Ph.D. student, was co-author on one paper and attended the meeting. The abstracts for the talks are listed below.

In addition to sampling the food and drink, the group visited the spectacular Iguazu Falls (see picture below). There are several legends relating to the falls. One legend of the falls is that a god planned to marry a beautiful girl who fled with her mortal lover in a canoe. The god was angry and created the waterfalls so the lovers would be condemned to an eternal fall. The rock type at the falls is flood basalt which formed about 100 million years ago.

Geoscience-Petroleum Engineering Integrated Graduate Education in the Mewbourne College of Earth and Energy: RESERVOIR CHARACTERIZATION EXAMPLE

FIGURE 1



ROGER M. SLATT, Reservoir Characterization Institute
YOUNANE ABOUSLEIMAN, PoroMechanics Institute

The Mewbourne College of Earth and Energy was formed a few years ago by merging the School of Geology and Geophysics, School of Petroleum Engineering and Oklahoma Geological Survey to promote integration of petroleum education and research. There have been many such directed efforts, including the one reported here…….the very popular graduate level Introduction to Reservoir Characterization course taught each Fall by Drs. Slatt and Abousleiman. This past year, 18 petroleum engineering and 18 geology and geophysics graduate students enrolled into the course, making this the largest enrollment of a graduate course within the College.

Dr. Slatt's part of the course involves lectures on various geological and geophysical aspects of oil and gas reservoirs, including unconventional shales, how to characterize them, and the methods used to attempt to optimize their production; labs are designed to teach students the principles of geologic core characterization, integration of petrophysical log and rock properties, regional to local scale correlations and mapping. Dr. Abousleiman's part of the course deals with the geomechanical properties of reservoir, source, and seal rocks, and how they affect wellbore stability, drilling, formation damage, and production; labs are designed to teach students the methods of geomechanical characterization in the Poromechanics Institute lab. All weekly labs are designed so that students work in integrated teams, merging the various student disciplines and talents.

Perhaps the highlight of the course is the 3-day field trip for a close-up examination of an outcrop analog to a typical reservoir. The analog is named Hollywood Quarry (**Figure 1**), near the town of Hollywood, Arkansas. Dr. Slatt has developed this quarry over a 15-year period into a natural laboratory for students of reservoir characterization. The quarry is periodically active, so that fresh walls are exposed, thus allowing, over the years, development of a 3D geologic model of the quarry. Most of the quarry is shallow-dipping, so that when standing on the quarry floor, one can consider themselves within a 3D reservoir; this is the "poor-persons visualization facility", modeled after the 3D visualization theaters used by many petroleum companies to allow drillers, geologists and geophysicists to "stand" inside a 3D seismic volume and select the best drilling location within the volume. Of particular educational importance is the fact that this quarry contains several common reservoir heterogeneities: 1) stratigraphic compartments, 2) faults with and without fault gouge (i.e. sealing and non-sealing faults), 3) a major anticline, 4) fractures, and 5) injectites (the latter of which are known to improve reservoir connectivity by up to 15% in North Sea oil fields (**Figure 2a**). The professors compare the "real world" of reservoirs with textbook images of reservoirs (**Figure 3**).

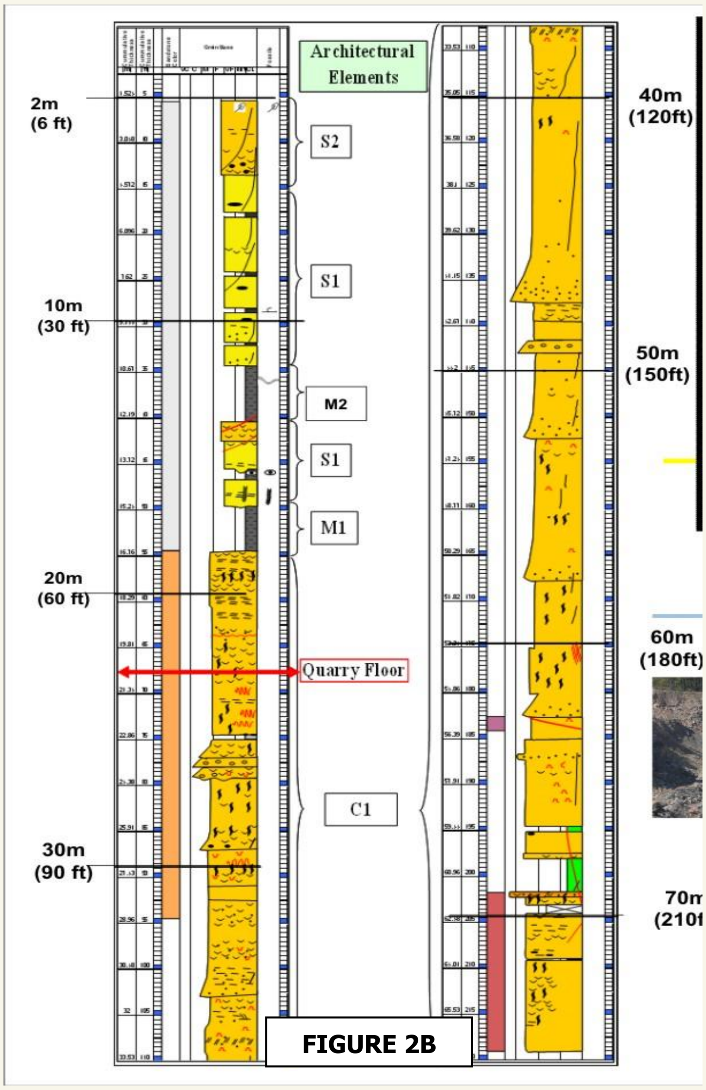


FIGURE 2B

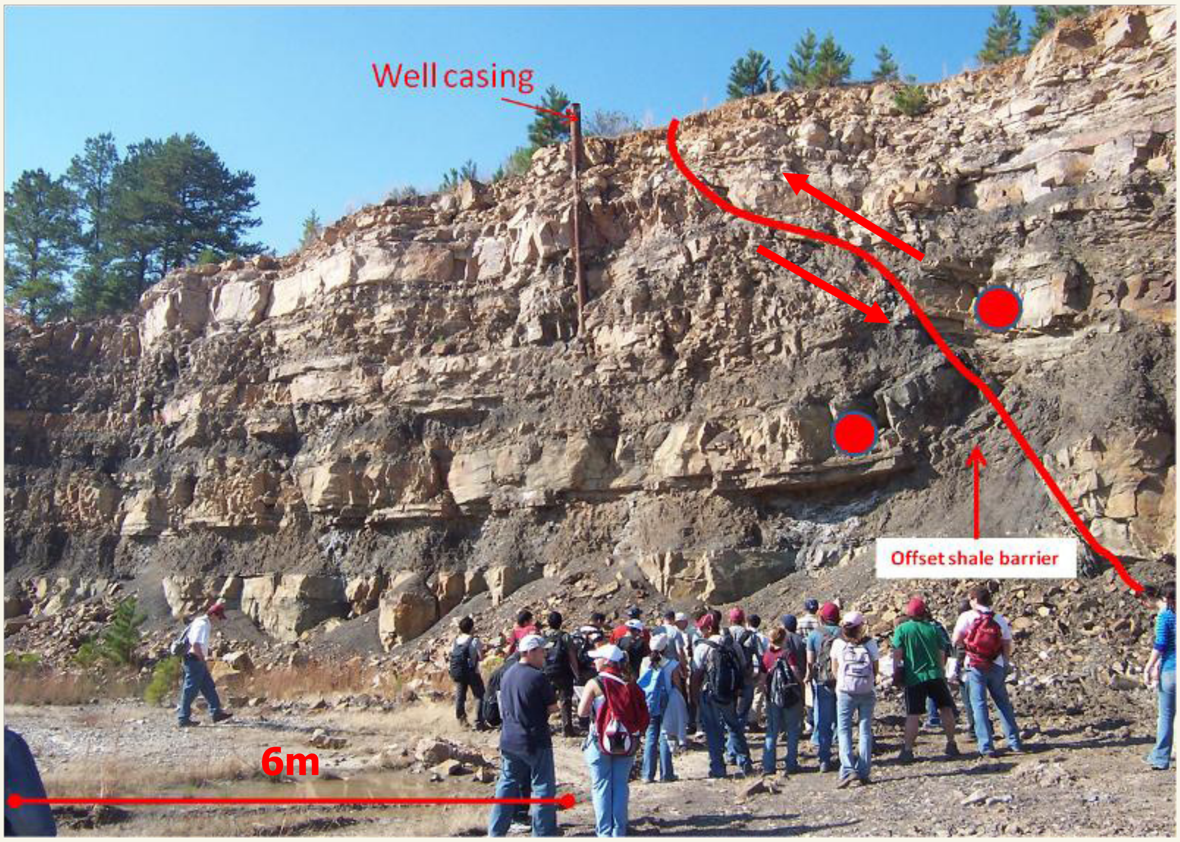
FIGURE 2A

In addition to periodic fresh rock exposure for measurement, through the years Dr. Slatt has teamed with Schlumberger to drill two wells behind the outcrop, log them (including borehole image log), and core continuously (**Figure 2B**). The drill casing of one of the wells now is exposed along a quarry wall that has been periodically cut back during drilling operations (**Figure 3**). A shallow seismic survey and a Ground Penetrating Radar survey have also been completed at the quarry (**Figure 4**). By standing in the quarry and directly observing the geologic features and showing the well logs, cores, and seismic sections from the quarry, students are provided with a better idea of what they are actually seeing (and not seeing due to resolution limits) when analyzing well logs or seismic volumes on their workstations. (**Figure 5**)

Not only do Drs. Slatt and Abousleiman lead the student field trip each year to this quarry, but Slatt also teaches reservoir characterization at the quarry with a petroleum engineering professor from Colorado School of Mines (Dr. Ramona Graves; Head of PE at Mines) three times annually for Schlumberger and takes other industry groups to the quarry for the same objectives.

This year's large group of 36 students was particularly enjoyable, as the teamwork, friendliness, and cooperation were clearly evident both on the outcrop (**Figure 3**) and during the nightly group dinners at the end of a long and educational day. The final exam for this course involved integrated teams of five students gathering data in the field, then building a geologic model of the quarry. Net sand sections were made from grids

FIGURE 3



overlaid on quarry photomosaics (**Figure 6**), fault offsets were measured (**Figure 7**), fractures were documented (**Figure 8**), and various other stratigraphic and structural features were described.

Many of the students who took this course proceeded onto the second semester Reservoir Characterization II course, which is designed to teach students how to use Schlumberger's Petrel™ software (taught by Schlumberger's Eva Peza), then to use it to build three geologic models: Hollywood Quarry, Canfield Ranch field in California, and the Barnett Shale in North Texas. An example of the students' Hollywood Quarry Petrel model is shown in **Figure 9**.

As stated at the start of this article, a goal of merging the two schools was to better integrate students so as to appreciate the types of work each discipline can bring to a reservoir. Based upon student response and the professors' own feelings, this goal was accomplished!!

# # #

FIGURE 4

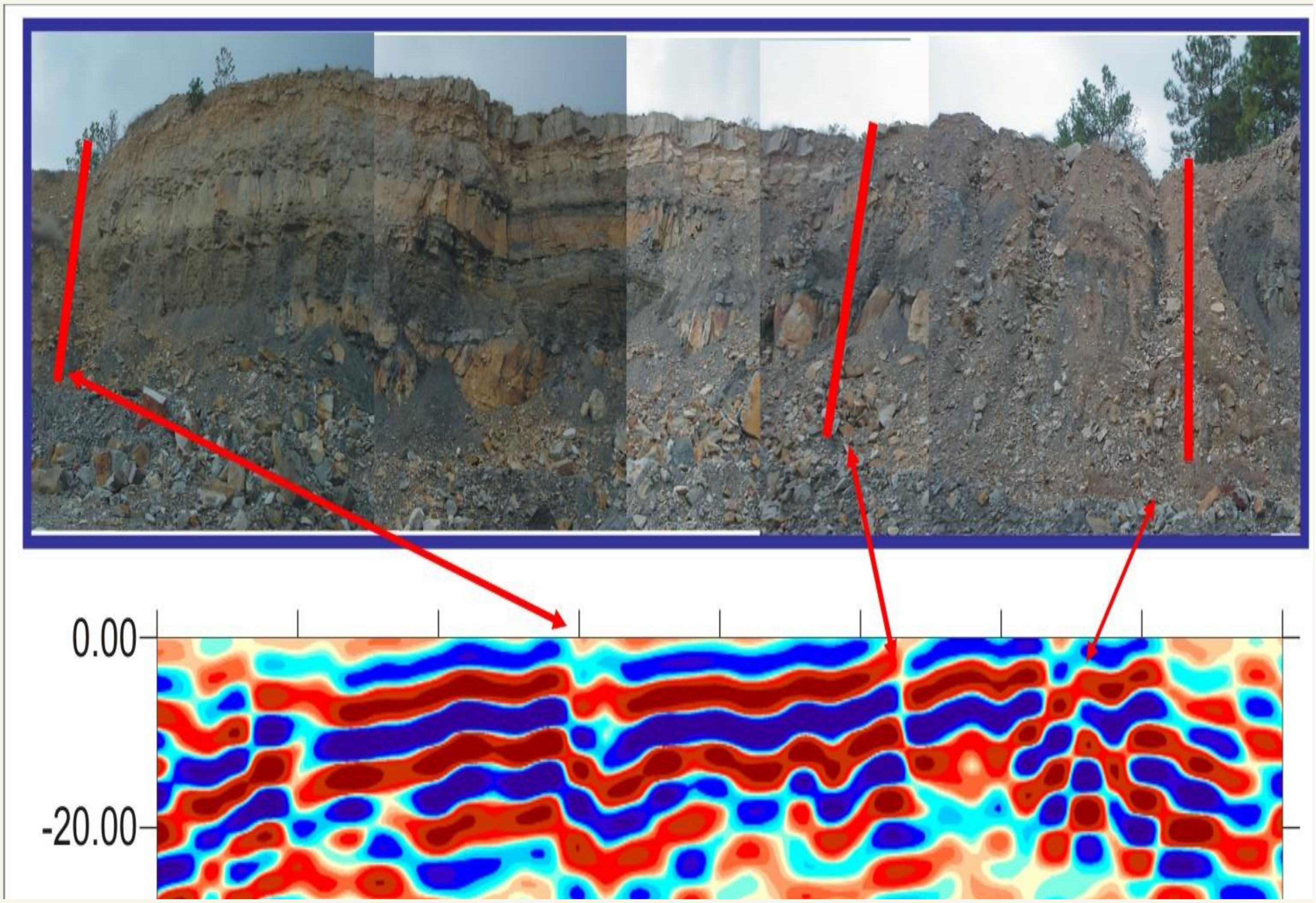


FIGURE 5

FIGURE 6

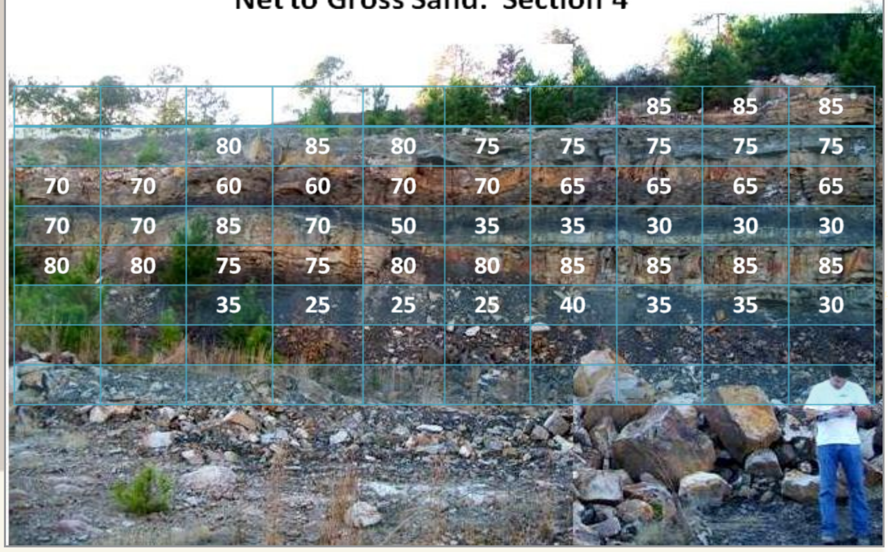


FIGURE 7

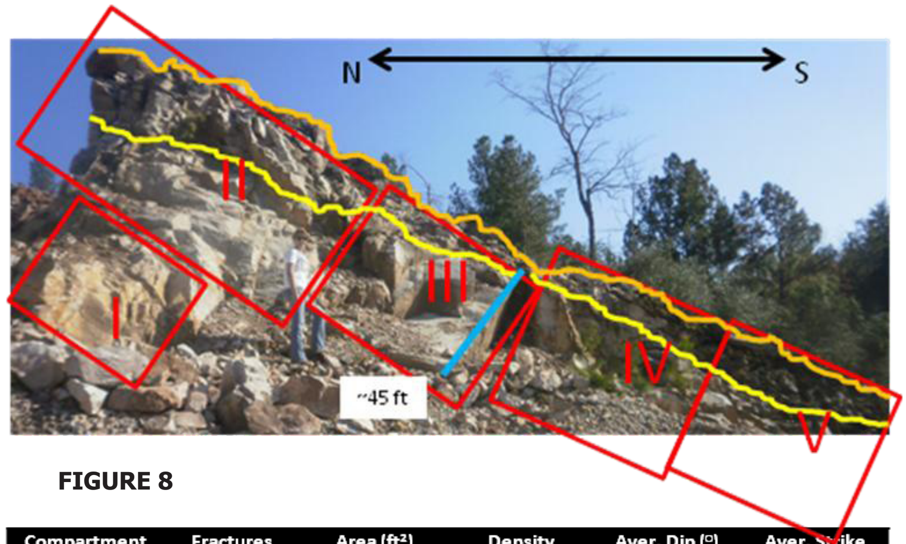


FIGURE 8

Compartment	Fractures	Area (ft²)	Density (fracture/ ft²)	Aver. Dip (°)	Aver. Strike
I	13	24	0.54	88	N 34°E
II	18 (13 v, 5 h)	168	0.107	88	N20°E
III	10 (6 v, 4 h)	110	0.091	90	N10°E
IV	12	70	0.171	90	N14°E
V	11	90	0.12	90	N11°E

Property Modeling

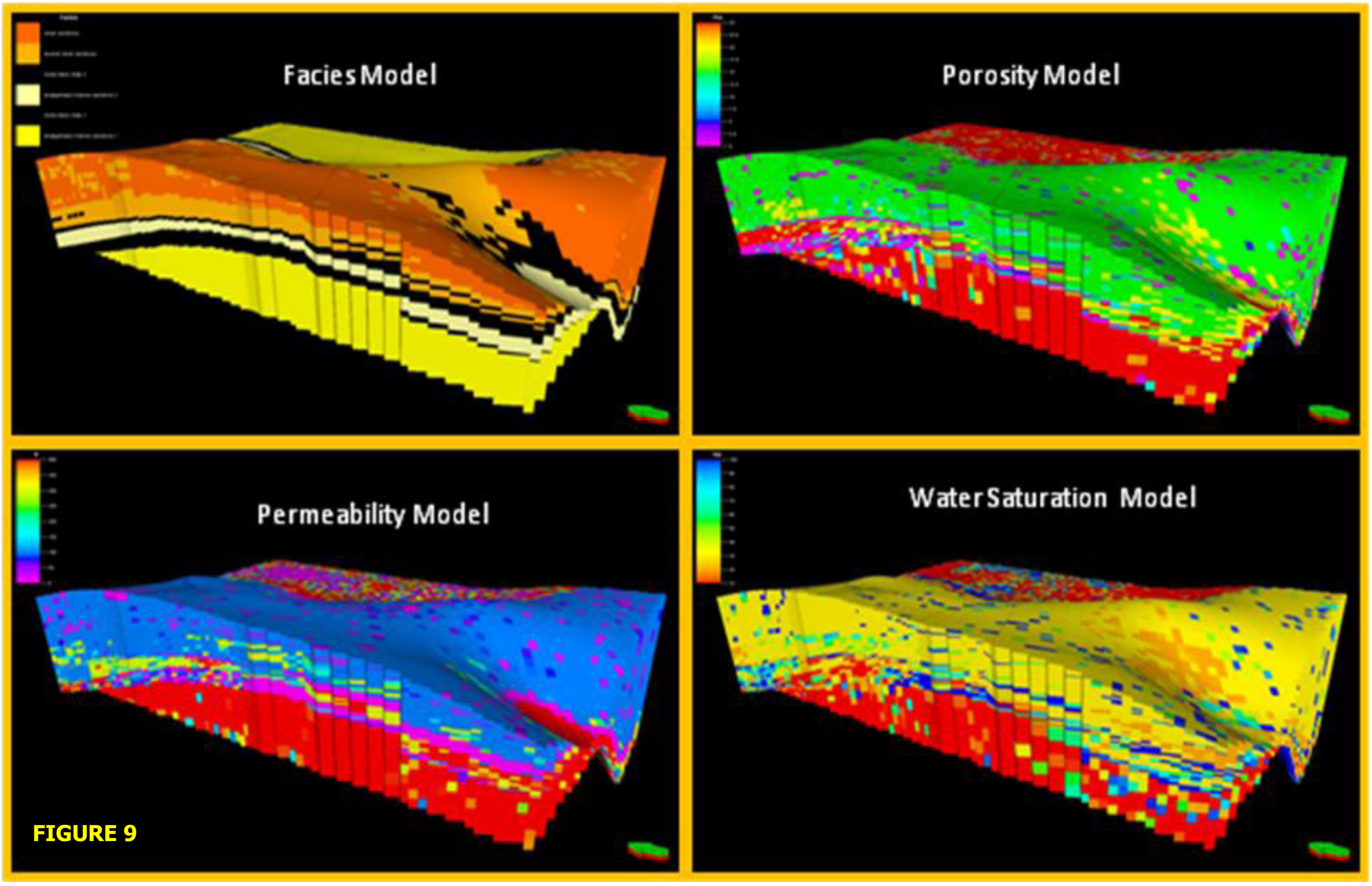
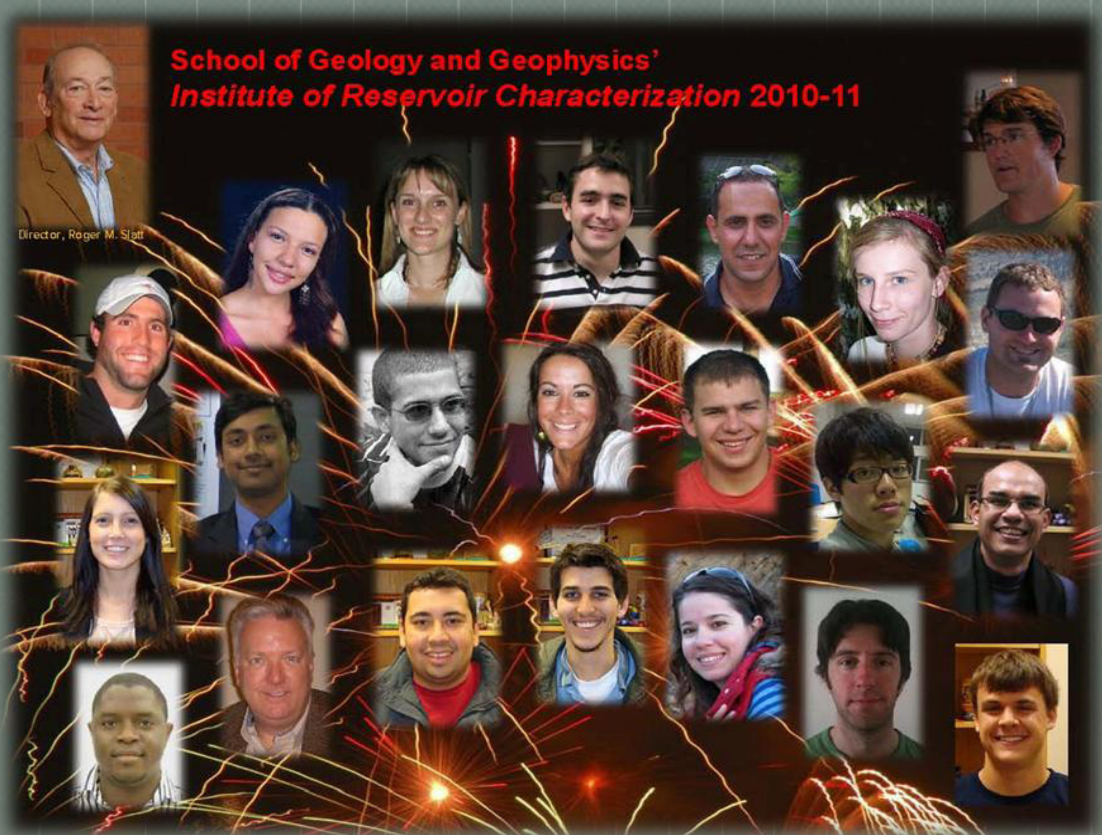


FIGURE 9

Activities of the Institute of Reservoir Characterization within the ConocoPhillips School of Geology and Geophysics: 2009-2010

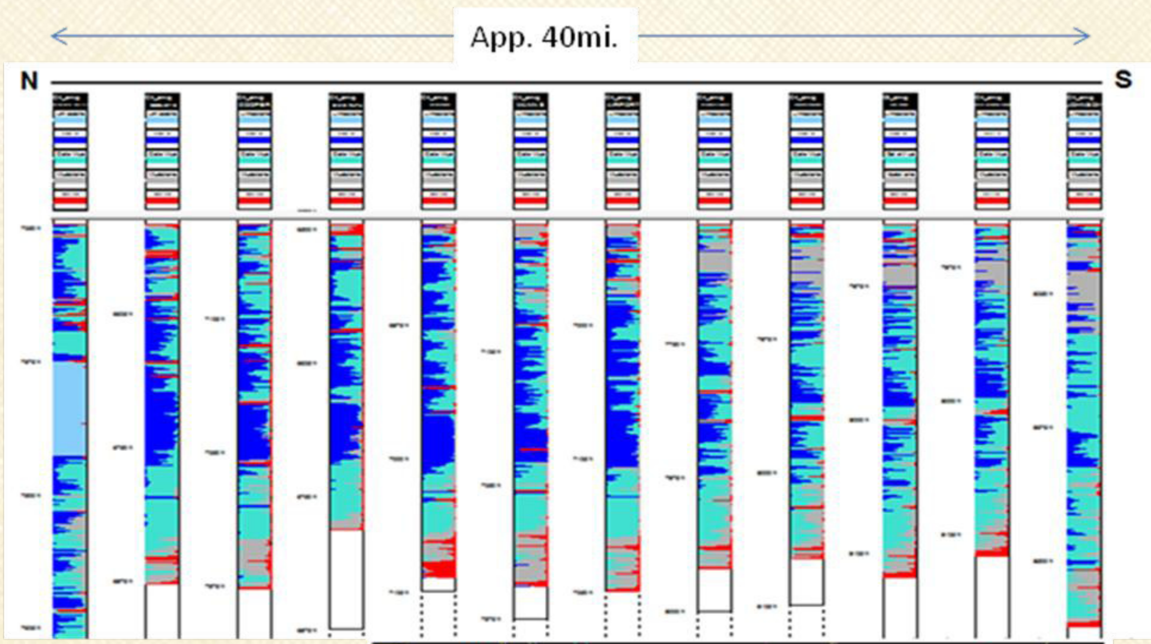
by
ROGER M. SLATT
Gungoll Chair Professor of Petroleum Geology and Geophysics

This year was another banner year for the Institute of Reservoir Characterization (see Activities article for 2008-09 in last year's Earth Scientist). The Institute, under the direction of Roger Slatt, Gungoll Chair Professor of Petroleum Geology and Geophysics, specializes in three focus areas: Unconventional Hydrocarbon Reservoirs (i.e. gas shales, tight gas sands), Reservoir Characterization, and Petroleum Geology of Deepwater Depositional Systems. A total of 10 M.S. students within the Institute program graduated during 2009-2010, and funding/data continued to be brought in for student and research support from Nexen Inc., Pioneer Natural Resources, WestStar Operating Co., Bromide Inc., Mt. Dora Energy, Continental Resources, Inc, Schlumberger Ltd., Pathfinder Exploration, and Devon Energy. Below is a summary of student and other activities during 2009-2010.



Unconventional gas shales/tight gas sandstones

Two new theses were completed to add to the list of theses on gas shales completed in prior years. Both ***Julieta Vallejos*** and ***Angel Gonzalez Canro*** applied a sophisticated, commercial computing program (GAMLS™) to quantify core-calibrated well log responses for regional interpretation and correlation of composition of Barnett Shale lithofacies in uncored wells **(Figure 1).** Such correlations provide improved stratigraphic interpretation for predicting the distribution of 'brittle' and 'ductile' lithofacies within the Barnett. The techniques are applicabable to other shales as well. Other Institute-affiliated students working on unconventional shales include ***Chris Althoff*** (Woodford Shale), ***Steven Arroyo*** (geologic model building), ***Henry Badra*** (Woodford Shale), ***Carlos Ceron*** (Fayetteveille Shale) ***Lindsey Guest*** (unnamed shale), ***Katie Hulsey*** (Horn River Shale), ***Brian Killian*** (Woodford Shale), ***Andrea Magoon*** (unnamed shale), ***Rafael Sierra*** (Woodford and Barnett shales), and ***Majia Zeng*** (China gas shales). Studies are focused on the stratigraphic aspects of shales and the affects of fabric and composition on their geo-mechanical properties at a variety of scales (jointly with ***Dr. Younane Abousleiman*** and his students). ***Dr. Omar Abouelresh***, Visiting Research Professor from the Faculty of Petroleum and Mining Engineering, Suez Canal University, Egypt has been collaborating with Dr. Slatt and students, and two joint papers on the Barnett Shale have been submitted for publication; Dr. Abouelresh also participated in a core workshop organized by the Petroleum Technology Transfer Council. Dr. Slatt works closely with noted shale experts ***Dr. Neal O'Brien*** (State University of New York) and ***Dr. Eric Eslinger*** (The College of Saint Rose) on specific issues of fabric and composition, respectively. Three key summary papers are also in press by Dr. Slatt and faculty/students on an integrated workflow for gas shale characterization, on karst-fracture/stratigraphy relations in the Barnett Shale, and on fracture patterns in the Woodford Shale and two additional papers on pores in shales and geomechanical properties of shales have been submitted.



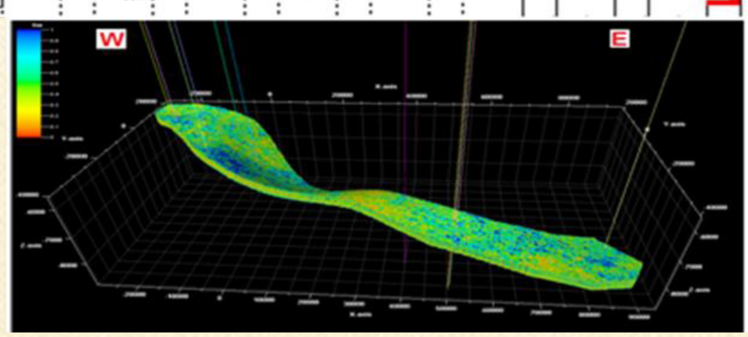


Figure 1. *Top figure is GAMLS™ correlated regional cross section of Barnett Shale in Johnson County, Texas. Lower figure is SW distribution of GAMLS correlated wells input into Petrel™.*

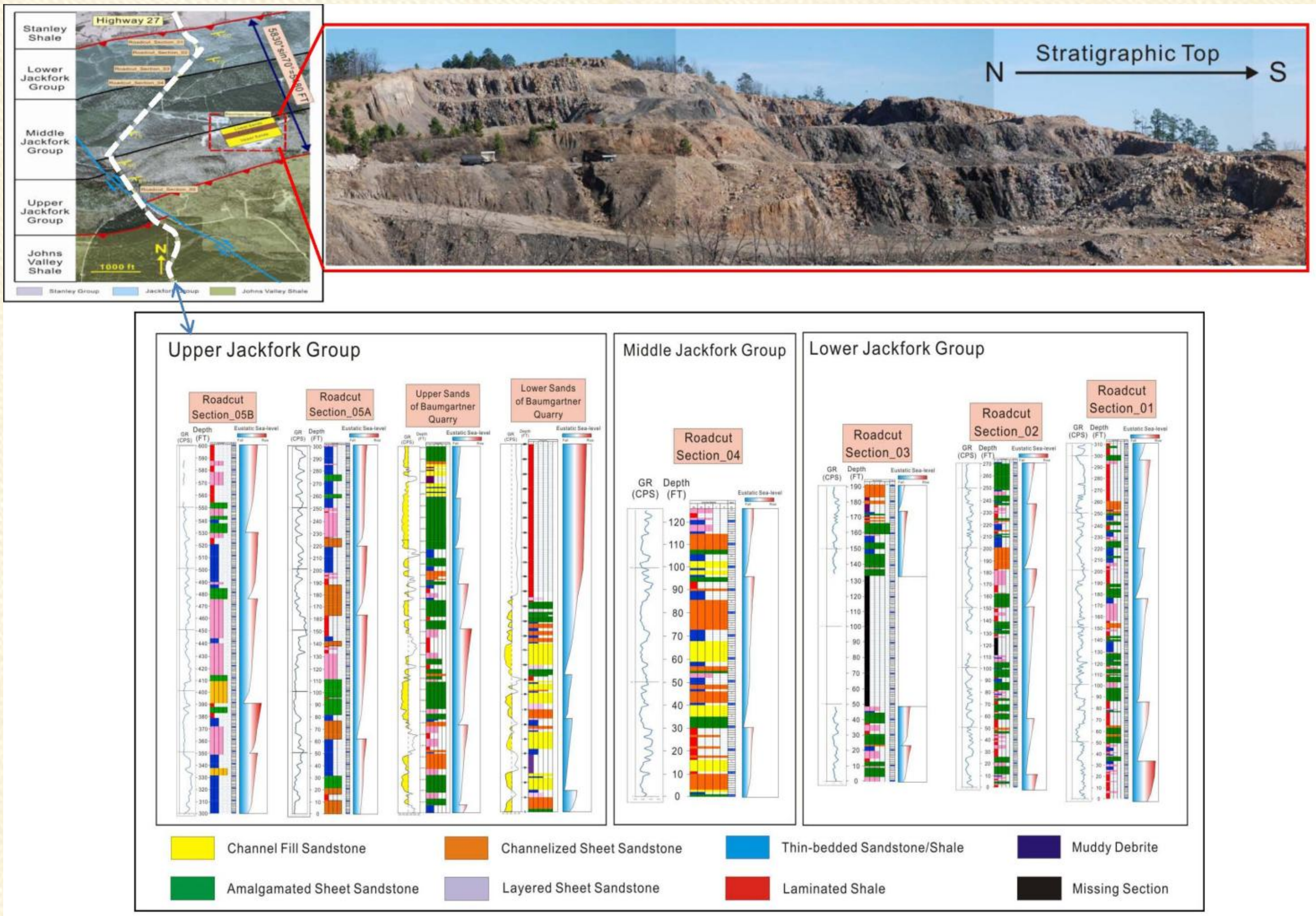


Figure 2. Areal photo (upper left) of the location of the 2000ft. Jackfork measured section (lower figure), and Baumgartner Quarry (upper photo).

In the area of tight gas sands, research continues to focus on the Jackfork Group of Arkansas and eastern Oklahoma and on the Lewis Shale in Wyoming. This past fall, students of the Reservoir Characterization class (see companion article in this issue of Earth Scientist) measured and interpreted a near-continuous 2000 ft. Jackfork section from the basal Stanley Shale to the overlying John's Valley Shale **(Figure 2).** M.S. candidate ***Fuge Zou*** completed measuring this section. It was published in a recent issue of The Shale Shaker. This complete section is a classic new area for comparision with deepwater reservoirs in the Gulf of Mexico and elsewhere. Nexen Inc. utilized this section in their recent company deepwater training field seminar. Zou's thesis covered all three of the Institute of Reservoir Characterization focus area: (1) characterization of a tight gas sand; (2) construction of a 3D quantitative geological model of part of this stratigraphic section (Baumgartner Quarry) from outcrop to Petrel™ and then into Eclipse™ for reservoir performance simulation; and (3) determination of different geophysical and fluid flow behaviors between deepwater lobe and channel sandstones in the Baumgartner Quarry section. A publication stemming from this thesis is currently in preparation for the AAPG Bulletin. Another Jackfork quarry, named Hollywood Quarry, continues to be a superb field laboratory for students and professionals. This quarry contains a number of easily seen reservoir types, including stratigraphic pinchouts, faults, folds, fractures, and injectites, and considerable work continues here. ***Ryan Davison*** is tackling the origin of injectites in this quarry for his M.S. thesis, and two undergraduate transfer

Figure 3. *Eva Peza from Schlumberger teaching a Petrel class.*

Figure 4. *Roger Slatt and David Pyles receive award for Best SEPM Poster at AAPG National Convention. The poster was titled: Integrating outcrop and subsurface data to define regional to reservoir scale patterns in Shelf-Slope-Basin systems, Lewis Shale and Fox Hills Sandstone, Wyoming.*

students, ***Richard Brito Leonet*** and ***Luis Castillo Morales*** completed seismic and GPR surveys along some newly quarried surfaces under the tutelage of Ph.D. student ***Oswaldo Davogustto***. Hollywood Quarry is the site of a twice-annual field seminar for Schlumberger geologists, led by Dr. Slatt and ***Dr. Ramona Graves*** (PE-Colorado School of Mines), and in Dr. Slatt's Reservoir Characterization II class this past Spring, students had the opportunity to incorporate field measurements taken during their Reservoir Characterization I class into Petrel™ for geologic modeling. ***Veronica Liceras*** is currently updating the model for her M.S. thesis. Each spring, ***Eva Peza*** from Schlumberger **(Figure 3),** teaches Petrel modeling to students in the Reservoir Characterization II course. ***Bob Davis***, also of Schlumberger, helps out in this course as well as co-leads part of the Schlumberger field seminar. ***Levi Pack*** is also completing a Jackfork thesis in an area in eastern Oklahoma. Regarding the Lewis Shale tight gas sandstone, this too is an area that Dr. Slatt and students have worked in for many years, both at Colorado School of Mines and OU. At least 15 M.S. and Ph.D. students have completed theses in this area, and it too has become a popular field area for industry field trips on shelf-to-basin facies tracts in a pro-gradational continental margin. This past year, Dr. Slatt and Dr. David Pyles, Colorado School of Mines, won the SEPM Best Poster Award at the Annual AAPG convention for some of their most recent work on this system **(Figure 4).** At present, ***Aslihan Deliktas*** is completing a shallow seismic study of the Lewis to add to the already-diverse outcrop and behind-outcrop data that has been acquired here.

Reservoir Characterization

The characterization of reservoirs for improved hydrocarbon production has always been a favorite research topic of Dr. Slatt and his students, often supported by local companies who donate data and financing for applied thesis research. Part of the popularity of this subject at OU is the fact that Dr. Slatt published a book on Reservoir Characterization in late 2006, and also because he and ***Dr. Younane Abousleiman*** team-teach a course on Reservoir Characterization each Fall (see companion article). Most of this thesis research is centered on mid-Continent reservoirs, and this year, students completed M.S. theses on the Skinner Sand (***Nathan Clees***), upper Red Fork Sandstone (***Juan Guzman***), Burbank Sandstone (***Dwain Veach***), Hunton Group (***Byron Solarte***), and Booch Sandstone (***Jarred Tarkington***). Currently, ***Marcelo Sanchez-Vargas*** is working on a regional Red Fork Sandstone thesis. Elsevier Publishing Co., the publisher of Dr. Slatt's book, requested a second edition, which he is currently working on (through a Fall 2010 Sabbatical Leave of Absence), and many of these studies will be included in a chapter on applied sequence stratigraphy for reservoir characterization. ***Austin Heape*** is just completing his thesis, jointly under the direction of Drs. Slatt and ***Shankar Mitra*** on the tectono-stratigraphy of the Oil Creek and Davis sandstones in the Sherman-Marietta Basin, Texas.

Petroleum Geology of Deepwater Depositional Systems

Also in 2006, Dr. Slatt co-authored a comprehensive book on the petroleum geology of deepwater depositional systems (AAPG volume). Even since that time, there have been many advances in understanding these valuable resource systems, but much still remains to be learned, including from the Institute group. ***Fuge Zou's*** thesis has already been mentioned above. This past year, ***Jonathan Funk*** completed an outcrop-based M.S. thesis on

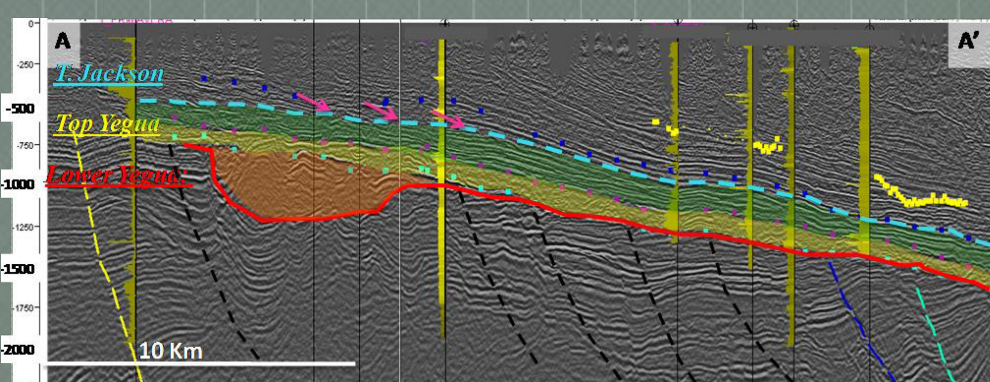
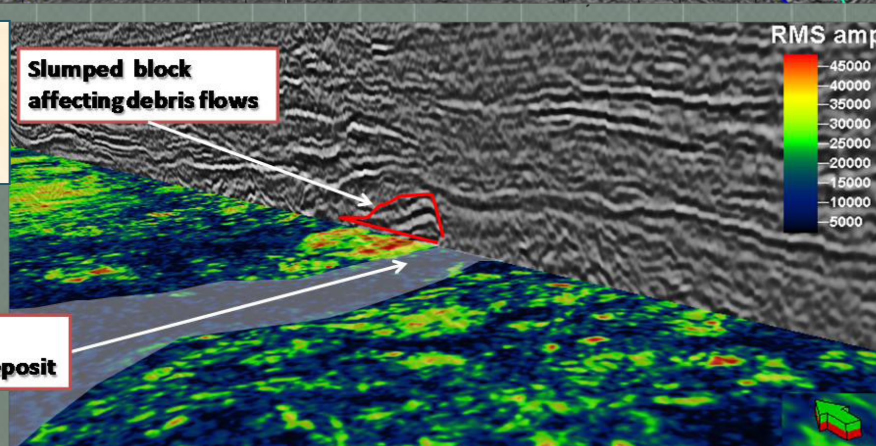


Figure 5. *(Top graph) Seismic stratigraphic interpretation of the Yegua and Jackson system, western Gulf Coast; (Bottom graph) seismic attribute display of a slump block in the lower Yegua.*



quantification of connectivity between channel-fill and other deepwater architectural elements. This study provides previously undocumented information for reservoir modeling and performance simulation to predict fluid flow across architectural element boundaries; it follows from a smaller-scale M.S. thesis completed last year by ***Carlos Santa-Cruz***. ***Diana Parada*** completed a comprehensive seismic-sequence stratigraphic study of an Eocene-Oligocene deepwater system in the onshore western Gulf Coast **(Figure 5)**; her's is a classic study which provides a workflow for systematic, integrated characterization of subsurface deepwater strata using a variety of analytical techniques and modern geologic concepts. ***Sunday Amoyedo*** continues his Ph.D. research on the affects of long-term production on geophysical-geomechanical-production performance properties of the Forties Field, North Sea. ***Supratik Sarkar*** is also well along with his Ph.D. dissertation on the sequence stratigraphy and reservoir properties of the northern Chicontepec field, with application to improved well performance in this giant, poorly-producing oil field in Mexico. ***Andrea Cadena-Mendoza*** is soon to start her master's thesis on seismic characterization of the Magdalena submarine fan.

Other activities of the Institute

Short courses on Deepwater Petroleum Geology, Reservoir Characterization **(Figure 6)** and Clastic Sequence Stratigraphy continue to be taught globally to national oil companies and international geosciences organizations. Emphasis this past year has been teaching in South America, mainly through the tireless efforts of ***Dr. Yoana Walshap,*** Director of the Energy Institute of the Americas at OU, but also in the U.S. and Indonesia. Dr. Slatt has initiated an external course on the geology of unconventional gas shales, which has been presented to interested companies.

The goal of the Institute is to promote the science of reservoir characterization through applied research and practical education, both within and outside OU.

A new group of enthusiastic graduate students has entered the program this Fall 2010, and you will be reading about them in next year's edition of this article.

Figure 6. *Roger Slatt teaching reservoir characterization to an enthusiastic group of students from EAFIT and employees of Ecopetrol-ICP in Bucaramanga, Colombia.*

NEIL H. SUNESON
Oklahoma Geological Survey
ConocoPhillips School of Geology and Geophysics

SUMMER FIELD CAMP REPORT 2010

This was one of the best groups of students we've ever had at field camp; and by "we", I mean the entire faculty (Jim Puckette – OSU, George Bolling – UCCS, and Tom Stanley and me – OGS and OU). The quality and enthusiasm of the students (58 total, including three from the University of Rhode Island!) made them a real pleasure to work with. And at that end of camp there were real tears. Sure, it was hard work………hard physically and mentally……….and everyone was glad to be headed home, but new friendships were made and geology in the field gained some new respect and maybe even some converts.

Those OU alums who've attended OSU's field camp in Cañon City from 2006 on will recognize the program. It hasn't changed very much. We start off (this year – May 24) with a tour of the area including the ever-popular and occasionally "death-defying" Skyline Drive. We then spend a day reviewing our field techniques, followed by a day at Red Cañon Park where we hone our orienteering skills *without* the aid of GPS. And yes, the topo maps really do match what's on the ground and yes, you ***really can*** locate yourself without artificial aids (aka satellites).

After this the real work begins. The infamous "death march" around and up through the Grape Creek area, section measuring at Grape Creek, and mapping (Grape Creek), mapping (Mixing Bowl), mapping (Twin Mountain). Interspersed in the geologic mapping is a short trip to see "Daddy's critters," sketch an outcrop along Phantom Canyon Road, study facies changes in the Ralston Creek Formation, map some metamorphic and igneous rocks at Blue Ridge, and get introduced to some field geophysics. All topped off with a map and written final on the last day (June 25).

On the infamous "Death March" at Grape Creek. Tad (standing, with field book), Simon (looking wrong way), Gaurang (balancing field case on arm), Brandon (green shirt), Matt K. (orange shirt), Kate (standing at attention, eyes right), Mike (far right), Rami (white hat).

"Death March" at Grape Creek

Standing, left to right: Tiffany Legg, Kate Whitmarsh, Austin Shock, Simon Anzaldua, Gaurang Patel, Matt Kendall, Rami Nyanat, Noah Morris, Tad Eccles, Brandon Guttery, Brittany Pritchett, Matt Miller, Ahmed Al-Shafei. Seated, left to right: Tom Stanley (faculty), Neil Suneson (faculty), Virginia Priegnitz, Earl Manning, Allison Stumpf (TA).

2010 summer field camp students

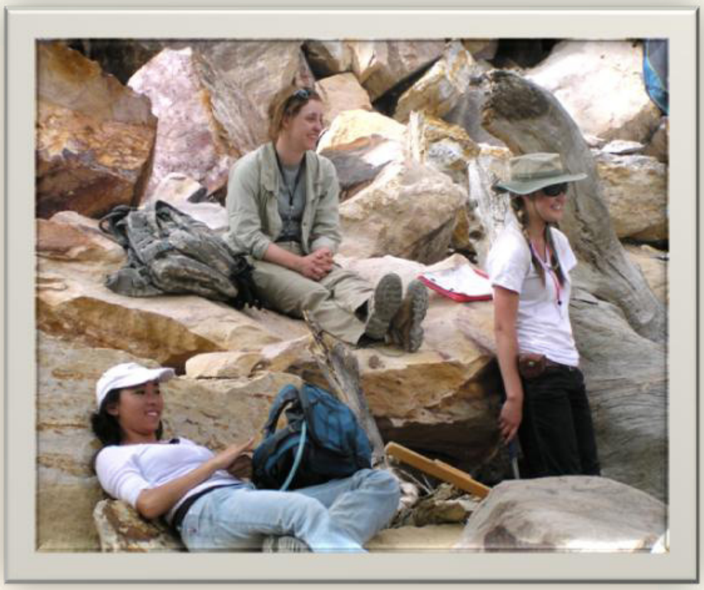
Field trips are a key part of the Colorado geology summer experience, and this year we did four – Pikes Peak/Garden of the Gods, Shelf Road/Cripple Creek, Victor gold mine/Mollie Kathleen gold mine, Raton Basin/Denver Basin, and Leadville. And again, as in previous years, the weather at Leadville was miserable – cold rain and snow.

Highlights from SUMMER FIELD CAMP – 2010

- Lots of dinosaur bones at the Garden Park Fossil Area. Of course, everyone left them right where they were.
- Intellectual discussions on the merits of azimuth vs. quadrant Bruntons. And what's this right-hand rule crap? Palm up or palm down, and how do you deal with measuring the undersides of beds? And would this work in Australia?
- Hot, hot, hot on the Death March. But no snakes! In fact, very few snakes all five weeks. But lots of cholla …… and nettles (……. Tiffany?).
- North End (student end of camp, vs. the South aka faculty end) games of "Waterfall" and "Circle of Death." Whatever happened to poetry readings?
- First weekend – a visit to the new and still under construction OU field camp across the valley. Earl discovers the bidets, and we all realize this will not be a field "camp" but a field "resort." Ahmed takes photos of the new buildings, in fact, of every log in the new buildings. In all he takes 2400 pictures at field camp.
- Cries of "I can't draw!" when it's time to do an outcrop sketch along the road. And it really is true – some students can't draw. At all. Period. Maybe a creative art class should be required as part of the undergraduate geology curriculum.
- Noah discovers free gold in a specimen from the high-grade pile at the CCV mine. Noah refuses to share it with the faculty. Noah flunks field camp.
- A "boot wire" is installed over the parking lot for severely used footwear.

Virginia with her boot stuck in the Fremont Dolomite at Twin Mountain. (Many thanks to Earl Manning for photo.)

- Saturday, June 5. Allison arranges for much of the camp to go rafting. Trip is wildly successful, "wildly" being the operative word. The water is incredibly high and fast, and one student (not from OU) ends up in the ER. Brittany (amongst most of the others) gets dumped, crashes into rocks, rafts, and other rafters, and worries she may have cracked a rib (fortunately just a bad bruise).
- Ever-agile Virginia gets her boot stuck in a crack in the Fremont Dolomite. In an effort to save her, Earl throws his notebook over the cliff.
- Mysterious discovery by Matt M. of petrified amber (?) in the Laramie Formation.



Relaxing after a hard day of mapping; at the famous Cottonwood Tree at Grape Creek. Brittany at top, Tiffany at right, Rami reclined.

- Beginning of Raton Basin/Denver Basin field trip dominated by talk of the demise of the Big 12. Hard to discuss CUSs in the Pierre Shale when football is on the line. Later part dominated by talk of Starbucks, and Virginia's "Pacing? I'm pacing myself to Starbucks."
- A hailstorm on the first day of the Mixing Bowl/ geophysics causes shelter-seeking in the bowl and all kinds of problems for the geophysicists.
- At the end of last day of Grape Creek mapping, many go for a dip in Grape Creek and work on eliminating their farmers' tan.
- Many of the male students attempt to grow beards (like mine). Many "beards" more properly called "small groups of thin whiskers" and all are the wrong color (not being gray). Matt M. ultimately wins the non-contest, progressing from a full beard to chops w/ Fu Manchu.
- Tad and Earl give up trying to look alike and resign themselves to being called the other guy.
- The delights of spear grass throwing are discovered.
- Third Saturday – despite the miserable weather, the "camp" "Olympics" are held. Not to be confused with oil wrestling. And speaking of sports, holding field camp at the same time as the NBA playoffs, the Stanley Cup, College World Series (Sooners were playing), and the World Cup (US was playing) is distracting.
- Five guys from camp (Matt K. and Noah from OU) go caving with Jason Conners, son of Ron C. who is building the new OU camp. All come back never wanting to go in a cave again, unless they can drive a car in it.
- Virginia jumps out of an airplane, having failed to read the small print in the OU Code of Student Conduct forbidding such conduct in Colorado.
- A big fire near Parkdale reminds us of how dry it's been. In fact, except for our Leadville day, rain is a non-issue this year.
- Brandon turns 21, and lemonade is served.
- Additions are made to the culvert under Hwy. 50 at Twin Mountain. Someone someday has to record (with appropriate deletions for family readers) the history inside this culvert.

First, but certainly not the last, encounter with good tearpants Fremont Dolomite. On the "Pancake" at "The Bowl." Left to right: Brandon, Austin (with right hand pretending it's the Harding Sandstone), Mike, Ahmed (trying to remove cholla from palm), Simon.

- Significant camp improvement introduced: outdoor movies on the side of one of the cabins and the basketball hoop (Allison blew everyone away).
- This is the year of the "teeth." One root canal (Ahmed), two cases of abscessed teeth, and two chipped teeth from a boulder-leaping face plant. And one incredibly fat lip (Gaurang) thanks to a nighttime insect bite. But, otherwise, a very healthy summer!
- Throughout the five weeks, I subjected my van riders to 60s and 70s rock (music, not geology). On the way back from the mapping final, Kate requests "Touch of Grey" by the Grateful Dead, and everyone joins in on the chorus, "We will get by, we will survive." And we did.

This will be our last year at OSU's camp. It has been an extremely good five years with them; lots of lasting friendships and contacts that will undoubtedly become professional have been made. Our experience shows we can be rivals in sports and colleagues in geology. Personally, I'd like to thank Jim Puckette for getting me started and continuing to educate me in Cañon City field-camp geology. It truly has been a wonderful collaboration. And I continue to value the friendship of George Bolling, our local pointman.

Next year OU will be at our new field camp across the valley, and OGS colleague Tom Stanley most likely will be joining me. Some projects will be the same; others will be new. Many aspects of geology field camp will remain (long days in the field, long nights over the drafting table), but some will be different (we'll have internet access!!!). For those OU geology alums who attended field camp in Cañon City, either at OSU's camp, the Abbey, or the camp "in the Dakota Hogback" when it was OU's, we extend an invitation to visit us at the new Bartell Field Camp. Come re-experience the confusion of the Mixing Bowl and the mystery of Nasty Knob. If all goes well, we should have some luxurious cabins in which you can stay.

New OU field camp. Earl discovers that bidets are being installed.

Ahmed and Tiffany at National Mining Hall of Fame and Museum in Leadville. (Thanks to Earl Manning for photo.)

At the Grape Creek Beach Club and Resort after a hot day of mapping. The water was quite pleasant following the initial shock. Left to right: Gaurang, Virginia, Mike, Simon.

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On the Dusty Trail: The Geologic Record of Atmospheric Dust

Dust is the poor stepsister of the geologic record. Omitted, ignored, sullied by many, including housekeepers. But dust is a formidable agent in the atmosphere, capable of both archiving and affecting Earth's climate. Geoscientists who study the modern and recent geologic record have long recognized dust – in the form of loess, or eolian silt deposits. Dust accumulation competes constantly with soil formation, such that loess deposits invariably contain intercalated fossil soils (paleosols), recording intervals when dust influx slowed, and soil formation won out. The most famous dust pile on Earth today occurs in China: the Chinese Loess Plateau consists of an enormous thickness of dust upwards of 100-200 m thick, punctuated with paleosols that record glacial-interglacial climate shifts of the last 2.5 million years or so.

The Akiyoshidai (southern Honshu, Japan) is a national park that exposes Permo-Carboniferous limestone within an intensely karstified terrain. The limestone is part of an atoll that formed in the paleo Pacific and was obducted by the end Permian. The treeless area is burned annually.

Professor Lynn Soreghan
ConocoPhillips School of Geology and Geophysics
University of Oklahoma

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But, dust falls everywhere; where preserved as a dust pile, we call it loess, but it also falls into the ocean, into lakes and carbonate reefs. And wherever it falls, it carries a record of atmospheric conditions with it. Theoretically, the size of the dust bears a strong relationship to the strength of the winds, and the composition of the dust betrays the wind direction. This is the "archival" value of dust. But dust forces the climate system too, through both direct radiative effects (e.g., scattering), as well as indirect effects (e.g., nutrient seeding that stimulates productivity).

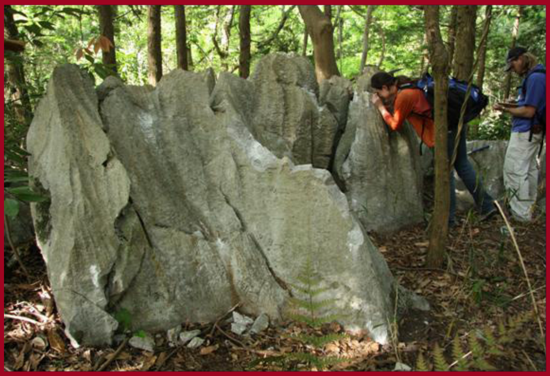
Dust, in the form of both loess and dust extracted from isolated marine systems, does have a respectable following amongst geo-scientists who study the "near-time" (late Cenozoic) sedimentary record. A library search on "loess" will yield thousands of hits, but all but a handful will be from the relatively recent record of loess, or of dust extracted from deep-sea cores. The sins of omission apply to the "deep-time" geologic record because dust becomes increasingly difficult to identify as dust given the ravages of deep time, e.g., dia-genesis and deformation. For example, although dust is commonly extracted from deep-sea cores of the remote Pacific, accessing the oceanic record becomes nearly impossible for the pre-Jurassic record, owing to constant renewal of oceanic crust.

Thankfully, *almost impossible* is not *impossible*, which is what led us to Japan and some remarkable limestone (see accompanying images). Following on the heels of work to extract ancient dust from isolated carbonate buildups of West Texas (see related abstract by Sur et al., in press in the *Journal of Sedimentary Research*), we headed to Japan in 2010 to sample Paleozoic limestone formed in the midst of the Panthalassic (paleo-Pacific) ocean and obducted to form part of Japan. The obduction process has not been kind to these limestone units, but — save for the stratigraphic inversion — many exposures remain unmetamorphosed. We have sampled two very complete sections of Pennsylvanian age at 10-cm resolution and are currently undertaking processing to reveal what we hope will be a "background dust" signal of the Pennsylvanian atmosphere.

Together with students and colleagues ranging from sedimentologists to geochemists and climate modelers, we are attempting to reveal the record and impact of dust flux through glacials and interglacials of the Permo-Pennsylvanian. Although Japan is our latest and most exotic locality to date, we are amassing data from various parts of the western U.S. (Texas, Nevada, the Four Corners' states, Oklahoma; see related article) as well as Canada. Over the past few years of this NSF-supported project, our group has included former and current OU graduate students Sohini Sur (PhD, Shell), Alice Stagner (MS, ConocoPhillips), Alisan Templet (MS, OU), Greg Augsburger (MS, OU), Kevin Hathaway (MS, OU), Jessica Pack (MS, OU), and Elisheva Patterson (MS, OU), as well as undergraduates Michael Merrill and Austin Shock. Ultimately, we hope to both reconstruct climate archives of this time and demonstrate how the dust may have acted as an agent in climate change.

Outcrops in the Akiyoshidai are quite massive; bedding is rare, owing to the incredibly clean nature of the limestone. The heavy rainfall dissolves the limestone into pinnacles such as those pictured here. We hope to obtain dust from these!

Measuring section proved challenging. The treeless area is protected; hence, we measured our sections in the rainforest keeping watch for Rodents Of Unusual Size. To complicate matters, the exposures consisted of pinnacles stratigraphically inverted.



Here, OU student Elisheva Patterson works with UCR student, Jeremy Owens, to sample for dust.

"2009-2010 Sacramento and Guadalupe Mountains Field Trips"

LYNN SOREGHAN
Brandt Professor
University of Oklahoma

The Fall 2009 Depositional Systems and Stratigraphy class in front of El Capitan

Dr. Lynn Soreghan led trips to the world-class outcrops of the Sacramento and Guadalupe Mountains (New Mexico and West Texas) as part of two courses in the 2009 - 2010 academic year. For Fall 2009, Geology 4113/5113 (Depositional Systems and Stratigraphy) took a 4-day trip to visit bus-accessible outcrops and study depositional systems ranging from eolian and deepwater clastics to all manner of carbonates, including the hike along the incomparable Permian Reef Trail. The accompanying photos show our whole crew in front of El Capitan, and those that completed the trek to the summit of the Reef Trail. In spring 2010, we took an extended (6-day) trip as part of Lynn's graduate course in Carbonates and Sequence Stratigraphy. Here, we used school vehicles, which, with some driver encouragement, enabled us to access even the most remote reaches of the Guadalupe Mountains. The study of seismic-scale outcrops offers an unparalleled opportunity to practice sequence stratigraphy in the field.

The graduate Carbonates and Sequence Stratigraphy class clowns around during the sunset at White Sands National Monument.

*"The **USArray** component of EarthScope is a continental-scale seismic observatory designed to provide a foundation for integrated studies of continental lithosphere and deep Earth structure. Over the wide frequency range of seismic waves transmitted through the Earth (hundreds of seconds to ten cycles per second), the sensors of the permanent and transportable seismic and magnetotelluric arrays will resolve the smallest background motions at the quietest of sites, while remaining "on scale" for all but the largest ground motions from regional earthquakes."*

(reprinted from EarthScope's Web site)

www.earthscope.org

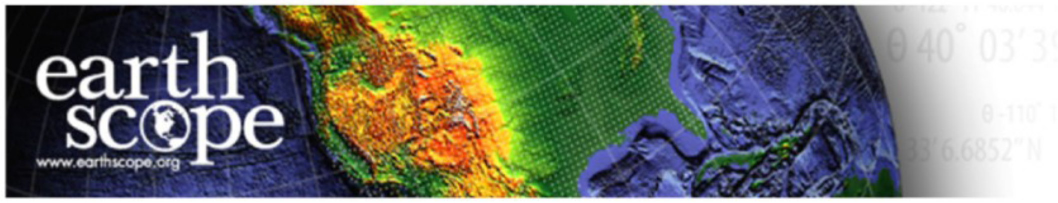
Austin Holland, OGS seismologist, speaking to the media near the Tecumseh site.

Catherine Cox standing near an installation site for seismometer vault.

Some OU students and the visiting scientists from China observing an installation.

G. RANDY KELLER
Director, Oklahoma Geological Survey
Edward Lamb McCullough Chair Professor of Geophysics

EarthScope's USArray Moves into Central Oklahoma



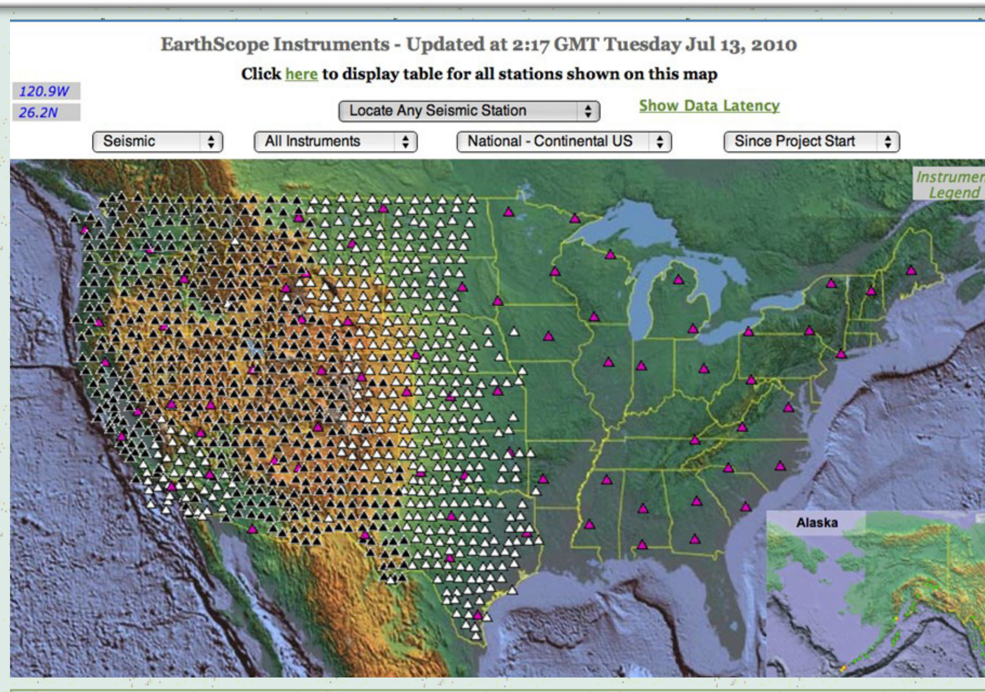
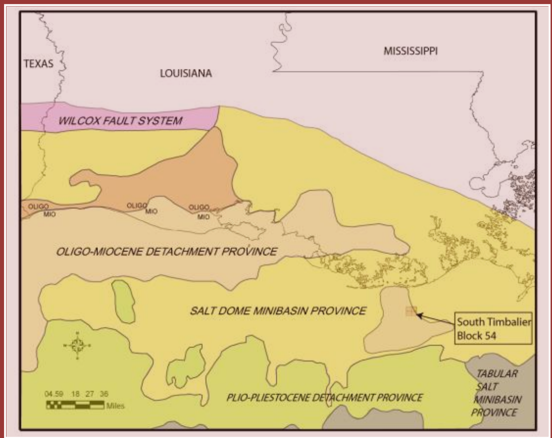


Figure 1: *A network of seismometers deployed across the U.S. to record earthquakes and provide high-resolution images of the continent's structure and the Earth's deep interior.*

The ConocoPhillips School of Geology and Geophysics and the Oklahoma Geological Survey have been very involved in the siting and use of the USArray advanced seismic stations that have been migrating into central Oklahoma over the past 18 months **(Figure 1).** "The data from these stations is proving to be a huge aid in our efforts to locate and understand the surprising number of earthquakes large enough to be felt around Oklahoma," Randy recently said. As part of the USArray program, Keller received a Student Siting Program grant to find locations for 39 the USArray stations to be installed in Oklahoma. This project had a number of positive outcomes for the students from the University of Oklahoma who were involved. These impacts began with our trip to the training workshop where they had a chance to meet fellow students from around the southwest and visit another university. The summer support provided them a positive professional experience. They all enjoyed seeing parts of our state they had never seen before and meeting landowners who where mostly very helpful. However, they did come back with some interesting stories about some of their encounters. An example of good relations with landowners is an event that occurred when a large group of students, faculty and media attended the equipment installation at a site near our university this spring. The landowner was very helpful and even cooked hamburgers for the crowd. We had two young visiting scientists from China who attended this event and also became very interested in EarthScope.

"Salt Cored Convergent Transfer Zone in the South Timbalier Block 54, Offshore Gulf of Mexico: New Insights from Balanced Cross Sections and Three-Dimensional Structural Models"

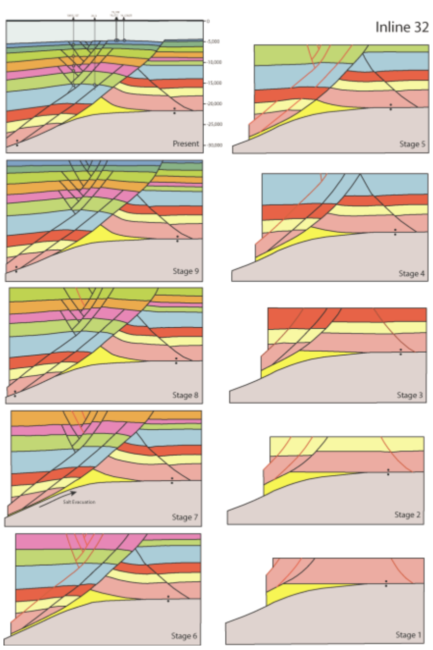


Tectono-stratigraphic provinces in the northern Gulf of Mexico and the location of block ST 54.

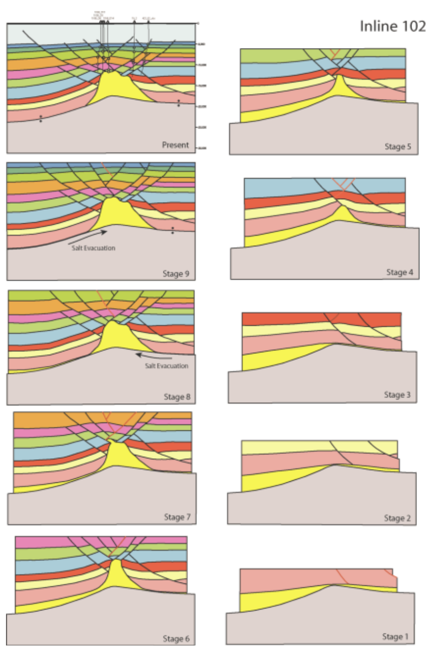
Shamik Bose, PhD Student in Geology and **Shankar Mitra,** Monnett Chair Professor

The structural style of Oligo-Miocene detachment province in offshore Louisiana is characterized by arcuate regional and counter-regional growth fault systems that form complex transfer zones above shallow, Miocene level salt bodies. South Timbalier Block 54 (ST 54) constitutes one such area where a convergent transfer zone is present between a basinward dipping regional and a landward dipping counter-regional fault. 3D seismic and well data have been used to interpret the structure of four offshore blocks adjacent to ST 54. The interpretation reveals that the eastern and western flanks of the structure contain salt in the footwalls of the main regional and counter-regional faults; the salt rises to a much shallower stratigraphic level in the central part of the transfer zone, forming a collapsed crest structure. Secondary antithetic and synthetic faults adjacent to the two main faults and also extending into the transfer zone are responsible for accommodating slip between the main faults. Kinematic restorations of a series of cross sections across the structure reveal that salt evacuation is a result of sediment loading and growth fault movement and the location of the transfer zone is controlled by the initial geometry of the salt body. A 3D structural model using depth-converted horizons, balanced cross sections and well tops has been constructed to accurately represent the subsurface structure. Understanding the evolution of the structure in ST 54 provides insight on similar structures in other areas of offshore Louisiana and aids in establishing the relationship between salt evacuation and transfer zone development.

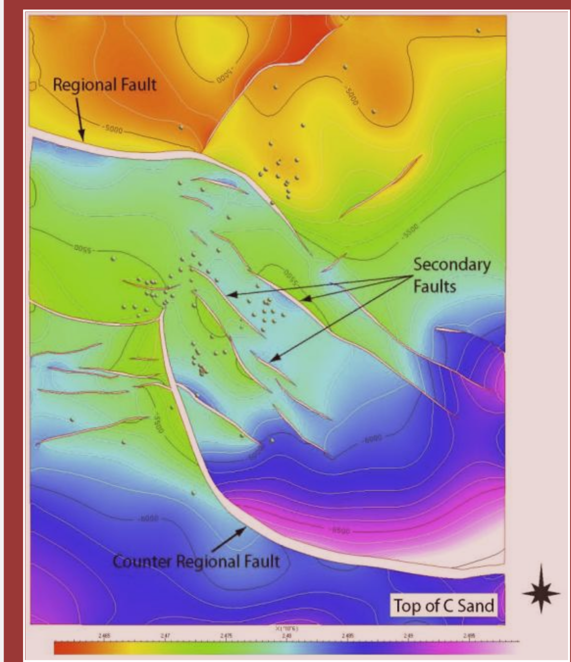
For more details on this article, please see Bose, S., and S. Mitra, 2010, Salt cored convergent transfer zone in the South Timbalier Block 54, offshore Gulf of Mexico: New insights from balanced cross sections and three dimensional structural models: Gulf Coast Association of Geological Societies Transactions, v. 60, p. 65-75.



Kinematic restoration of Inline 32 by sequential removal of units and application of decompaction. Restored faults are marked in red and direction of salt evacuation is shown right before salt welds have formed.



Kinematic restoration of Inline 102 through the center of the transfer zone, showing the evolution of a salt diaper and a crestal collapse garden.



Seismic depth surface created from depth converted time surfaces fitted to well tops and balanced cross sections for the top of the C Sand.

The China Connection

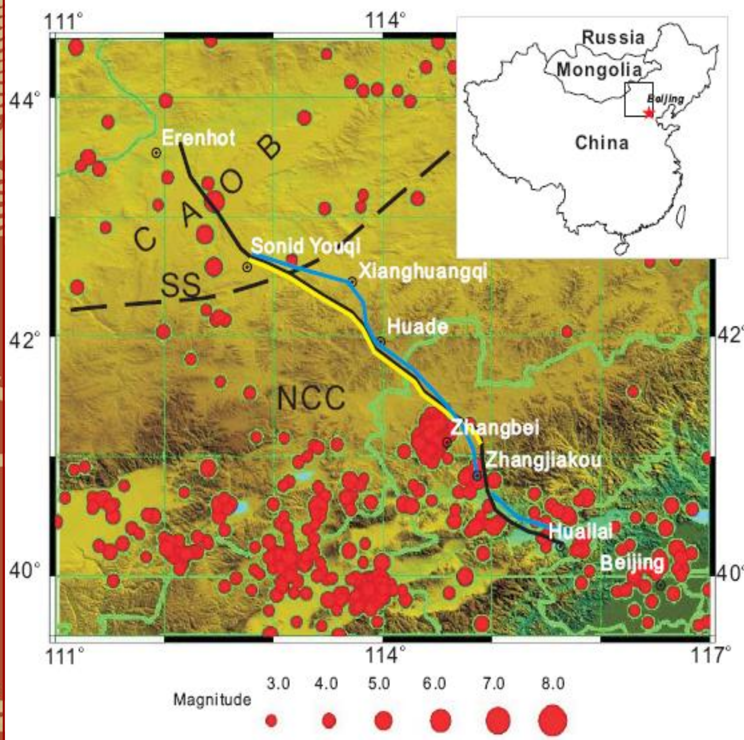


Figure 1

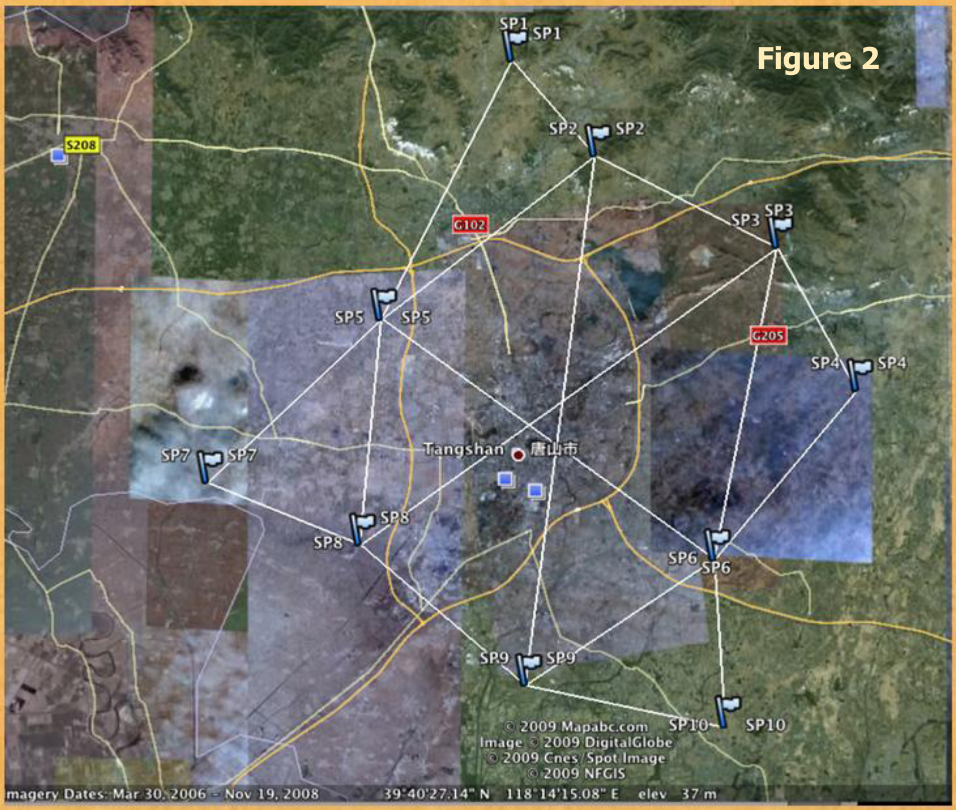
Professor Randy Keller is involved in a major National Science Foundation (NSF) study that seeks to better understand the intraplate earthquakes that occur in northern China and the central US. As part of this project, Randy's group was involved in two large seismic experiments in China that were joint efforts with Chinese collaborators. These experiments employed 500 seismic recorders from the NSF-funded IRIS/PASSCAL instrument pool. These instruments were designed by Randy and colleagues as part of a series of research grants.

One OU collaboration is with the Chinese Academy of Geological Sciences that leads the SinoProbe project. SinoProbe is China's ambitious national joint earth science research project that was established to develop a comprehensive understanding of the deep interior beneath the Chinese continent. As one of the eight major programs within SinoProbe, the SinoProbe-2 group and OU undertook a large-scale, controlled-source seismic experiment in North China in December of 2009. In addition to Randy, Steve Holloway, graduate students **Catherine Cox** and **Jefferson Chang**, and UTEP colleagues traveled to China to participate in this project, which consisted of three coordinated seismic reflection and refraction recording efforts along a profile that extended from near Beijing northwestward to the Mongolian border **(Figure 1)**. The project was successfully carried out in difficult field conditions (e.g. snow and -40°C at times).

The profile began near the eastern edge of the Western Block of the North China Precambrian craton, crossed this feature to the Solonker suture zone, and ended in the Central Asian orogenic belt (CAOB) **(Figure 1).** In the southern segment of the CAOB, the Solonker suture zone was involved in the final closure of the paleo–Asian Ocean and amalgamation of the North China craton and Mongolian arc terranes and is thus a key feature for understanding the evolution of this complex Permian orogenic event. South of the Solonker suture zone, the zone of seismicity

Group photo of the SinoProbe-2 project team in Zhangjiakou.

(Left to right: OU students Xiao Xu, Rica Hood, Murari Khatiwada, and Galen Kaip (UTEP student) moving seismic equipment.



around the city of Zhangbei **(Figure 1)** is the most seismically active region in north China and includes the 19 January 1998 Zhangbei earthquake that claimed approximately 50 lives and caused severe damage.

OU is also working with the Chinese Earthquake Administration as part of Randy's grant, and a second experiment was conducted in January of 2010. This experiment was centered on the city of Tangshan that was destroyed by an earthquake in 1976 which caused at least 250,000 casualties. Keller, Holloway, UTEP colleagues, and six OU graduate students participated in this effort along with a large team from the Chinese Earthquake Administration and Chinese Universities. This experiment involved deploying an array of seismographs in and around the city **(Figure 2)**. The design of this array and the experiment in general was primarily the responsibility of the US team. The goal of this experiment is to advance our understanding of the cause of this devastating earthquake and aid efforts to minimize the loss of property and life in the next one by providing an image of the structure of the area to a depth of about 20 km.

During the spring of 2010, OU hosted a series of Chinese scientists (three senior scientists, one postdoctoral scientist, and a PhD student from the Chinese Academy of Geological Scientists) who came to take part in the processing, modeling, and interpretation of the SinoProbe-2 data along with OU students. At the same time, an OU PhD student ***Jefferson Chang*** *processed, picked arrival times and began modeling the data from the 2-D array deployed around Tangshan.*

Left to right: Professor Randy Keller, Catherine Cox, and Jefferson Chang standing by an outcrop in Inner Mongolia.

The OU entourage having their last dinner in Beijing before returning home.

Correlating heterogeneous production to seismic curvature attributes in an Australian coalbed methane field

Jeremy C. Fisk*, *Kurt J. Marfurt , The University of Oklahoma; Dennis Cooke, Santos, Ltd.*

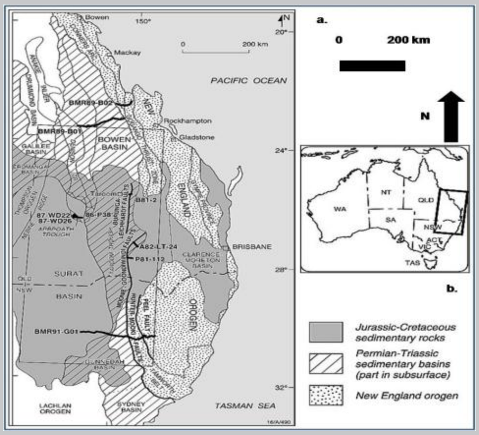


Figure 1: *(a) This map presents a closer look at the geology of this area. (b) The black box surrounds the location of the Bowen and Surat Basins in Australia. The Bowen and Surat Basins contain more than 70 small commercial oil and gas fields. Many of these fields are in anticlines that formed due to New England orogen thrusting (Korsch, 2004).*

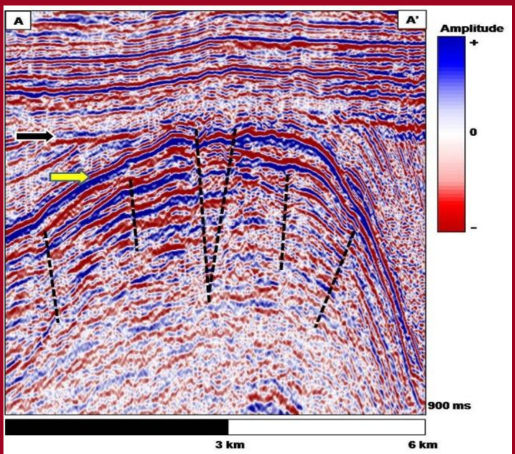


Figure 2: *The coalbed methane reservoir lies within this prominent anticline. The yellow block arrow points at the top coal seam (a strong negative amplitude). The black block arrow points to the visible unconformity that separates the Triassic and Jurassic time periods. The black dashed lines are interpreted faults that have formed as a result of the folding in this area.*

Summary

Australia is the world's second largest producer of coalbed methane (Faiz, 2008). Characterized as a marginal tectonic setting, the Bowen Basin of Queensland displays a thick succession of numerous thin bituminous rank coal seams. The area's heterogeneous production is particularly perplexing; it is not unusual for production to change as much as 50-75% between neighboring wells within a few kilometers of one another. A myriad of factors can affect coalbed methane production and include coal thickness, coal cleat architecture, local maximum horizontal stress direction, and the *in situ* stress magnitude.

We show how seismic curvature attributes illustrate lineaments that correlate to production. We use a technique to generate 3D rose diagrams from curvature attributes and show that the diagrams depict the face and butt cleat architecture.

Introduction

Unconventional reservoirs continue to contribute an increasing percentage of the total amount of oil and gas production in the world. Shale and coal are examples of low-permeability unconventional reservoirs that often act as both the primary source rock and the reservoir. The application of seismic attributes and multiattribute transforms are incrementally pushing the limits of seismic resolution and facilitating different data analysis perspectives to use during reservoir characterization.

Geologic Background

The Bowen Basin is a Permian-Triassic age major economic coal basin that extends approximately 900 km in a generally north to south direction in the eastern portion of Queensland, Australia. The Bowen Basin is one portion of the Bowen-Gunnedah-Sydney foreland system that formed as a result of the collision of the paleo-Pacific and paleo-Australian plates beginning as early as 294 Ma in the Early Permian. This orogenic belt is often referred to as the New England fold belt. **Figure 1** is a map of Australia which outlines the approximate geographical limits of the Bowen Basin in Queensland.

Toward the end of the Permian, the coal measures formed in environments described as fluvio-deltaic. Structurally, this reservoir lies within a large anticlinal structure that Korsch (2004) has labeled a fault-propagation fold.

Figure 2 is a seismic inline view of the fault propagation fold from the 3D seismic data for this study with interpreted faults. **Figure 3** shows the seismic line (A-A') from **Figure 2** and well production data for this 3D seismic survey.

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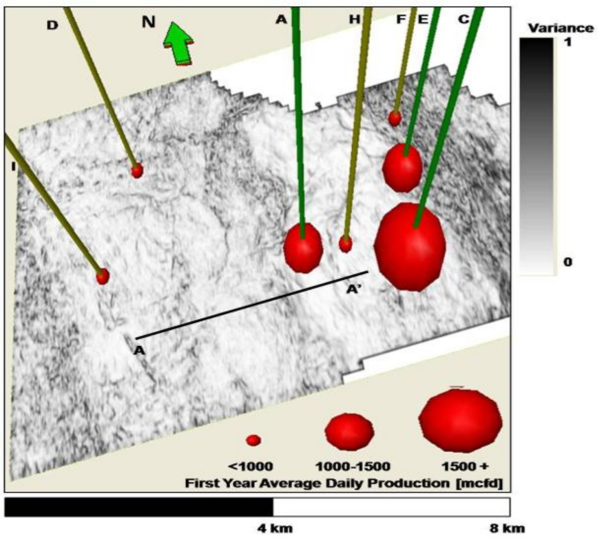

Figure 3: *A time slice of the variance cube depicting the wells in the study area. The A – A' line is the vertical section in* ***Figure 2.*** *The first year average daily production for the wells in million cubic feet per day are depicted with the bubbles. The name of each well is listed to the left of the wellbore.*

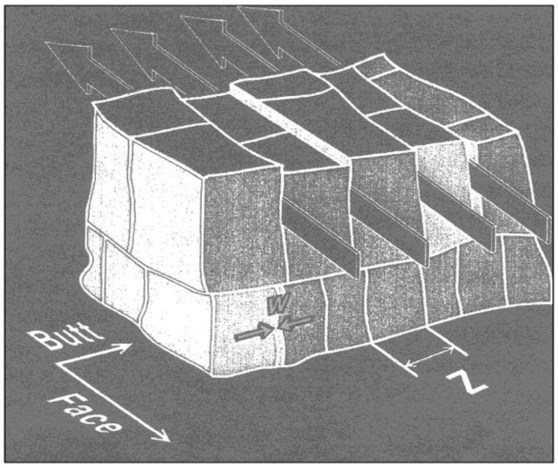

Figure 4: *Depiction of a coal block showing the variables that influence the fracture permeability (Nelson, 2001) in coal defined by the equation* $k_F = w^3/(12*z)$*, where* k_F *is the fracture permeability, w is the cleat aperture width, and z is the average cleat spacing (Modified after Scott, 2000).*

Seismic Data Quality

The company's primary goal for this 3D seismic survey was the improved mapping of the upper coal horizons within the basin. The survey size is 31.56 km^2 of rolling farmlands. The data were recorded using 45 source lines with a 200 m interval and 23 receiver lines with a 200 m interval, resulting in a natural bin spacing of 25 m x 12.5 m. Four Mertz M26 vibrators vibrated with a sweep length of four seconds and a sweep frequency range from 6-130 Hz. Group arrays consisted of twelve sensor SM4, 10 Hz geophones in a linear array with the source in the middle of each line, resulting in a multiplicity of 36 fold. The sampling rate of the data is 2 ms. Pre-stack processing parameters included surface consistent deconvolution, 10-110 Hz spectral whitening, and spatial dealiasing DMO. Some of the final post-stack parameters were spectral balancing between 10-110 Hz, *f-x* deconvolution, and modified residual migration with 100% smoothed velocities.

Previous Studies

Marroquin and Hart (2004) use seismic attributes to map lineaments in coal and correlate production to those seismic lineaments in the Fruitland Formation. McCrank and Lawton (2009) present a seismic study that includes seismic horizon interpretations and an acoustic impedance inversion of Ardley coals in Canada. Chopra et. al (2009) use curvature azimuth and shape- revealing attributes to generate 3D rose diagrams that assist in the interpretation of structural features and their potential connection to image logs or production. In addition, Nelson (2001) shows through outcrop and numerical methods that flexure-related fractures will be greatest at the location of maximum curvature.

Theory and Method

Cleats

Cleats are the natural fractures that develop in coal as a result of factors such as dehydration, differential compaction, and paleotectonic stresses (Close,1993). Two main sets of cleats that form in coalbeds are face cleats and butt cleats. Face cleats are typically the primary cleat set, are the tallest and longest cleats in the coalbed, and are the first fractures to form in the coal (Grout,1991). Butt cleats are the secondary cleat system that are orthogonal to the face cleats and perpendicular to bedding (Solano-Acosta et al., 2007). **Figure 4** depicts a typical array of cleats within a coalbed. Cleats provide the main permeability pathway in coals for Darcy flow of gas and water.

Curvature

Volumetric curvature seismic attributes gauge the lateral variability in dip magnitude and dip azimuth (Mai et al., 2009). Curvature in three dimensions represents the values of the radii of two orthogonal circles fit tangent to a surface. Since curvature, k, is equal to the reciprocal of the radius of curvature for these circles, k_{min} represents the circle that fits tangent to the surface with the largest radius and k_{max} is the other circle tangent to the surface with the smallest radius (Chopra and Marfurt, 2007).

Figure 5 provides a visualization of the relationship between curvature and geologic features in a 3D reference frame. The mathematical calculation of curvature from an interpreted surface requires fitting a quadratic surface, $z(x,y)$, to a window of data points. The resulting principal curvatures are computed

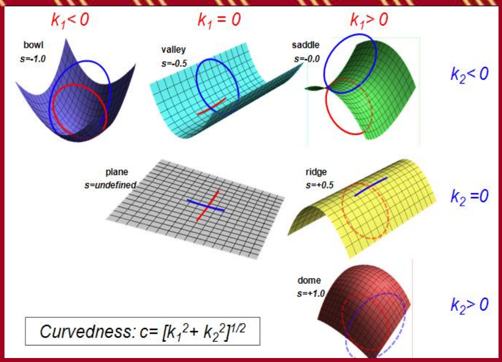

Figure 5: *This figure defines 3D quadratic shapes in terms of most-positive, and most-negative principal curvatures, k_1 and k_2. Bowl features have negative curvature values for both k_1 and k_2 while dome features have positive curvature values for both k_1 and k_2.while for a plane, both k_1 and $k_2$have values of zero. The shape index, s, is shown for each of the five basic shapes. (After Mai, 2010).*

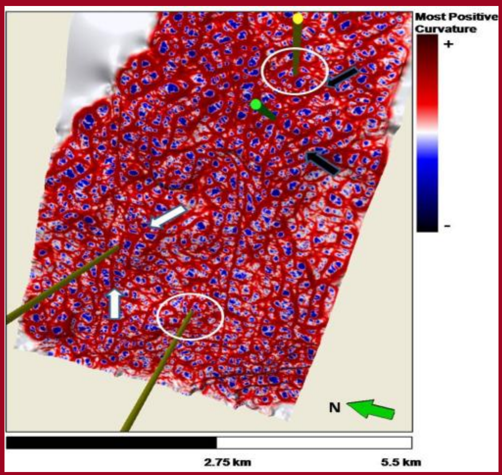

Figure 6: *This view of the top coal seam through the most positive amplitude curvature volume. High values (red) indicate locally high reflectivity lineaments. The high producer (well A) shows strong most positive amplitude curvature trends (black block arrows) from orthogonal directions leading to the wellbore. The surrounding low producers do not show this same trend (white block arrows and circles).*

from first and second derivatives of these picks. *Volumetric* structural curvature is similar, but replaces the first derivative calculations with volumetric estimates of the inline and crossline dip (Marfurt, 2010). Chopra et al. (2009) point out that the most-positive and most-negative principal curvatures are the most effective in "mapping subtle flexures and folds associated with fractures in deformed strata." In volumetric *amplitude* curvature calculations, the first derivative calculations are replaced by volumetric estimates of the inline and crossline gradients as directional measures of amplitude variability (Chopra and Marfurt, 2007).

Shape Index modulated by Curvedness

Curvedness provides a measure of the intensity of structural deformation at a given point. Chopra and Marfurt (2007) define the curvedness, *c*, of a surface as:

$$c = \left[(k_1^2 + k_2^2)/2\right]^{1/2}, \qquad (1)$$

where k_1 is the maximum principal curvature and the minimum principal curvature is k_2. These principal curvatures measure the maximum and minimum bending of the surface at each point (Lisle, 1994). Roberts (2001) defines the shape index, *s*, as:

$$s = \frac{2}{\pi} tan^{-1}\left[\frac{k_2 + k_1}{k_2 - k_1}\right]. \qquad (2)$$

The result of the shape index is a seismic attribute volume whose amplitudes correspond to shapes, where the shape index of a dome is 1.0, a ridge is 0.5, a saddle is 0.0, a valley is -0.5, and a bowl is -1.0 **(Figure 5).** When the shape index is co-rendered in a seismic display with curvedness, high curvedness values that correspond with ridge and valley shape indices are directly related to lineaments (Chopra et al., 2009).

3D Rose Diagrams

Estimation of face and butt cleat orientation is critical to planning wellbore trajectory and completion procedures. Since the resolution of my seismic survey is limited to about 8 m, we need to use an indirect approach in determining the orientation of cleats. Multiple studies have determined that coal butt and face cleats, having apertures on the order of millimeters, are correlated to the regional fracture geometry. Nelson (2001) found that regional fractures usually parallel cleat directions, with face cleats corresponding to the systematic regional fracture set and butt cleats the non-systematic regional fracture set. Grout (1991) notes that cleats in the southern Piceance Basin correlate to fractures in overlying clastic rocks.

We determine the fracture set orientations seismically through the generation of 3D rose diagrams. In this process, a seismic volume is binned in even squares of 250 m x 250 m. Then, the magnitude of a given rose petal at a single horizon is defined by the summed and scaled ridge or valley component of curvature values within a bin. The strike direction of the rose petal is defined by the value for the strike of minimum curvature, which is the axis of the folding plane. More details for this process are documented in Chopra et al. (2009).

Discussion and Results

Using image logs from wells in the survey area and borehole breakouts, Johnson et al. (2002) determined the maximum horizontal stress, $\sigma_{H\text{-}Max}$, of the survey area to be northeast. Cleats and fractures aligned parallel or near parallel to the maximum horizontal stress are more likely to be open and are likely to be the face cleats. Conversely, cleats and fractures aligned perpendicular to the maximum horizontal stress are more likely to be closed. Marfurt et al. (2009) suggest that the ridge component is better to use in compressional regimes, and the valley component is better to apply in extensional environments. We first consider the most-positive principal *structural* curvature attribute to illuminate anticlinal features that may be highlighted as result of the thrust system in this 3D seismic survey. **Figure 6** shows the most positive *amplitude* curvature with high red curvature values indicating strong high-amplitude lineaments. I investigate the fracture orientations near the top coal horizon with the 3D rose diagrams. I expect that better producing wells will show a strong presence of fractures oriented parallel to $\sigma_{H\text{-}Max}$. **Figure 7** is the top coal surface with the 3D rose diagrams overlain. This image reveals that the higher producing wells A and C show a strong bi-directional trend, suggesting that contributions from both systematic and non-systematic fracture sets or a strong presence of face and butt cleats may be contributing to the wells' deliverability. Furthermore, rose diagrams of the lower producing wells H and F show a more uni-directional trend.

The shape index co-rendered with curvedness **(Figure 8)** provides additional insight into the topography of the top of the coal seam. **Figure 8** shows the areas of high curvedness and intense structural deformation that correspond with different shapes, most notably ridge features associated with compressive stress regimes.

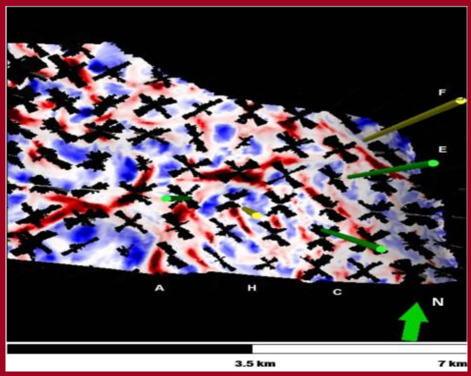

Figure 7. *This map view of the top coal seam shows the 3D rose diagrams at the respective well locations. The rose diagrams show strong bi-directional trends at higher producing wells A and C, and lower producing wells H and F show a more uni-directional trend.*

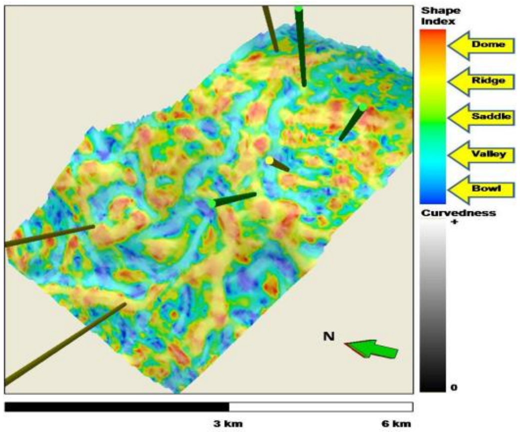

Figure 8. *The top coal displayed as the shape index co-rendered with the curvedness. The areas with greater curvedness and more structural deformation appear with white undertones.*

Conclusions

Seismic curvature attributes are effective at mapping features that relate to production in coals. Bi-directional, orthogonal lineaments in the 3D rose diagrams show areas of enhanced permeability and higher production. We interpret this higher production to be due to a strong presence of face and butt cleats. The amplitude curvature volume reveals high amplitude lineaments along the maximum and minimum horizontal stress directions leading to the wellbore of a high-producing well. Low-producing wells reveal weak, amplitude curvature lineaments in the vicinity of the well locations. Finally, the shape index co-rendered with the curvedness allows the interpreter to map surface topography and identify areas associated with heightened structural deformation.

Acknowledgements

We wish to thank Santos, Ltd., for guidance, insight and permission to use and publish their data. We thank Brian Cardott of the OK Geological Survey for his mentoring on coalbed methane and the sponsors of the OU Attribute-Assisted Seismic Processing and Intepretation Consortium for their financial support. Finally, we thank Schlumberger for Petrel licenses used for research and education.

Assessment of Hydrate Reservoirs as Potential Methane Sources on Mars

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Introduction

Gas hydrates are gas molecules surrounded by a cage of water ice and form under low-temperature and high-pressure conditions. They have been identified as both a potential energy resource and a possible source of greenhouse gas emissions, which can affect the climates of both Earth and Mars (Hoffman, 2000). The influence of gas hydrates on these atmospheres, and hence climate change, is under investigation. Due to the difficulty of direct measurements, especially on Mars, the size and distribution of hydrate reservoirs, as well as the rate of hydrate formation and dissociation, must be estimated and constrained experimentally.

Plumes of methane have been observed on Mars by satellites in Martian orbit and Earth-based instruments. In 2004, Formisano et al. measured the small amounts of methane (0-30 ppbv) in the Martian atmosphere using the Planetary Fourier Spectrometer (PFS) on the Mars Express spacecraft. Later, in 2009, Mumma et al. used ground-based telescopes to describe the size and magnitude of the methane plumes. A possible source for these methane plumes on Mars is the dissociation of methane hydrates.

This paper aims to summarize the methane hydrate dissociation and diffusion rates in the literature and determine if the fluxes of methane produced by the dissociation of potential methane hydrate reservoirs on Mars are comparable to the seasonal methane plumes observed by the PFS and Earth-based telescopes.

Methods and Results

Literature rates for hydrate formation and dissociation span several orders of magnitude due to numerous factors (pressure, temperature, gas composition, and reaction mechanism) that can affect the hydrate formation and dissociation kinetics. In order to test the feasibility of a hydrate source for the observed Martian plumes, dissociation rates and diffusion coefficients from the literature were compiled **(Table 1).**

These dissociation rates were determined over a limited range in temperatures, 258 to 277 K. In order for these rates to be relevant to the conditions present on Mars, hydrate dissociation rates were extrapolated to lower temperatures, from 200 to 270 K, using a variation of the Arrhenius equation:

$$\log \frac{k_1}{k_2} = \frac{Ea}{2.303 * R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

where k_1 and k_2 are rate constants, Ea is the activation energy in J/mol, R is the gas constant with a value of 8.314 J/K mol, and T_1 and T_2 are temperatures of rates k_1 and k_2, respectively. Two activation energies, representing the maximum and minimum values found in the literature for the temperature range being investigated, were used: 20.1 kJ/mol (Takeya et al., 2002) and 59.8 kJ/mol (Staykora, 2003). Minimum and maximum dissociation rates from the literature as well as a representative diffusion rate are shown in **Figure 1.**

__Table 1.__ Methane hydrate dissociation rates and diffusion coefficients from the literature

T (K)	P (MPa)	k or D	Source
276.65	10.48	0.34 - 0.4x10^{-3} mol/m^2s	Rehder et al., 2004
272.65	0.1	1.70x10^{-13} m/s	Komai et al., 2004
271.15	0.25	6.70x10^{-14} m/s	Komai et al., 2004
268.15	0.5	2.90x10^{-14} m/s	Komai et al., 2004
270	6	7.5x10^{-2} m^2/s	Kuhs et al., 2006
268	6	7.44x10^{-2} m^2/s	Kuhs et al., 2006
263	9	7.31x10^{-2} m^2/s	Kuhs et al., 2006
263	3	7.31x10^{-2} m^2/s	Kuhs et al., 2006
263	6	7.31x10^{-2} m^2/s	Kuhs et al., 2006
258	6	7.17x10^{-2} m^2/s	Kuhs et al., 2006
267	0.1	1x10^{-5} - 3x10^{-6} mol/m^2s	Sun & Chen,2006

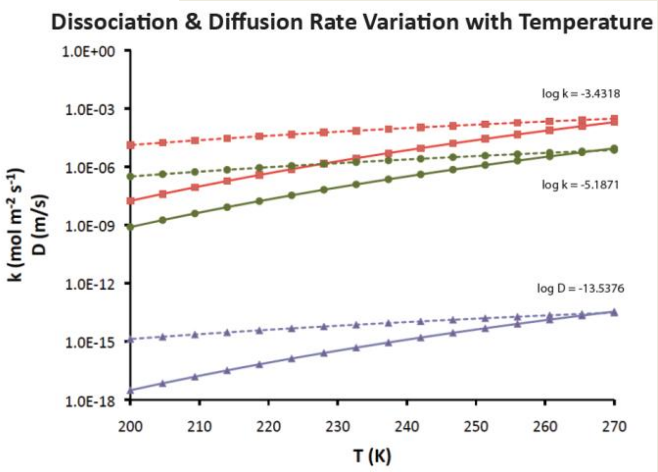

__Figure 1.__ The dissociation (red and green lines) and diffusion (purple lines) rates were calculated using the Arrhenius equation over a temperature range of 200 to 270 K and for two activation energies, 20.1 kJ/mol (dashed lines) and 59.8 kJ/mol (solid lines).

The extrapolated dissociation rates were then used to calculate the minimum and maximum methane hydrate source footprints needed to produce the observed methane plumes ($1.17x10^9$ mol methane), as described by Mumma et al. (2009). Assuming a release period of 120 days and a maximum footprint of $5.56x10^5$ km^2, the rate of methane released over the footprint area was calculated to be $2.03x10^{-10}$ mol/m^2s. The minimum and maximum methane hydrate footprint needed for the observed plume release from an unconfined hydrate reservoir was then calculated using the amount of methane released over the same amount of time and the minimum and maximum dissociation rates extrapolated for both activation energies. The results of these calculations are summarized in **Table 2** and a visual comparison of the different footprint sizes is presented in **Figure 2.**

Table 2. *Calculated minimum and maximum rates and footprints from selected literature.*

Ea (kJ/mol)	20.1 (Takeya et al., 2002)	59.8 (Staykora, 2003)
Rehder et al., 2004		
Minimum Rate (200 K)	$1.3x10^{-5}$	$1.74x10^{-8}$
Maximum Rate (270 K)	$2.98x10^{-4}$	$1.95x10^{-4}$
Minimum footprint (km^2)	0.38	0.58
Maximum footprint (km^2)	8.83	6481.49
Sun & Chen, 2006		
Minimum Rate (200 K)	$3.13x10^{-7}$	$7.83x10^{-10}$
Maximum Rate (270 K)	$7.19x10^{-6}$	$8.77x10^{-6}$
Minimum footprint (km^2)	15.70	12.87
Maximum footprint (km^2)	360.53	144,172.77

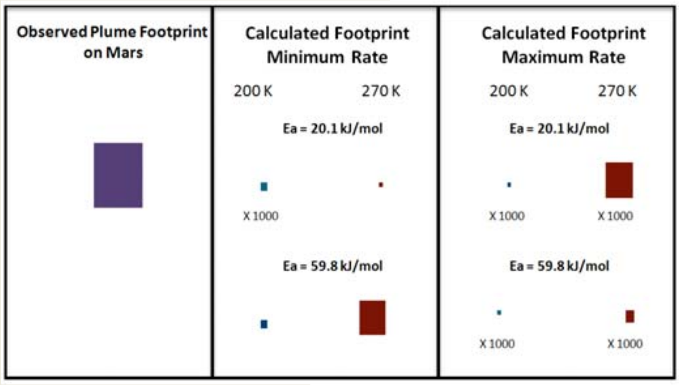

Figure 2. *A comparison between footprint sizes calculated from observations in Mumma et al. 2009 (purple box) and the extrapolated dissociation rates from Rehder et al. 2004 (blue boxes) and Sun and Chen 2004 (red boxes). Note some footprint sizes were multiplied by 1000.*

We also determined the feasibility of methane release from a confined methane hydrate reservoir by determining the maximum thickness of permafrost overlaying a potential hydrate deposit. This thickness, or the maximum diffusion path length, can be calculated using Fick's Law:

$$J = -D\frac{\Delta\, concentration}{\Delta\, depth}$$

where J is the flux (mol/m^2s), calculated from the information from Mumma et al. (2009) over a range of footprint areas ranging from 1 to $5.56x10^{11}$ m^2, D is the diffusion rate (m/s) calculated from Komai et al. (2004), Δconcentration (mol/m^3) is the difference in the concentration of CH_4 in hydrate at depth and at the surface, and Δdepth (m) is the thickness of the overlying ice. **Figure 3** shows the relationship between the path length needed to produce the observed methane flux and the footprint size. These overlying thicknesses can be compared to the modeled thicknesses of ice over a hydrate reservoir as a function of latitude (Elwood Madden et al. 2010) as seen in **Figure 4** to test the feasibility of a confined methane hydrate source.

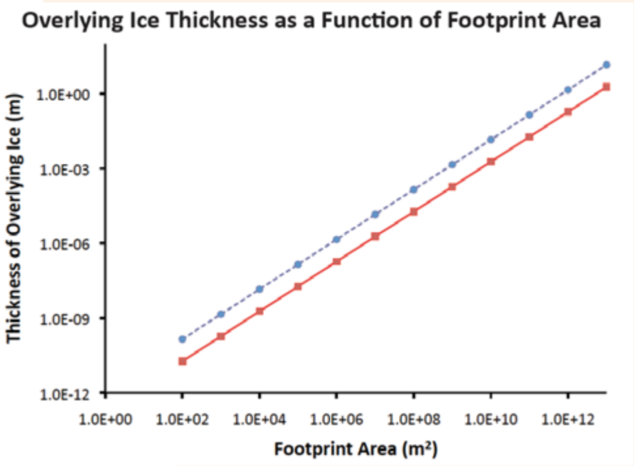

Figure 3. *The relationship between the maximum thickness of overlying ice and footprint area. Two activation energies were used, 20.1 kJ/mol (dashed line) and 59.8 kJ/mol (solid line).*

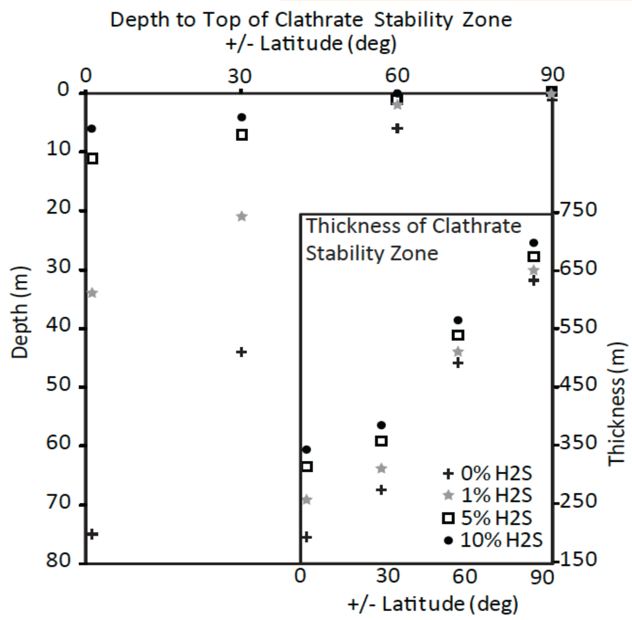

Figure 4. *Illustration of the depth to the top of the clathrate (hydrate) stability zone over a range of latitude. (Elwood Madden et al., 2010)*

Conclusions

Several conclusions can be drawn from this feasibility study. For open reservoirs, those with cracks in the overlying permafrost, enough methane to create the seasonal plumes on Mars (20 to 50 ppb) could be released through dissociation of very small hydrate reservoirs. As seen in **Figure 2,** for open system hydrate dissociation, the maximum footprint size described by Mumma et al. (2009) is up to six orders of magnitude larger than the footprints calculated from the literature rates. In a closed hydrate system, the methane flux is controlled by the diffusion rate of methane through the overlying ice. This suggests that the reservoirs must have no more than 14 m of overlying permafrost ice **(Figure 3).** As seen in **Figure 4**, pure methane hydrate needs at least 40 m of overlying permafrost ice at low latitudes, the location of the plumes observed by Mumma et al. (2009). Overlying permafrost greater than 14 m would limit the flux of methane release to levels below the observed flux from the methane plumes, suggesting that the potential source for the methane plume on Mars is not pure methane. Mixing methane with hydrogen sulfide allows for the expansion of the hydrate stability field to shallower depths. According to thermodynamic modeling, a mixed hydrate of 5% H_2S would result in a stable hydrate at depths between 10 to 12 m and 10% H_2S at depths within 6 m of the surface. Both of these depths are within the thickness range calculated using Fick's Law **(Figure 3).**

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PROFESSOR MICHAEL SOREGHAN RECEIVES RESEARCH GRANT
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Dr. Michael Soreghan was awarded a research grant from the National Geographic Society for a project entitled "Potential Impacts of Anthropogenic Change on Shell Beds of Lake Tanganyika." Lake Tanganyika, within the East African Rift, is an ancient lake (12- 14 MY) with variable sedimentation caused by tectonic asymmetry in the rift; the age and variable substrates have set the stage for extensive endemic diversification in numerous metazoan taxa of the lake. One unique substrate within Lake Tanganyika is the vast "shell beds" and they harbor a diverse and specialized fauna including numerous endemic sponges, mollusks, crabs, other invertebrates, and a number of shell-brooding cichlid fish.

These shell beds occur over large regions of the non-rocky lake bottom in shallow water of Tanganyika. They consist of whole gastropod shells, bivalve shells and variable amounts of silt and sand. This unique environment, however, is poorly understood in terms of its mechanism of formation, its maintenance, and its ecological structure. In addition, observations of the shell beds over the last several years strongly hint at severe anthropogenic changes, such as silt mantling the shell beds; the effects of these changes on the substrate, and consequent changes to the ecology of the shell beds, however, is unknown.

The overall goal of Dr. Soreghan's research is to conduct a detailed survey of one of these shell bed substrates within Lake Tanganyika in order to better understand the geologic variability of the deposits and the nature of anthropogenic changes, and thus provide critical data in collaboration with biologists to better understand the ecology and ecologic changes within these habitats.

*Underwater photo of typical shell bed substrate within Lake Tanganyika. The shells are **Neothauma tanganyicnese** and are covered in spots by endemic sponges. Note small cichlid fish. It uses the shells as a brooding nest. (Photo courtesy of J. Michler)*

2010 ConocoPhillips SPIRIT Scholars' Field Trip – Arbuckle Mountains

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Figure 1. *Ft. Sill limestone at Cattle Pens stop beneath I-35. Here, the group is examining the "ribbon" carbonates at Ft. Sill which show a distinct cyclicity, suggesting tidal influence.*

HOT does not do justice to this exercise in mere survival. On our way home the bank thermometer in Sulfur read 105°. It didn't say whether it was recording in °F or °C – it felt like it could have been the latter. My (NHS) thought was, "Where is Jim Inhofe when you need him?", to remind us that global warming isn't happening. But regardless of the heat, this truly was a wonderful group of ConocoPhillips SPIRIT Scholars students to take into the field. Even the longhorn (note the absence of capitalization) students enjoyed themselves in, as they put it, the "belly of the beast."

The ConocoPhillips SPIRIT Scholars who came to Norman and went on the field trip are a select group of graduate students from OU, Texas A&M, the University of Texas, and the Colorado School of Mines. This year's students and advisors were Christie Sava, Jeremiah Moody, and Tiffany Dawn Jobe from Mines; Jennifer Piper, Leslie Uptain, and Charles Choens from TAMU; Will Burnett, Ryan Harbor, Erin Eastwood, Philip Guerrero, Ryan Phelps, and Alex Urquhart from UT – Austin; and Fuge Zou, Supratik Sarker, and Nabanita Gupta from OU. Yuval Boneh (OU) was one of our drivers. In addition, Frank Rodriguez and Bill Clopine (OU MS „86, PhD „89) from ConocoPhillips came along and took us from the outcrops we were looking at to real-world CP plays and fields. (Bill's description of CP's production from granite in Viet Nam was particularly fascinating.) We all met at 9:00 Saturday morning

Special thanks to Fuge Zou for all the photographs!

(August 14th) in the lobby of Sooner Legends Inn. Surrounded by Crimson and Cream, the burnt orange T-shirts really looked quite helpless and provided the basis for some friendly jokes. After some introductions and three (yes, three!) release forms were signed, we headed south on I-35 to the closest rocks with a dip of more than a couple degrees.

Stop 1 – the Cattle Pens stop at exit 47. None of the students from the Texas or Colorado schools had ever visited the Arbuckles, so an introduction to the Southern Oklahoma Aulacogen (aka Oklahoma's answer to the Ancestral Rockies) seemed appropriate. (We also had to explain to the Texas students why the rocks weren't horizontal.) After passing out the bug spray and receiving the usual Oklahoma warning about ticks, chiggers, poison ivy, and snakes, we looked at the Upper Cambrian Royer Dolomite and Ft. Sill Limestone **(Figure 1)** and discussed the possible role of karst in petroleum reservoirs and the significance of the thrust faults in the debate over the importance of left-lateral wrench faulting in the origin of Arbuckle Mountains structure. A good stop and not only because it was in the shade. But it was starting to get a little warm.

At **Stop 2,** we drove into an oil reservoir in fractured Viola Limestone, but only after taking on a complex of old (and now dirt +/- rock) haul roads and losing (temporarily) one of the vans. The long-abandoned U.S. Asphalt No. 2 quarry is always a favorite because here you can collect thoroughly oil-saturated rocks **(Figure 2)** and see oil leaking out of the fractures and dripping down the face of the quarry walls. If ever there was a day to observe oil stalactites forming it was today but alas, it wasn't yet hot enough - probably only 95^{o} (at 11:30). **Stop 3** was just down the road – an outcrop familiar to all OU students – the famous Hunton Anticline. Because we were running a bit late and because the quarry might have provided us some shade, we decided to forego seeing the anticline and instead hiked directly to the adjacent outcrop of Woodford Shale. Here we talked about how what used to be referred to as source rocks and/or seals are now drilled as reservoirs **(Figure 3)**. As the outcrop thermally matured in front of our eyes, we discussed some of the different factors – geological and engineering – that make for good, economic gas-shale wells.

LUNCH, **Official Stop 4**, was at Pavilion Springs in Chickasaw National Recreation Area – lots of shade, lots of cold though "tasty"/smelly spring water, and lots of spiders under every overhang; and an opportunity to discuss the upcoming (not really, as they are already occurring) water wars. I (NHS) told the students about the recent Arbuckle-Simpson Aquifer study conducted by the Oklahoma Water Resources Board and some of the issues that were addressed and will undoubtedly continue to be argued about for years. How are surface water and groundwater geologically and legally distinguished? And who owns which? What do you call it when a pit is dug below the groundwater table and it fills with water – is it groundwater or surface water? And how do you balance jobs, society's need for industrial minerals, and individual property rights with the long-term need by local cities for a reliable source of water and the preservation of natural ecosystems? Good questions all, and ones to which geologists will be able to contribute answers. (Meanwhile, it's getting warmer ……. probably about 100^{o} at this point.)

Figure 2. *Collecting oil-saturated fractured Viola Limestone at abandoned asphalt quarry. "So this is what money smells like!"*

Figure 3. *Outcrop of Woodford Shale near Hunton Anticline stop. No one was quite sure what was more impressive – the distinct odor of hydrocarbons on fresh surfaces or the difference in fracturing in the more mud-rich layers compared to the more siliceous layers.*

Martin – Marietta has an aggregates quarry in the Troy Granite (1.4 billion years old) a few miles south of Mill Creek. What is special about the quarry **(our Stop 5)** is that the granite is riddled with Cambrian diabase dikes that probably are related to the Southern Oklahoma Aulacogen. Thanks to Dan Persyn (quarry supervisor) and Jason Parker, we were graciously allowed to visit the quarry and collect samples. Even the petroleum types were impressed, despite the obvious lack of porosity and permeability in the rocks. Some of us were even able to collect hand specimens that crossed the granite-diabase contact. No breeze. Air temperature – 105°??? Easy to sympathize with the granite being intruded by hot dikes.

For the last stop **(No. 6)** of the trip, we returned to sedimentary rocks and petroleum reservoirs – the Oil Creek sand (Ordovician Simpson Group) at the U.S. Silica Company pit north of Mill Creek **(Figure 4)**. Quarry supervisor George Matthews has always been extremely cooperative in letting us visit the quarry and reminding us to drink our liquid refreshments in bottles (not cans), and to dispose of them properly not by recycling but rather by throwing them through a window. Glass is the primary finished product for the sand, but USS also quarries the Oil Creek as a frac proppant. George is an alumnus of the Colorado School of Mines, a fact not lost on our Mines students, so several pictures of the '75 grads with the soon-to-be grads were taken. The geological community really is a small world. Temperature? Probably no hotter than at the granite quarry, but that white sand and "beautiful" clear blue sky made it seem almost hot enough to …… melt glass.

Figure 4. *George Matthews (blue hardhat) discussing the origin of the Simpson sands and the hydraulic mining technique that U.S. Silica uses for quarrying the sand.*

The idea at this point was to go for a swim and have dinner at a local bed and breakfast in Sulphur, but that was destined not to happen. So Bill and Frank suggested that we return to Sooner Legends for a swim (great idea) and that ConocoPhillips would treat us all to dinner at the restaurant there (another great idea). It was an extremely fitting end to a wonderful day in the field with a bunch of remarkable students. Everyone thanks ConocoPhillips not only for sponsoring the students' visit to Norman, the field trip, and dinner, but their scholarship support to these four schools.

Fracture analysis using 3D seismic attributes in the Hunton Limestone, Oklahoma, USA

Evan Staples*, *Kurt J. Marfurt, and Ze'ev Reches, ConocoPhillips School of Geology and Geophysics, The University of Oklahoma*

Summary

The Hunton Limestone in Oklahoma is an important reservoir in the oil and gas industry. Al-Shaieb et al. (1993) find that fractures in the Hunton Limestone are one of the key components of porosity with fracture permeability enhancing production. Fracture identification from surface seismic is an important topic, but little research in this area has been done on the Hunton Limestone. Hart (2006) has analyzed fractures using post stack seismic in the San Juan Basin, while Narhari et al. (2009) have analyzed fractures using post stack seismic data in Kuwait, both sandstones. Nissen et al. (2009) have used post stack seismic attributes to map fractures in the Arbuckle Limestone of Kansas, and calibrated their findings using a horizontal well adjacent to, but not in, the seismic survey area. To our knowledge, little has been published on quantitative correlation of lineaments seen on post stack seismic attributes to fractures seen in horizontal wells. Therefore, this project is very important for developing an understanding of fracturing in limestones. From a preliminary 3D seismic attribute analysis of the area of interest, the attributes of curvature (positive and negative) and energy ratio have been the most helpful in predicting where a high density of fractures might exist and their general orientation. In addition to these attributes, approximately 10 miles of proprietary horizontal image logs have been obtained in the area of interest and will be studied to correlate fractures in the logs with proposed areas of fracturing in the seismic volume.This correlation should provide valuable information to locate and identify fracture patterns in the Hunton Limestone and enhance the ability to predict good areas of high porosity and permeability in both the Hunton and possibly other carbonates. Fieldwork is being conducted in a specific test area in Oklahoma where an outcrop of the Hunton Limestone is exposed to characterize fractures in outcrop and create an analog for fracture patterns in the subsurface. Seismic data will be obtained in the outcrop area to further characterize the visible fractures with a seismic wavelet. After obtaining and studying all of the data, it is proposed that fractures and fracture patterns in the Hunton Limestone will be better understood and the ability to predict areas of high-density fractures will be enhanced.

Introduction: The Hunton Limestone

The Hunton Limestone or Hunton Group lies beneath the Woodford Shale which is separated from the Hunton by an unconformity. The Hunton Group is made up of shallow-marine carbonates deposited from the Late Ordovician to the Early Devonian and formed on a gently inclined ramp. Due to this depositional environment, the Hunton is laterally extensive in Oklahoma (Al-Shaieb et al., 1999).

Method: Seismic Attributes

The operator acquired a small 3D survey over the target area, which was processed through prestack time migration. The data quality at the Hunton horizon **(Figure 1)** is good but suffers from acquisition footprint. Next we generated horizon slices through volumetric estimates of coherence and both long wavelength and short wavelength curvature **(Figures 2a, 2b, 2c, and 2d).** The long wavelength curvature attributes are typically indicative of larger bends and folds, while the short wavelength curvature attributes aid more in identification of smaller features, like possible fracture areas. Areas shaded dark red are most positive curvature, while conversely, areas colored dark blue are most negative curvature for both long and short

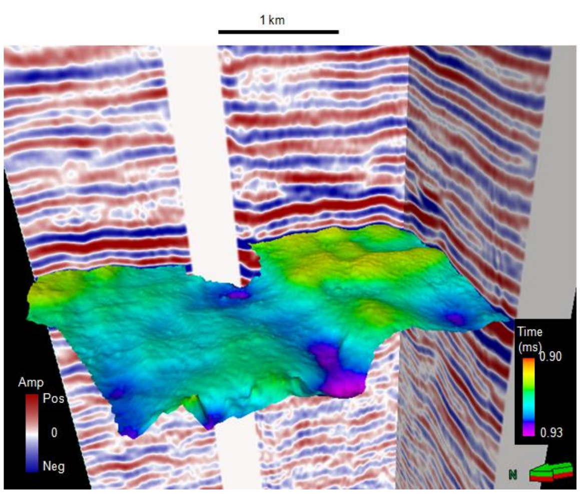
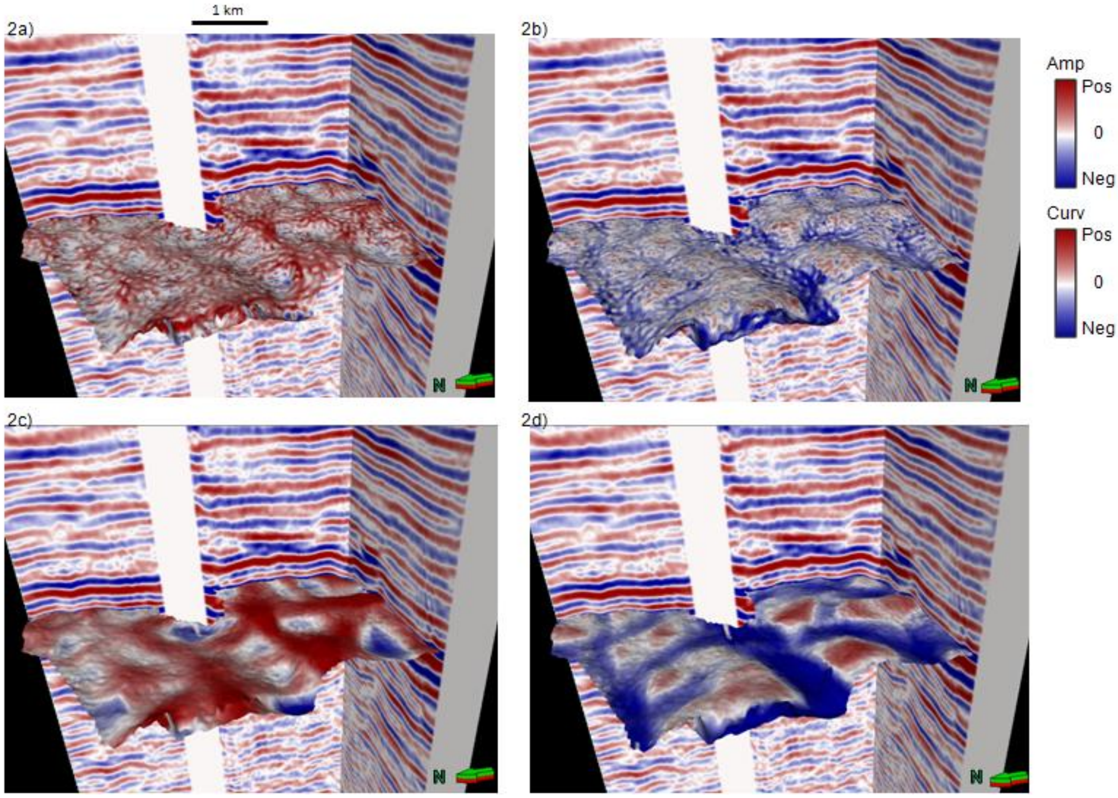


Figure 1. *Horizon slice of the Hunton Limestone shown with the seismic data. The colorbar for the horizon slice shows two-way travel time in ms. Reds and yellows are highs with purples and blues indicating lows. The seismic amplitude colorbar shows positive peaks in red and negative troughs in blue.*



Figures 2a, 2b, 2c, and 2d. These figures illustrate positive and negative short wavelength and long wavelength curvature, respectively. The seismic data appear to be very high quality and the amplitude is shown by the colorbar labeled "Amp" indicating peaks are red and troughs are blue. The curvature has a similar colorbar and the most positive areas are red and the most negative are blue. These images are shown on the picked Hunton horizon in the seismic data.

wavelength calculations. The coherence attribute (e.g. Chopra and Marfurt, 2007) measures the similarity between waveforms or traces such that areas of high discontinuity appear as darker shades of grey to black, while more continuous areas vary from light grey to white **(Figure 3).** Fracture zones theoretically should be found in areas of high discontinuity (low coherence and no lateral continuity) and significant folding (highest curvature). In **Figures 4a, 4b, 4c, and 4d** we co-render the coherence image with the four previously displayed curvature images allowing a visual correlation of incoherent areas with high curvature.

Method: Initial Calibration with Image Logs in Horizontal Wells

Next, we correlate possible areas of high fracturing in the attribute volume with the location of one of our image logs shown by the yellow line on **Figures 3-4d.** Using XY coordinates from the horizontal well mentioned above has allowed us to pinpoint specific locations within the seismic data to allow for specific study of those areas in well logs. At present, our correlation is only visual and a more detailed analysis of the image logs in necessary. In theory, this will

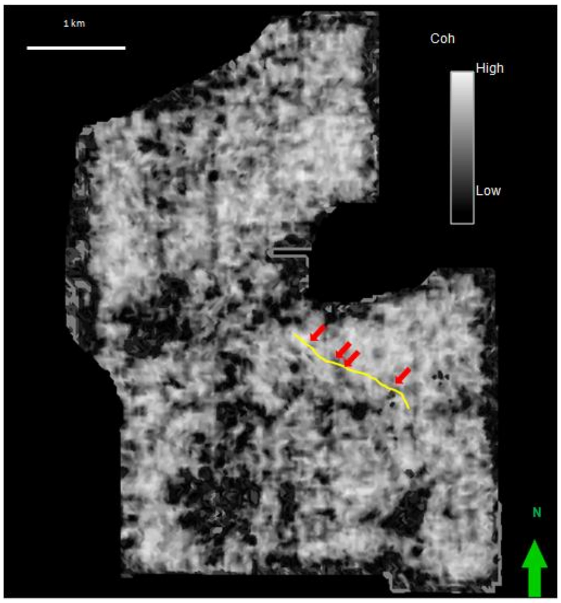


Figure 3. *Coherence attribute showing areas that are coherent and incoherent as indicated by the colorbar. Light colored areas are highly coherent and dark colors are more incoherent. The yellow line is a horizontal well-bore in the seismic data. Red arrows indicate areas of possible high fracture density.*

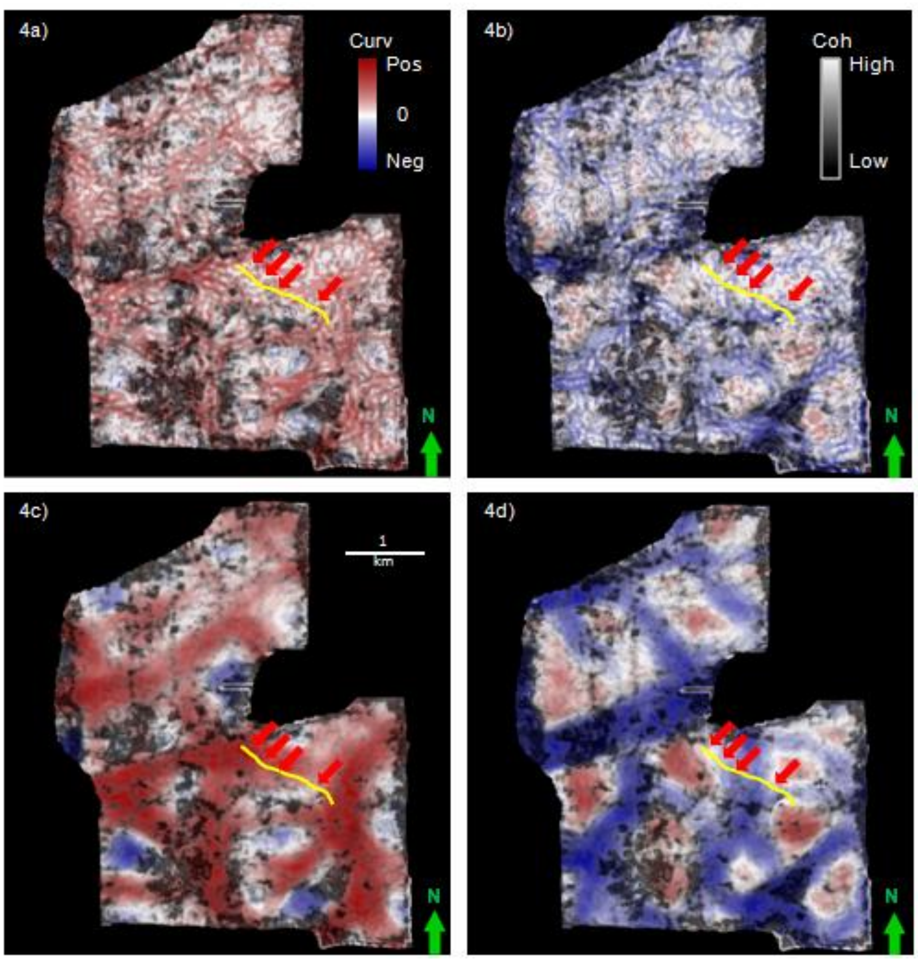
allow characterization of high fracture density areas in both well logs and seismic data. Next, the entire length of image logs will be analyzed to see potential areas where seismic did not indicate high areas of fracturing and seismic attributes will be recalculated to ensure proper calibration if needed. Following this, field work will be conducted in the area of interest on fractures to understand in outcrop how fractures and fracture patterns behave in the Hunton Limestone. After this characterization, seismic data will be acquired near the field area to allow for seismic correlation with real-life fracture patterns which will then be compared with the seismic correlation between the image logs and 3D data previously studied. Theoretically, all of these correlations should be consistent and aide in understanding the complex identity of fractures in the Hunton Limestone. However, fracture patterns in outcrop are theorized to differ slightly from those in the subsurface due to release of confining pressure with exhumation of the Hunton Limestone. Hopefully this possibility causes only a slight difference but could pose a significant challenge. However, regardless of the effect of exhumation of the Hunton Limestone, this analysis of fractures using 3D attributes will contribute positively to developing a better understanding of the connection between fractures and surface seismic through correlation between image logs and seismic attributes.

Conclusions

From the preliminary visual correlation between horizontal image logs and the seismic attributes, it appears that there is a relatively high correlation between these data. From these initial successes in correlation it appears that this current workflow may contain the key to high-density fracture identification in the subsurface. However, a more detailed image log correlation, fracture analysis in outcrops, and additional seismic data is imperative to calibrate the attributes correctly and is the required next step in the workflow.

Acknowledgements

Thanks to Pathfinder Exploration, LLC for permission to publish these results. Also, thanks to Schlumberger for granting licenses to Petrel for use in research and education.



Figures 4a, 4b, 4c, and 4d. These figures show a co-rendering of the coherence and curvature attributes previously shown in the figures above. The yellow line on each image is the location of a horizontal borehole. Areas where both curvature and incoherence are high should be good areas to find high density of fractures. The colorbar for curvature shows that red is positive curvature and blue is negative curvature. The colorbar for coherence indicates that light colors are coherent and dark colors are incoherent. Red arrows indicate areas of possible high fracture density due to high curvature and incoherence.

Evan Staples

Fault weakening and earthquake instability by powder lubrication

Ze'ev Reches, Professor of Geology, University of Oklahoma (a summary of Reches and Lockner, 2010, Fault weakening and earthquake instability by powder lubrication, Nature, v. 467, p. 452-456.

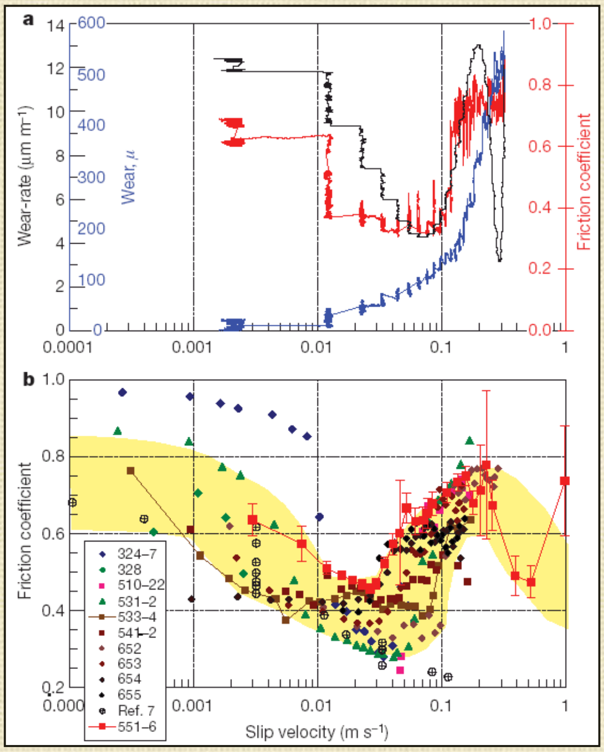


***Figure 1.** Experimental friction-velocity relations in Sierra White granite samples. **A.** Friction (red), fault wear (blue), and wear-rate (black) in run 616 as function of slip velocity (text). We notice similar trends in friction and wear-rate variations. **B.** Experimental friction coefficients for 35 runs (run numbers shown) with 254 values; each datum point is the average friction value at the velocity interval; standard deviation bars are shown only for one run for the sake of clarity yellow shading bounds the data without outliers.*

Earthquake instability has long been attributed to fault weakening during accelerated slip, and a central question of earthquake physics is identifying the mechanisms that control this weakening. Even with much experimental effort, the weakening mechanisms have remained enigmatic. We present evidence for dynamic weakening of experimental faults that are sheared at velocities approaching earthquake slip rates. The experimental faults, which were made of room-dry, solid granite blocks, quickly wore to form a fine-grain rock powder known as gouge. At modest slip velocities of 10–60 mm/s, this newly formed gouge organized itself into a thin deforming layer that reduced the fault's strength by a factor of 2–3. After slip, the gouge rapidly 'aged' and the fault regained its strength in a matter of hours to days. Therefore, only newly formed gouge can weaken the experimental faults. Dynamic gouge formation is expected to be a common and effective mechanism of earthquake instability in the brittle crust as (1) gouge always forms during fault slip; (2) fault-gouge behaves similarly to industrial powder lubricants; (3) dynamic gouge formation explains various significant earthquake properties; and (4) gouge lubricant can form for a wide range of fault configurations, compositions and temperatures.

The dynamic rupture of earthquakes requires a strength loss from pre-slip, static friction to co-seismic, dynamic friction, and so major experimental effort has been devoted to determining fault friction. Rock friction is typically measured using saw-cuts of cylinders or direct-shear geometry, in which rock blocks slide at low velocity and over short distances, or with rotary-shear devices that allow for high slip velocity over long distances. Low-velocity experiments revealed weakening by time dependent creep at contacting asperities on bare-rock surfaces, and grain rolling in a granular shear zone. High-velocity experiments revealed weakening by melting on rock surfaces4 or silica gel flow in quartz-rich rocks. Fault gouge, the fine-grain rock powder that is found in almost all field faults and in laboratory experiments was also recognized as controlling fault rheology during earthquakes and experiments.

We developed in the University of Oklahoma a rotary apparatus specifically designed to simulate earthquake weakening on a laboratory fault that is comprised of two room-dry, bare, solid blocks of Sierra White granite. The upper block has a raised ring structure with inner diameter of 63.2 mm and outer diameter of 82.3 mm, and the lower block was flat. The blocks were pressed against each other along the raised ring. The experimental run times ranged from 2 s (high velocity) to 3000 s. We conducted hundreds of sliding tests on four samples of Sierra White granite. The upper block has a raised ring structure with inner diameter of 63.2 mm and outer diameter of 82.3 mm and the lower block was flat.

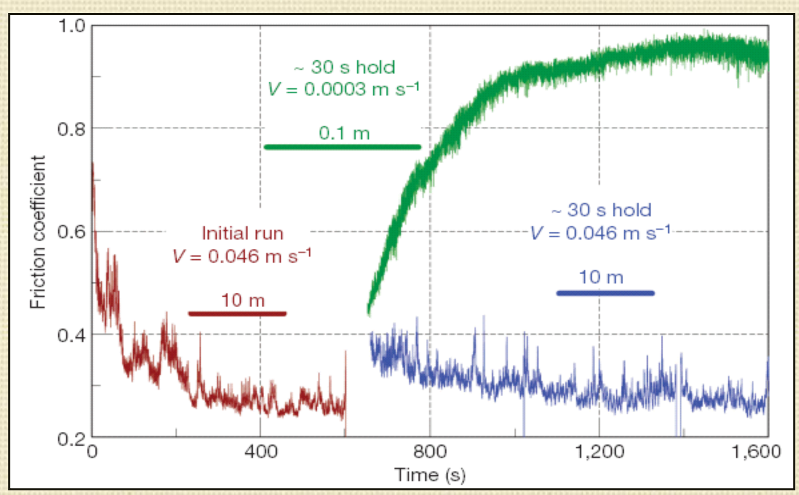


***Figure 2.** Friction measurements in slide-hold-slide experiments. Initial shearing (brown, 0.046 m/s) produced steady-state friction of ~0.3 after ~220 s (=10 m), followed by hold (no slip) for ~30 s. Then slip was restored, once at 0.046 m/s (blue), and once at 0.0003 m/s (green). Note initial small strength recovery after the 30 s hold-time for both consecutive runs, but the second run at 0.046 m/s subsequently weakened, the run at 0.0003 m/s strengthen to a steady-state friction of ~0.92.*

The blocks were pressed against each other along the raised ring. The experimental run times ranged from 2 s (high velocity) to 3000 s. We conducted hundreds of sliding tests on four samples of Sierra White granite with cumulative slip distance up to 1,180 m per sample. In a typical run, the slip velocity, *V*, was increased or decreased in steps under constant normal stress, σ_n. Each velocity step was maintained for a constant time interval (e.g., 180 s) or a constant slip distance (1-2 m). Fault strength is reported by μ, the ratio of measured shear load to measured normal load. We determined 254 friction-velocity values in 35 runs with increasing or decreasing velocity up to 1 m/s, and σ_n=0.5-7.1 MPa.

In a representative experiment, the sample was subjected to 31 velocity steps *V*=0.002 to 0.16 m/s, σ_n=2.4 MPa, ~1.1 m slip at each step and total slip of 35 m. The friction-velocity relationship (red curve, Fig. 1A) is characteristic of all runs (Fig. 1B). We recognize five friction-velocity regimes (Fig. 1B): (a) For *V*<0.003 m/s, friction varies widely with μ= 0.45-0.95 between different runs, but relatively stable in a given run. (b) For *V*=0.003 to 0.01 m/s, friction values are scattered and decrease to μ=0.4-0.6 with increasing velocity. Friction may drop abruptly during a single velocity step. (c) For *V*=0.01-0.05 m/s, friction reaches a minimum of μ ~0.3. (d) For *V*=0.05-0.25 m/s, friction rapidly rises up to μ=0.80. (e) For *V*=0.25-1.0 m/s, slip becomes unstable with stick-slip activity and sample failure; the few data points in this range suggest friction drop.

We ran a series of slide-hold-slide experiments. In the present example, the fault slid first at 0.046 m/s for 600 s (brown curve, Fig. 2) to steady-state μ~0.3 after ~10 m slip; then, the fault was held stationary for ~30 s. When sliding was resumed at the same velocity, a slight strength recovery was followed by weakening back to μ~0.3 (blue curve, Fig. 2). But when the sliding was resumed at a much lower velocity, *V*=0.0003 m/s (green curve, Fig. 2), the friction increased to μ~0.92 within 600 s. Similar behavior was observed for quartzite, and time-dependent strengthening of fine-grained rock powder, and has been incorporated in the 'slowness' law form of rate- and state-friction. The present strength recovery reflects grain agglomeration, sintering, or re-crystallization. As strength recovery is active even *during slip* (green curve in Fig. 2), it may lead to self-healing of a slipping fault.

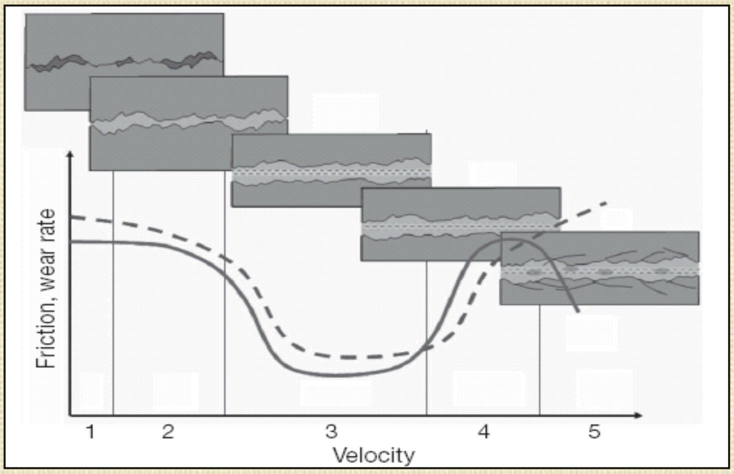


Figure 3. *Proposed model of fault weakening as it accelerates from rest to ~1 m/s. Friction- solid curve; wear-rate dashed curve; compare with Fig. 1A. Stage I. Initial setting signifies bare surfaces or healed gouge; Stage II. Wear, initial gouge formation, no lubrication; Stage III. Cumulative wear, critical gouge layer and powder lubrication; Stage IV. Strengthening (e.g., by dehydration); Stage V. Unstable slip, global failure.*

MODEL FOR DYNAMIC FAULT WEAKENING

Different lines of evidence indicate that the new gouge, which formed *during* slip, controls friction in our experiments. First, as gouge accumulates from the onset of slip and it adheres to fault surfaces; it is always present during slip. Second, the 100-300 micron thick gouge layer eliminates asperity-asperity contacts, and the slip is accommodated within this layer. Third, an observed strength transition at ~150°C is consistent with a surface hydration/dehydration mechanism of fine-grain powder. Fourth, steady-state friction is achieved here after slip distances of 3-10 m (brown curve, Fig. 2), and in previous experiments after ~1 m in quartzite, and ~15 m in gabbro; these distances indicate that steady-state requires prolonged wear and gouge accumulation. Fifth, the time-dependent strength-recovery is common to fine-grained rock powders with large surface area. Finally, the experiments show that *friction* and *wear-rate* vary similarly with slip velocity (Fig. 1A), and both are high at low velocities, low at intermediate velocities, and high again at high velocities. This inter-dependence of friction and wear-rate implies that gouge formation and accumulation are linked to friction intensity.

We propose a phenomenological model for fault strength evolution (Fig. 3):

1. Initially, the fault includes bare surfaces (ground sample), or healed gouge zone.
2. At low velocity, friction and wear-rate are high (Fig. 1A), but only minor gouge amount accumulates.
3. Fault weakening at intermediate velocity corresponds to the gouge layer serving as a “third body”.
4. The highly reactive gouge may undergo temporal strengthening even during slip (Fig. 2).
5. Slip becomes unstable at high velocity (0.25-1.0 m/s) leading to failure of our granite sample.

Dynamic gouge formation is expected to be a common and effective mechanism of earthquake instability in the brittle crust as (1) gouge always forms during fault slip; (2) fault-gouge behaves similarly to industrial powder lubricants; (3) dynamic gouge formation explains various significant earthquake properties; and (4) gouge lubricant can form under a wide range of fault configurations, compositions, and temperatures.

ACKNOWLEDGEMENTS: This study is supported by the National Science Foundation, Geosciences, Equipment and Facilities, Grant No. 0732715.

Gauging an Extreme: Rock Weathering in the Coldest, Driest, Windiest Place on Earth

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The University of Oklahoma

The western United States is renowned for its desert alluvial fans, and the text-book descriptions of fan sediments emanate from this region. But in the rock record, how does one distinguish between clastic sediments deposited in an arid alluvial fan and those that formed in, e.g., a wet cold (proglacial) fan? Sedimentologically, these two environments can appear remarkably similar. This question motivated the research that led us to become the first OU geoscientists to work in the Antarctica. The story began in the western U.S., where Dr. Lynn Soreghan and students have been entertaining the hypothesis that highlands of the late Paleozoic Ancestral Rocky Mountains may have been, at times, glaciated. Our research led us to classic "alluvial fan" strata of the Cutler and Fountain formations, and attempts to distinguish possible hot versus cold origins for these systems. Recent OU PhD graduate Dr. Dustin Sweet (now at Chevron) focused on the Fountain Formation (see recent publications) and devised a new means to assess a possible glacial influence via analysis of SEM data. We also planned to assess chemical weathering signatures in sediments from various climates, but Dustin graduated before we ever received funding for this work.

Upon arrival in Antarctica, the first task for any field-bound newbie is "Happy Camp School" where we learn how to (hopefully) survive. Here we are on a cold night next to our Scott tent.

After the arrival of geochemist Dr. Megan Elwood Madden, we readdressed the weathering issue and secured pilot NSF funding to study weathering of granitoids in the extreme environment of the Dry Valleys of Antarctica.

Arrival on the ice: OU PhD student Kristen Marra and other new arrivals walk over the Ross Sea ice to board "Ivan The Terra Bus" for the ride to McMurdo Station.

We arrived on January 1st, a holiday and the scene of the biggest music festival on the continent. Why are those people hula hooping in shirt sleeves?

The polar glaciers of the Dry Valleys lose water primarily by sublimation. In the few weeks of the Austral summer, however, some melting can occur, as seen here along the margin of Clark Glacier, Wright Valley.

Our field team, our last day in Antarctica: (L to R) Kristen Marra, Dr. Lynn Soreghan, Dr. Brenda Hall (University of Maine), and Allison Stumpf.

Antarctica is the coldest, driest, windiest place on the planet, and thus provides one end member in the spectrum of temperature and precipitation extremes we are targeting in our research that involves both sediment and water sampling. These photos document a few of our adventures during our visit to Wright and Taylor valleys (January, 2010), aided by Dr. Brenda Hall, an Antarctic expert from the University of Maine. We are currently processing our data from Antarctica, beginning analyses from the Wichita Mountains (an intermediate climate), and hope to eventually secure funding for the sites representing the other climate extremes. In addition to Drs. Soreghan and Elwood Madden, this work involves OU students Allison Stumpf (MS), Leslie Keiser (PhD), and Kristen Marra (PhD).

(Left) *Our work consisted of sampling sediments and water from various drainages emanating from the polar glaciers. Here, Allison (smiling) and Kristen do the work, gloveless, while the gloved professor snaps the photos.*

Glacial Weathering Indicators: Comparing Sediments and Water from Antarctic Dry Valleys and the Wichita Mountains

The goal of this research is to discern and quantify differences in granite weathering under different climate conditions. This past year, researchers from CPSGG have collected sediment and water samples from one of the coldest, driest, places on Earth-Antarctica. As a warmer, wetter comparison, they also collected a similar suite of samples from the Wichita Mountains in Oklahoma. We hope to find weathering proxies we can use to distinguish these two climates through a comparative analysis of water and sediment geochemistry, as well as sediment textures. If we accomplish this goal, it may be possible to distinguish clastic sediments deposited in warm, semi-arid alluvial fans from those deposited in periglacial systems, which otherwise look very similar in the field.

This past January, Dr. Lynn Soreghan, Dr. Brenda Hall (University of Maine), Ph.D. student Kristen Marra, and M.S. student Allison Stumpf spent 12 days in the Dry Valleys collecting sediment and water samples. Sample sites within Wright Valley included melt water streams from Clark Glacier, Denton Glacier, No Name Glacier, and Lower Wright Glacier, which included Lake Brown and the Onyx River. Taylor Valley collection sites include Goldman Glacier, Howard Glacier, and Moa Glacier **(Figure 1).** Clark Glacier stream, Lower Wright Glacier, Howard Glacier, and Goldman Glacier produced the most samples of both valleys. During this past spring and summer, Ph.D. student Leslie Keiser, M.S. student Allison Stumpf, and M.S. student Earl Manning collected water and sediment samples from the Blue Beaver Creek drainage basin in the Wichita Mountains of Oklahoma **(Figure 2)**. Both locations had similar drainage areas, relief, and bedrock lithology.

The geochemistry of a portion of the water samples from both locations has been analyzed. The results are in **Figures 3 and 4** below. The geochemistry of the sediment and bedrock samples are currently being analyzed, as well as thin sections of the bedrock and grain mounts of sand.

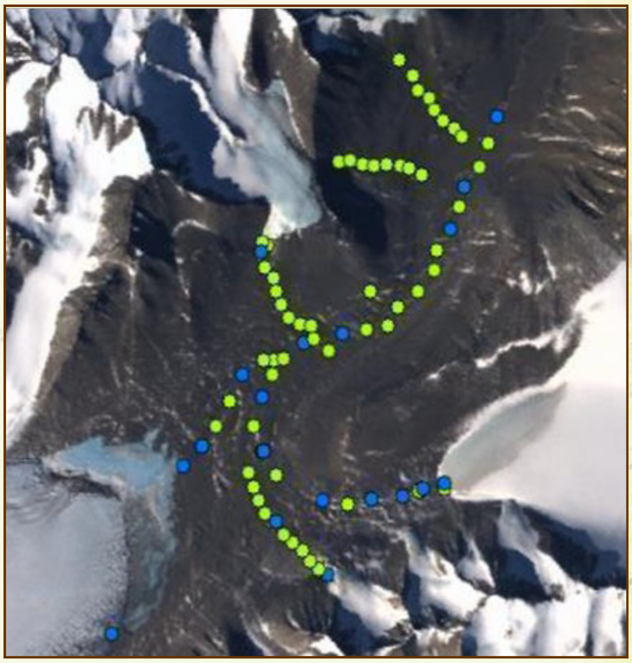

Figure 1.* *Map of Dry Valleys, Antarctica and sample site locations.

ALLISON STUMPF, M.S. student, ConocoPhillips School of Geology and Geophysics
LESLIE KEISER, Ph.D. student, ConocoPhillips School of Geology and Geophysics

Figure 2. Map of Wichita Mountains, Oklahoma and sample site locations.

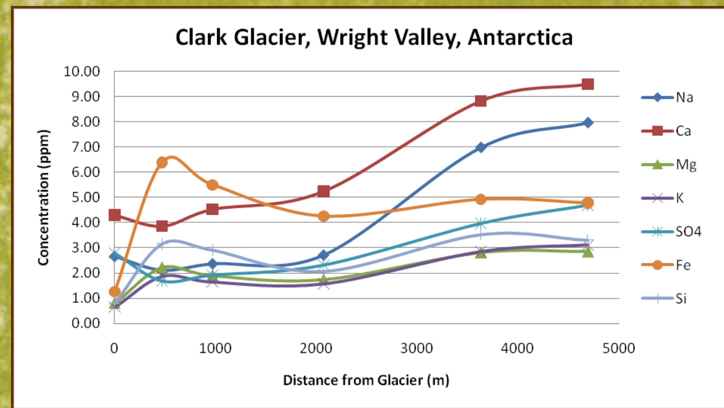

Figure 3. Graph of elemental concentrations vs. distance from glacier.

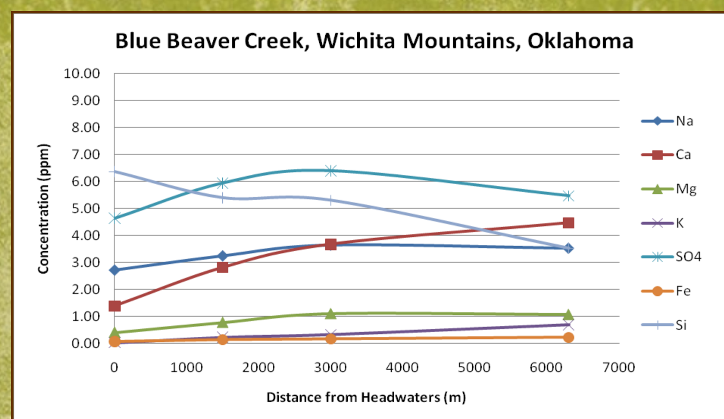

Figure 4. Graph of elemental concentrations vs. distance from headwater.

Although this is only preliminary data, it is already evident that there are geochemical differences between the two climates. The concentrations of the measured elements are noticeably different within the first 5000 m for each drainage basin. The Clark Glacier data from Antarctica shows a general increasing trend in dissolved iron concentrations from the base of the glacier to 5000 m downstream. Whereas the Blue Beaver Creek data from the Wichita Mountain's shows a fairly constant trend from the headwaters to approximately 5000 m downstream.

In the Wichita Mountains, we predict that chemical weathering should be more prevalent (than in Antarctica) because of the warmer, wetter environment (more water); however, water is not continually flowing and precipitation of secondary minerals does occur, removing aqueous species from solution. In Antarctica, the melt water stream is continually flushing the elements downstream through the summer. Saturation and precipitation of secondary phases such as clay is, therefore, unlikely in glacial systems.

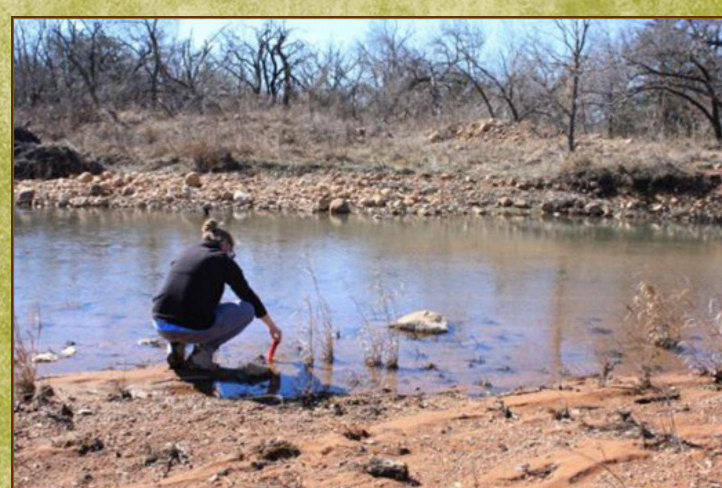

Figure 5. M.S. student Alison Stumpf collecting a water sample from Blue Beaver Creek on Fort Sill.

The effects of these differences in secondary mineral precipitation may be seen in **Figures 3 and 4**. The elemental concentrations in **Figure 3** increase downstream which is likely the result of continued chemical weathering of sediments without secondary mineral precipitation in the Clark Glacier drainage. In Blue Beaver Creek, the concentrations remain fairly constant as secondary minerals possibly precipitate out of solution. Initial observations of the Blue Beaver Creek sediment samples indicate an abundance of clay-sized secondary minerals in the waters where there are none in the Clark Glacier sediment samples. This supports the idea that secondary mineral precipitation controls elemental concentrations in the cold-arid and warm semi-arid drainages of this study.

This preliminary data combined with continued research will hopefully contribute toward building the evidence needed to distinguish clastic sediments deposited in warm, semi-arid alluvial fans from those deposited in periglacial systems. We are excited to continue this research and see it to completion.

(Above) ***Figure 6.*** *Ph.D. student Leslie Keiser collecting a sediment sample from Blue Beaver Creek on the Wichita Mts. Wildlife Refuge. (Bottom)* ***Figure 7.*** *M.S. students Earl Manning and Allison Stumpf discussing the next sample locality.*

Figure 8. *Ph.D. student Kristen Marra and M.S. student Allison Stumpf sampling from the Onyx River, Wright Valley, Antarctica.*

Figure 9. *Dr. Lynn Soreghan taking pH and temperature measurements at Lower Wright Glacier, Wright Valley, Antarctica.*

Figure 10. *Ph.D. student Kristen Marra breaks the ice to take a pH measurement near Denton Glacier, Wright Valley, Antarctica.*

Building Evidence for Oklahoma's Permian Dust Bowl?

Jessica Pack
Associate Geologist, Chesapeake Energy Corporation, M.S. in Geology, University of Oklahoma

Alisan Sweet
M.S. Candidate in Geology, ConocoPhillips School of Geology and Geophysics, University of Oklahoma

Permian redbeds are a well-known fixture of Kansas, Oklahoma, and north Texas **(Figure 1)** but the origin of this vast pile of fine-grained red sediment remains debated. As part of a NSF-funded study on deep-time dust headed by the Soreghans (see related article), **Jessica Pack** and **Alisan Sweet** are tackling parts of this question by targeting members of the Wellington (Leonardian, Sumner Group) and Flowerpot Shale/ Blaine Formation (Guadalupian, El Reno Group; **Figure 2**) in their Master's thesis work.

Through a detailed core analysis of a 91 m core from Kay County, Oklahoma, the Wellington study examines the depositional environment, origin, and climatic implications of Permian redbeds. The Wellington core exhibits high-frequency facies changes, which appears to cycle from organic-rich laminated mudstone with finely laminated dolomite **(Figure 3a,b)**, to variegated laminated mudstone with gypsum **(Figure 3c,d)** to massive mudstone composed of either red or greenish-gray colors with pedogenic overprinting **(Figure 3e)**, and to very fine siltstone **(Figure 3f)**. Evidence from this study, including but not limited to finely laminated, primary dolomite, primary gypsum, dominant siliciclastic material, and the association of redbeds with Vertisols and loess, suggests the Wellington Formation records deposition in a shallow, ephemeral saline lake during a time of increasing aridity with strong seasonality **(Figure 4)**, evident by abundant mudcracks **(Figure 5a)**, vertic-type paleosols **(Figure 5b)**, conchostracans **(Figure 5c)**, and lungfish burrows. Features of the mudstone and siltstone of the Wellington indicate eolian transport from a distant source based on a uniform and < 13 μm grain size, the clay-rich composition of the mudstone, and lack of evidence supporting fluvial-discharged plumes. Geochemical analysis **(Figure 6)** indicates a mixed provenance with the mudstone primarily sourced from Ouachita Mountains possibly during more humid, interglacial periods and the siltstone sourced from the Ancestral Rocky Mountains (ARM) possibly during arid, glacial periods **(Figure 7)**.

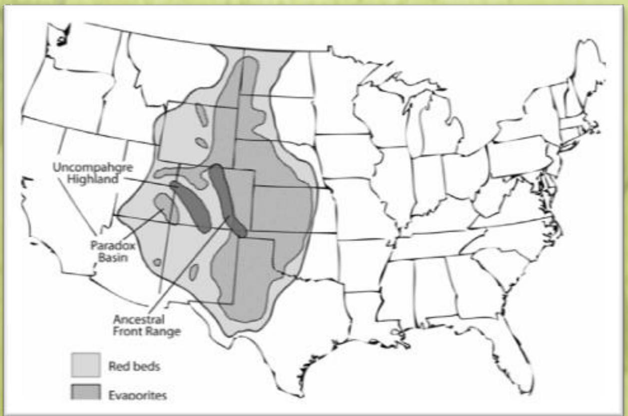

Figure 2: *Distribution of Permian redbeds and evaporites in the United States (modified from Walker (1967) and Benison and Goldstein (2001)).*

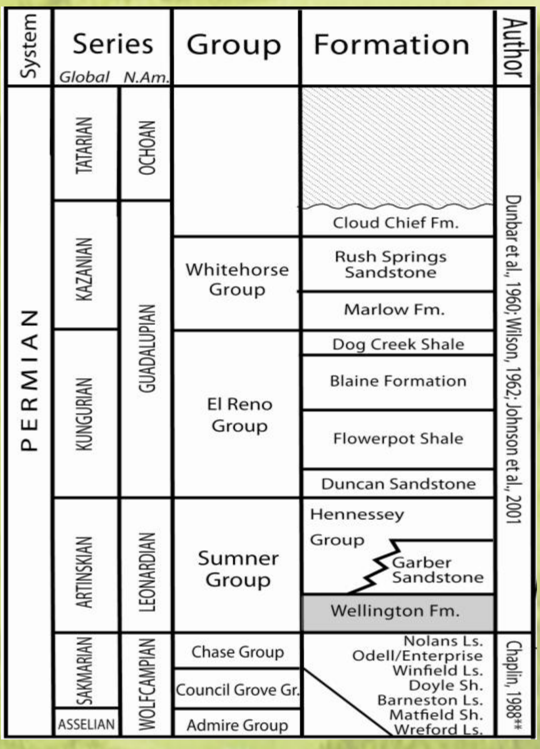

Figure 1: *Permian stratigraphy in north-central Oklahoma, combining the work of Dunbar et al. (1960), Wilson (1962), Chaplin (1988), and Johnson et al. (2001).*

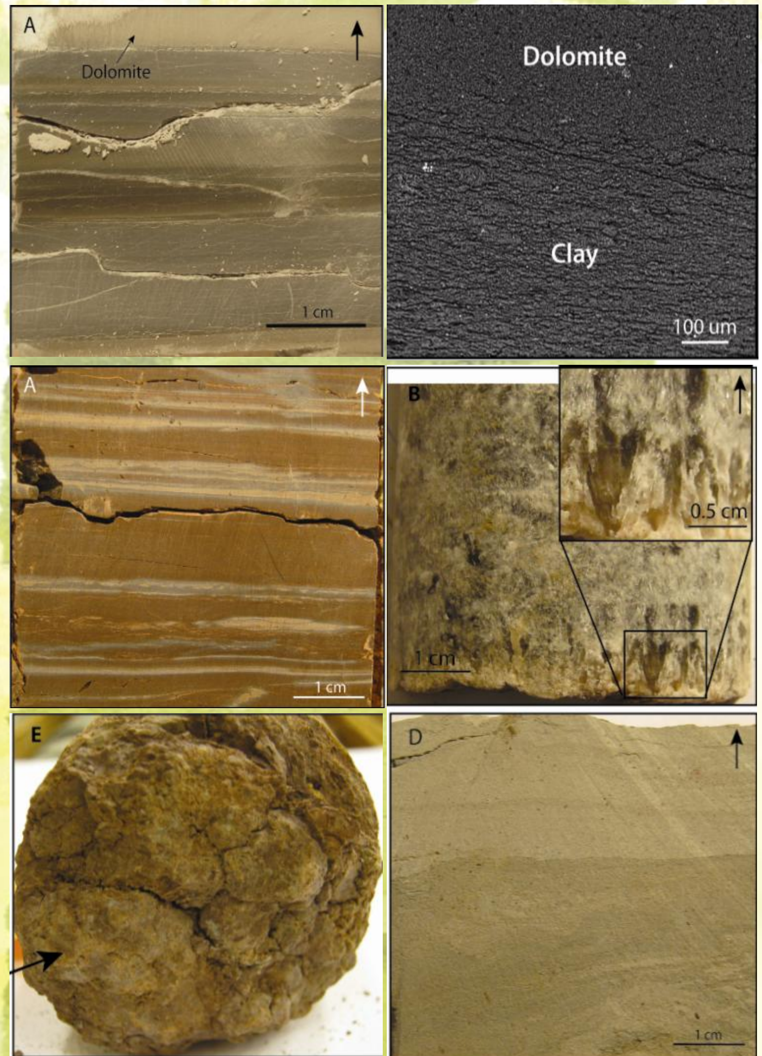

Figure 3: *a) Organic-rich laminated mudstone with finely laminated dolomite (24.9 ft; Midco); b) SEM-BSE image of finely laminated dolomite; c) Typical fine laminations within variegated mudstone (144.8 ft; Otoe); d) Thicker gypsum bed within variegated laminated mudstone facies with vertical swallow-tail. The sharp corners of this crystal indicate it is unaltered (94.0 ft; Midco); e) a massive mudstone composed of either red or greenish-gray colors with pedogenic overprinting; f) Faint laminations of very fine siltstone (127.5 ft; Otoe).*

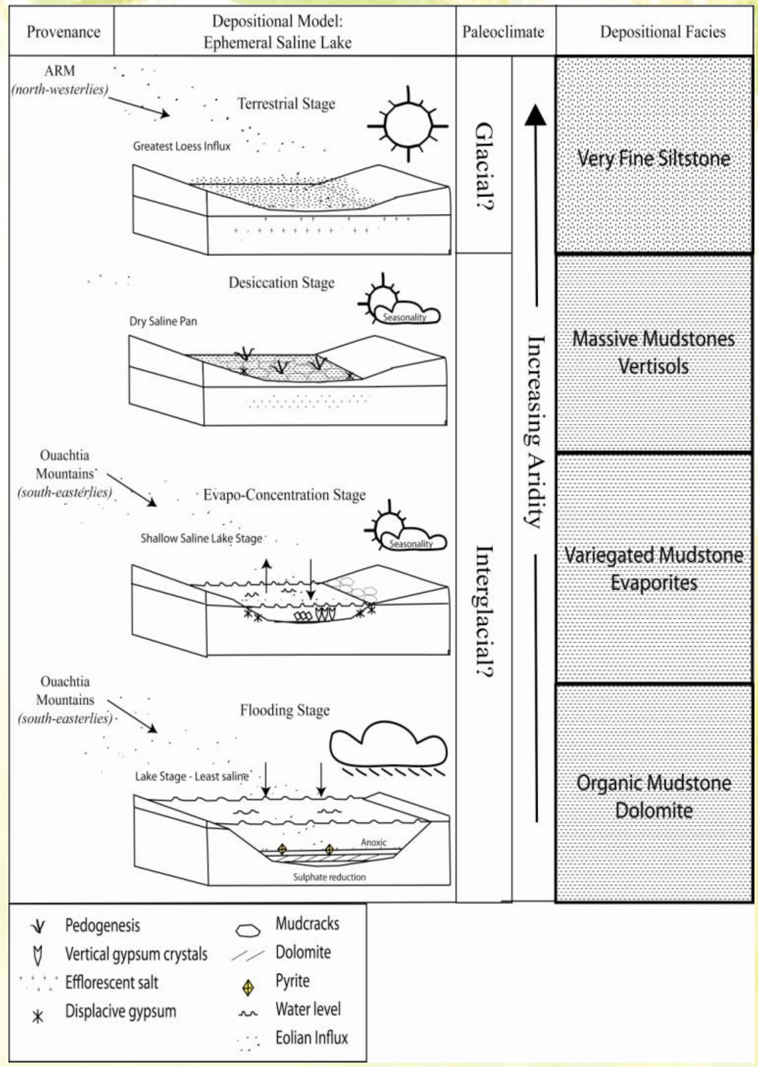

Figure 4: *Integrated interpretation for deposition of the Wellington based on the KC-1 core. (1) The cycle begins with the flooding stage, depositing the organic mudstone and dolomite. (2) With increased aridity, evaporation caused an overall decrease in water level, though seasonality persisted with water level fluctuations. (3) As aridity continued to increase, most of the water evaporated and the variegated mudstone was pedogenically over-printed, creating Vertisols. (4) Finally, the greatest loess influx represents the driest, terrestrial stage.*

Field and laboratory analyses were performed on mid Permian (Guadalupian) rocks from Blaine County (Roman Nose region; **Figure 8**) and Major County (Glass Mountains region; **Figure 9**), Oklahoma. The Flowerpot Shale and Blaine Formation of the El Reno Group have long been interpreted to record tidal flat and/or marginal marine deposition, primarily on the basis of the gypsum content. However, the depositional setting, provenance, and transport process of the clastic sediments remain debated. To date, our results show that the predominant (>75%) fine-grained siliciclastic component of these sections is most consistent with eolian delivery. Key features include the primarily silt grain size, moderate to good sorting, sheet-like geometry, and massive bedding. We further suggest eolian delivery into both continental (Flowerpot Shale) and marine (Blaine Formation) environments. A continental environment for the Flowerpot Shale is evidenced by the occurrence of multiple pedogenic horizons hosted within otherwise massive siltstone of inferred eolian origin. These paleosol horizons exhibit a variety of features, including blocky ped structures **(Figure 10)**, downwardly-bifurcating (inferred root) traces, subtle clay-rich horizonation with local nodular gypsum, and reduced haloes and horizons. In contrast, the Blaine Formation contains multiple units of claystone, dolostone, and gypsum interpreted to record marine deposition; however, the origin of the volumetrically-predominant fine-grained siliciclastic component is mostly easily reconciled with eolian delivery into a marine system.

Figure 5: *Typical complex mudcrack present in variegated laminated mudstone facies; b) developed slickenside typical of the vertic-type paleo-sols; c) Imprints of conchostracans, sizes range from ~1-5 mm.*

In 1964, Fay suggested at least two possible sources for these sediments: the Arbuckle/Ouachita highlands and the Ozark Dome. We employed whole-rock geochemistry buttressed by detrital zircon geochronology to suggest that the Appalachian highlands could have provided a significant source region **(Figure 11)**, in addition to the accepted Arbuckle/Ouachita highlands, and a minor signal from the Ancestral Rocky Mountains. Interpretation of an eolian origin reflects a marked change from previous interpretations, and this along with sedimentologic and geochemical data implies widespread delivery of eolian dust to this region and thus remarkable dustiness in western equatorial Pangea. Ongoing studies will examine possible climatic impacts of this "Paleozoic Dust Bowl."

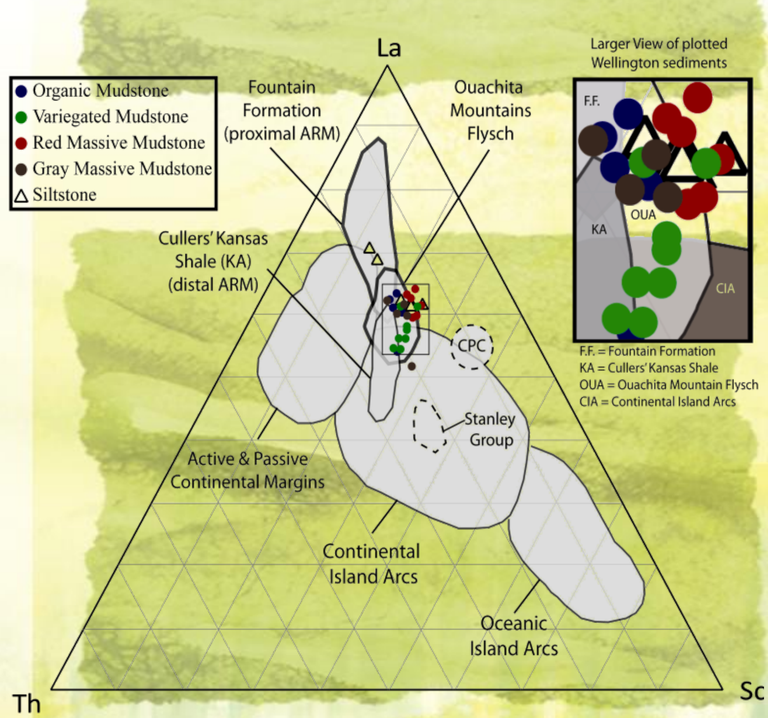

Figure 6: *Ternary diagram of La-Th-Sc with fields of specific source areas outlined. The Wellington facies are plotted as colored dots and triangles (see legend, left). Light box around plotted dataset is enlarged to the right. An explanation of outlined fields follows: the Fountain Formation outline represents the composition of proximal Pennsylvanian shale in Colorado derived from the ARM (Cullers and Stone, 1991); Culler's Kansas Shale (KA) represents the compositions of distal Pennsylvanian and Permian shale in Kansas derived from the ARM; Active and Passive Continental Margins represent weathered silicic sources (Cullers, 1994); Continental Island Arcs and Oceanic Island Arcs represent increasingly more mafic sources (from Bhatia and Crook, 1986); Ouachita Mountains flysch is an outline around averaged datasets of both Gleason et al. (1995) and Totten et al. (2000). Gleason et al. (1995) dataset is obtained from a mixture of the Ouachita flysch, while Totten et al. (2000) solely examined the Stanley Formation; The Stanley Group dashed line is an outline of Totten et al.'s (2000) more mafic dataset from the Stanley Group, as Totten et al. (2000) suggested multiple sources for the Stanley, both silicic and basic; Avg. CPC represents the average composition of the Colorado Plateau Crust (Condie and Selverstone, 1999). After Cullers, 1994.*

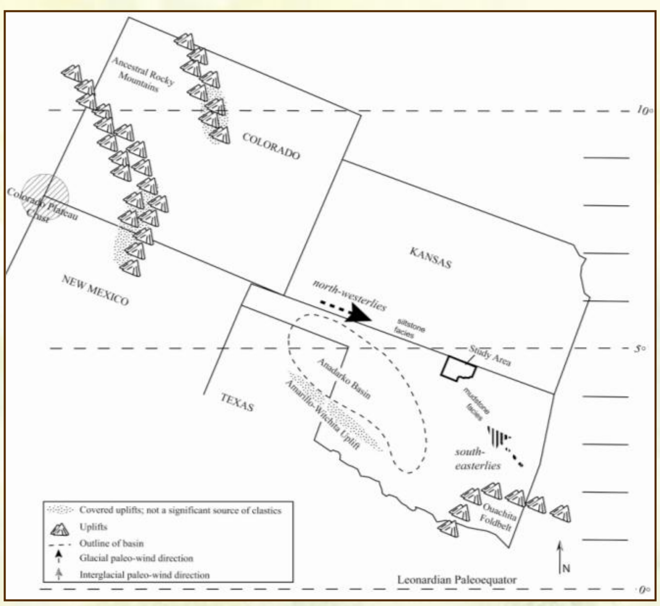

Figure 7: *Inferred wind directions for the Leonardian based on this study. Northwesterlies represent arid glacial intervals and deposited very fine siltstone from the Ancestral Rocky Mountains. Southeasterlies occurred during more humid interglacials and sourced the mudstone facies from the Ouachita Mountain flysch.*

Figure 8: *Strategraphic section measured at Cat Canyon, Blaine County, northwestern Oklahoma (location is south of the Lone Mountain section). This 53-meter section consists of approximately 24 m of Flowerpot Shale with the remaining 29 m, Blaine Formation.*

Figure 9: *63 m strategraphic section measured at Lone Peak, Glass Mountains, Major County, northwestern Oklahoma, comprised primarily of Flowerpot Shale. Note upper, thick white layer is basal gypsum of the Blaine Formation.*

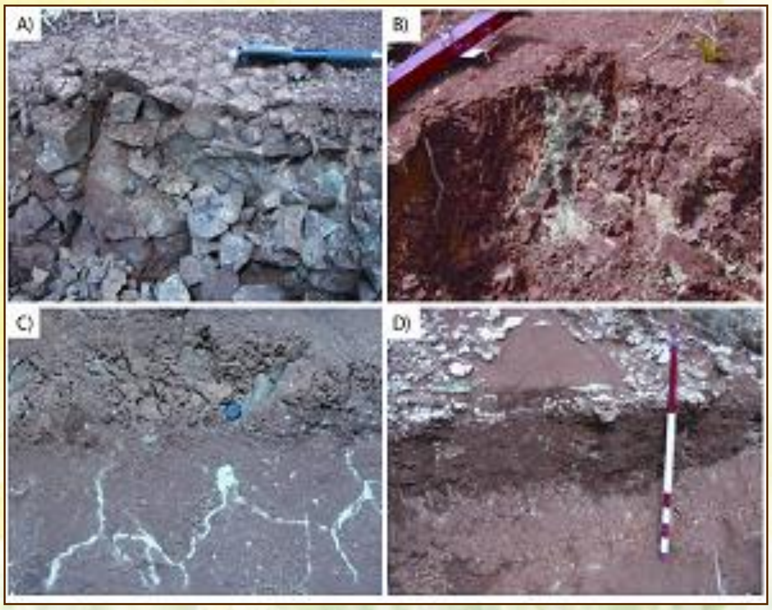

Figure 10: *Macromorphology of inferred paleosols within the Flowerpot Shale. (A) Large, blocky ped structures with numerous reduction haloes. Located at base of the Cat Canyon measured section. (B) Clayey interval with reduced bifurcating (inferred) root traces. (C) Root traces higher up-section – sits just below a gypsic horizon (D). (D) Discrete, continuous, gypsic horizon in lower Flowerpot Shale consisting of a white, soft, sugar-like texture.*

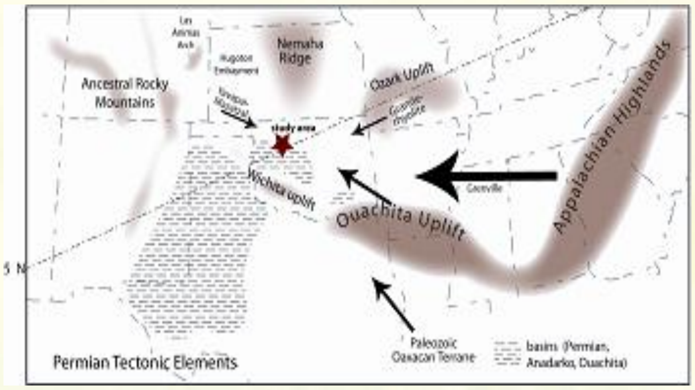

Figure 11: *Detrital zircon geochronology was used to identify source terranes for sediments in the lower Flowerpot Shale of the Lone Mountain study area. Major source signals are represented by larger black arrows (Paleozoic terranes, Grenville, and Yavapai-Mazatal), while smaller black arrows represent smaller source signals (Wichita Rift & Neoproterozoic Terranes and Granite Rhyolite).*

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SHAYDA ZAHRAI, B.S. Candidate in Geology, Earth and Planetary Geochemistry

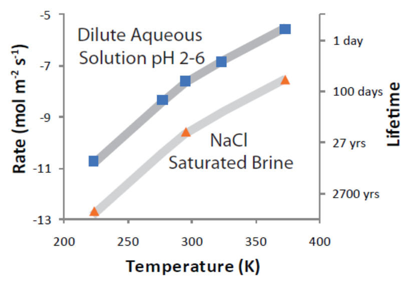
"USING THE DISSOLUTION RATES OF JAROSITE PARTICLES TO DETERMINE THE DURATION OF WATER ON MARS"

Jarosite is ferric sulfate that forms in acidic, oxidizing, iron-rich environments on Earth. It has been observed in outcrops throughout Meridiani Planum by the Mars Exploration Rover Opportunity. Studies of the dissolution rate of jarosite under acid mine drainage (AMD) and Mars-relevant conditions provide students of planetary geology the opportunity to measure the lifetime of jarosite-bearing sediments on Mars. The lifetime of a dissolving mineral particle can be calculated using the initial diameter, molar volume, and dissolution rates of the mineral particle and applying those values to a shrinking sphere equation.

Jarosite has a very narrow stability range. By determining the rate of metal release during dissolution, it is possible to constrain the lifetime of jarosite. This study measures the rate of Na- and K-jarosite in dilute solutions to determine the lifetime of water in jarosite-bearing sediments on Mars. By measuring changes in Na+ and/ or K+ concentrations, dissolved sulfate concentration, and pH of the resulting fluid, the rate of jarosite dissolution can be determined.

Experimental Conditions	log k
277 K, UP water	-8.6
295 K, NaCl	-9.8
295 K, pH 4	-7.85
295 K, pH 2	-7.95
295 K, pH 6	-7.7
295 K, Oxalic acid	-7.72
323 K, UP water	-7.1
323 K, Oxalic acid	-7

The conditions of the different K-jarosite experiments and the rate of dissolution for each experiment. With increased temperature, the dissolution rate is faster, regardless of pH or oxalic acid. However, the dissolution rate of the NaCl-saturated brines is much slower than all of the other experiments, regardless of temperature.



Dissolution rates and particle lifetimes for K-jarosite particles in dilute aqueous solutions and NaCl-saturated brines indicate that at higher temperatures, the dissolution rates are faster, regardless of pH. Therefore, the duration of the K-jarosite particles diminishes at higher temperature conditions and can be extended in high salinity brines.

Batch reaction dissolution experiments using synthetic K- or Na-endmember jarosite were conducted at different conditions with temperatures ranging from 277 to 323 K in ultrapure water and at pHs buffered at 2 and 6. Experiments were stirred continually by a stir bar on a stir plate ranging from hours to days. After AA analysis and calculations, the shrinking sphere model was then applied. The results provide particle lifetimes over a range of temperature and salinity conditions that correspond with conditions on Mars. Results of the studies indicate that the dissolution rate of K-jarosite is not affected by pH or dissolved iron concentration in the presence of oxalic acid. The rates vary significantly with temperature, however, which suggests an activation energy of 55 kJ/mol. Rates were also lower in NaCl–saturated brine, which suggests that the activity of water has an effect on the dissolution rate.

Applying the shrinking sphere equation to the dissolution rates, jarosite lifetimes ranged from days to tens of thousands of years. Therefore, aqueous fluids were active at Meridiani Planum over only a very short period of the billions of years since the Burns Formation was deposited. This water may have been active during a single prolonged period or over several shorter episodes. Overall, Mars is and has been a dry planet over much of its geologic history. Preservation of jarosite at Meridiani Planum demonstrates that water was an ephemeral phase on Mars.

Shayda sampling a K-jarosite experiment.

GOETHITE ON JAROSITE

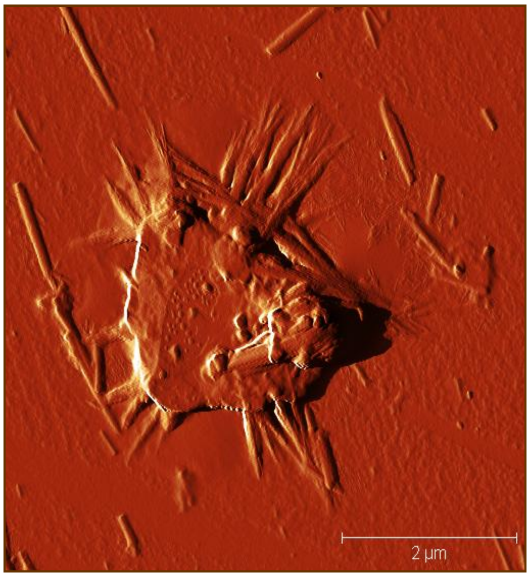


Image provided by Professor Megan Elwood Madden

Geomechanics field characterization of Woodford Shale and Barnett Shale with advanced logging tools and nano-indentation on drill cuttings

YOUNANE ABOUSLEIMAN, MINH TRAN, AND SON HOANG, *PoroMechanics Institute, University of Oklahoma*
J. Alberto Ortega and Franz-J. Ulm, *Massachusetts Institute of Technology*

The Woodford Shale and Barnett Shale have emerged as prolific gas plays in the U.S. Mid-Continent. However, the intrinsically low permeability of these gas shales hinders profitable production unless horizontal well drilling and multi-stage hydraulic fracturing are employed. The success of these operations depends on accurate determinations of the anisotropic elastic and poroelastic properties of these shale formations.

Recent applications of nano-technology advances have facilitated direct measurements of shale anisotropic mechanical properties at a scale never investigated before, e.g., displacements as small as 100 nm to 100 µm and maximum applied forces of less than 1000 µN. Thousands of nano-indentation tests on a variety of preserved shales have revealed an anisotropic unit basic building block, or a Representative Elementary Volume (REV), for all shales (Ulm and Abousleiman, 2006). This unique observation has led to the development of a theoretical model, the GeoGenome™ model, for estimating shale anisotropic elastic and poroelastic properties. The method integrates the nano-indention results with porosity and mineralogy composition, obtained from spectral gamma ray logs or from X-ray diffraction (XRD) mineralogy analysis of drill cuttings. Pervukhina et al. (2008) have independently calibrated the GeoGenome model with their Ultrasonic Pulse Velocity (UPV) measurements on several shales and observed decent agreement.

In this work, a suite of recently developed wire-line logs—Elemental Capture Spectroscopy (ECS) log, sonic scanner log, and multiple porosity logs—was run across Woodford and Barnett formations. The log data were used to estimate the anisotropic elastic and poroelastic properties of these gas shales using the GeoGenome model. Comparison between the simulated data, laboratory UPV measurements on preserved core samples, and sonic scanner log data has shown excellent agreement, and confirmed the reliability of the GeoGenome upscaling model in obtaining shale anisotropic mechanical properties from an anisotropic REV observation (Abousleiman et al., 2009).

In addition, a new technique was developed using nano-indentation to extract shale mechanical and strength properties from drill cuttings. The results on Woodford Shale samples have shown great potential for cost-effective mechanical characterization for shale and other rock types using just retrieved drill cuttings (Abousleiman et al., 2009).

Nano-indentation and the GeoGenome model

A schematic of the nano-indenter is shown in ***Figure 1***, together with a typical force-displacement curve from nano-indentation tests and an Atomic Force Microscope (AFM) image of the nano-indentation cone geometry with base side dimensions of 4 µm and depth of 500 nm on Woodford Shale. Valuable material properties such as hardness and elastic modulus can be extracted from the force and displacement curve as shown by Equations 1–3,

$$H = \frac{P}{A_c} \tag{1}$$

$$M = \frac{1}{2}\sqrt{\frac{\pi}{A_c}}\frac{dP}{dh} \tag{2}$$

$$M = \frac{E}{1-\nu^2}, \tag{3}$$

where H is the hardness of the material, M is the indentation modulus, P is the peak load of the loading curve, h is the indentation depth, and A_c is the area of the contact surface between the indenter cone and the rock. For an isotropic rock, the indentation modulus M can be expressed in terms of the Young's modulus, E, and Poisson's ratio, ν, as shown in Equation 3 (Oliver and Pharr, 1992).

For transversely isotropic rocks such as shale, there are two indentation moduli, i.e., M_1 when indenting parallel to bedding and M_3 when indenting perpendicular to bedding.

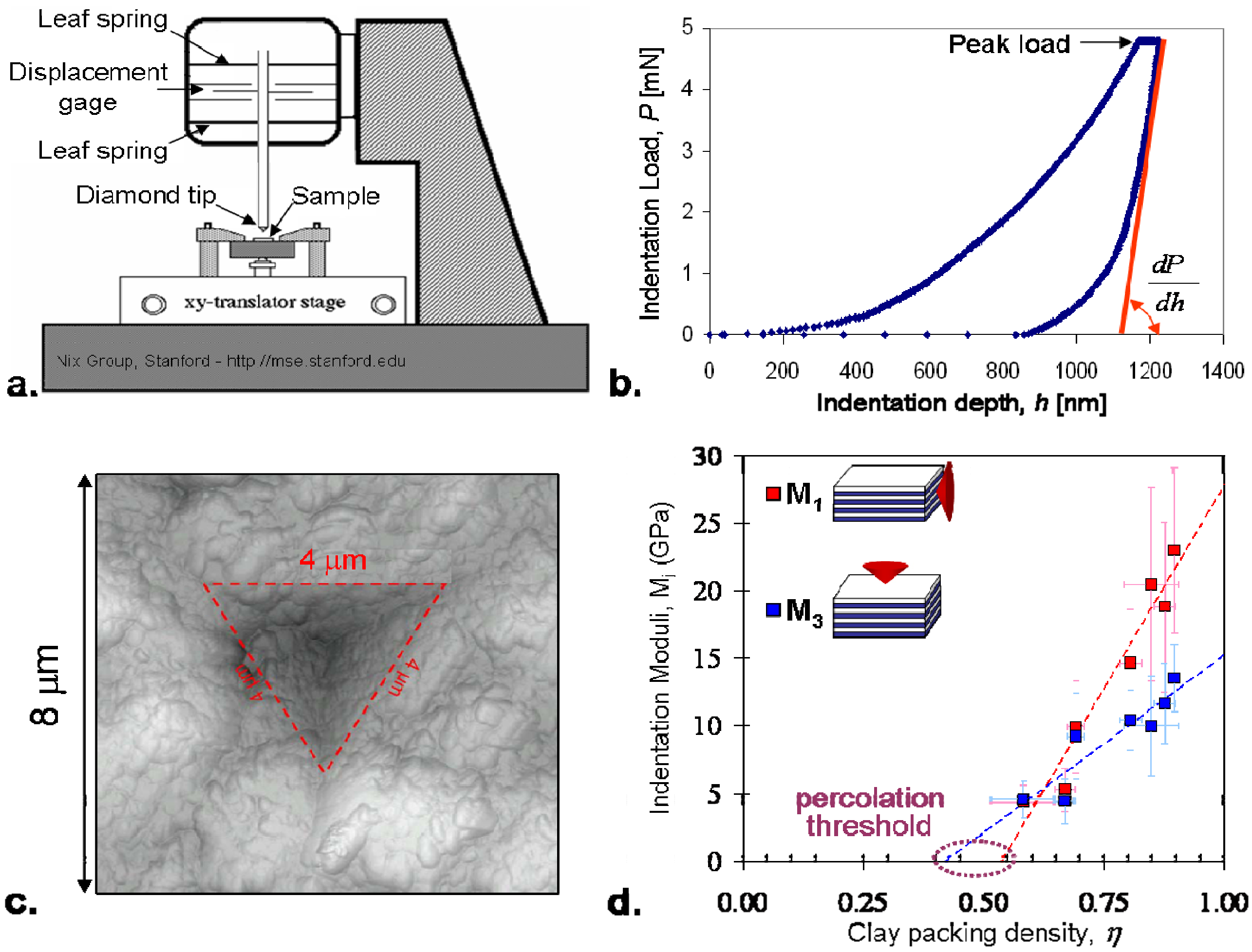


Figure 1. a) *Schematic of the nano-indenter.* b) *A typical force-displacement curve.* c) *An indentation mark on Woodford Shale.* d) *Indentation moduli M_1 (indenting parallel to bedding) and M_3 (indenting perpendicular to bedding) versus clay packing density* ***η*** *(adapted from Abousleiman et al., 2009).*

These indentation moduli from over 5,400 nano-indentation tests on the clay phase of seven different shales (excluding Woodford and Barnett Shales) are plotted versus clay packing density, η, in Figure 1d. The clay REV is clearly anisotropic because moduli M_1 and M_3 diverge as the clay packing density approaches 1 (solid clay). On the other hand, both M_1 and M_3 reduce to 0 at a clay packing density of approximately 0.5, which suggests that the clay REV can be represented by spheres within the framework of micromechanics modeling (Ulm and Abousleiman, 2006).

Based on the experimental observations above, the GeoGenome upscaling model has been constructed for anisotropic nano-granular materials based on a microporomechanics approach. In this approach, macroscopic elastic and poroelastic properties of shale depend on the clay packing density, η, the volume fraction of the non-clay phase, f_{inc}, and the organic volume fraction, f_{org} (Ortega et al., 2009). Parameters f_{inc}, η, and f_{org} can be calculated directly from formation porosity and mineralogy composition using Equations 4–6,

$$f_{inc} = (1-\phi)\frac{\sum_{k=1}^{total\ non-clay}\frac{m_k}{\rho_k}}{\sum_{k=1}^{total\ non-clay}\frac{m_k}{\rho_k}+\sum_{l=1}^{total\ clay}\frac{m_l}{\rho_l}+\sum_{n=1}^{total\ organic}\frac{m_n}{\rho_n}} \quad (4)$$

$$\eta = 1-\frac{\phi}{1-f_{inc}} \quad (5)$$

$$f_{org} = \frac{\sum_{n=1}^{total\ organic}\frac{m_n}{\rho_n}}{\sum_{l=1}^{total\ clay}\frac{m_l}{\rho_l}+\sum_{n=1}^{total\ organic}\frac{m_n}{\rho_n}}, \quad (6)$$

where m, ρ, and Φ are the mass percentage, density, and porosity, respectively. The subscripts k, l, and n indicate the non-clay phase, the clay phase, and the organic phase, respectively.

Woodford Shale characterization

A suite of logs, ECS, neutron porosity (NPHI), density, density porosity (DPHI), and sonic scanner (MSIP), was run in a vertical well penetrating the Woodford formation. The quantitative mineralogy composition given by the ECS log is shown in Figure 2 and defines two distinct geological zones—Upper Woodford with lower clay content and Middle Woodford with higher clay content. The ECS log results were calibrated with XRD mineralogy analysis performed on core samples from the same well. Abousleiman et al. (2007) and Tran (2009) found a difference of less than 15% between the ECS and XRD results, thus confirming the reliability of ECS log data for formation geomechanical characterization. The raw log porosity, Φ_{log}, was also calibrated using ΦHg-injection porosity, Φ_{Hg}, to obtain the calibrated log porosity, $\Phi_{log\ calibrated}$, displayed on ***Figure 2***.

Laboratory UPV measurements were conducted on seven preserved Woodford samples including two samples from the Upper Woodford interval and five samples from the Middle Woodford interval. The results are compared with sonic scanner data in ***Figure 3***.

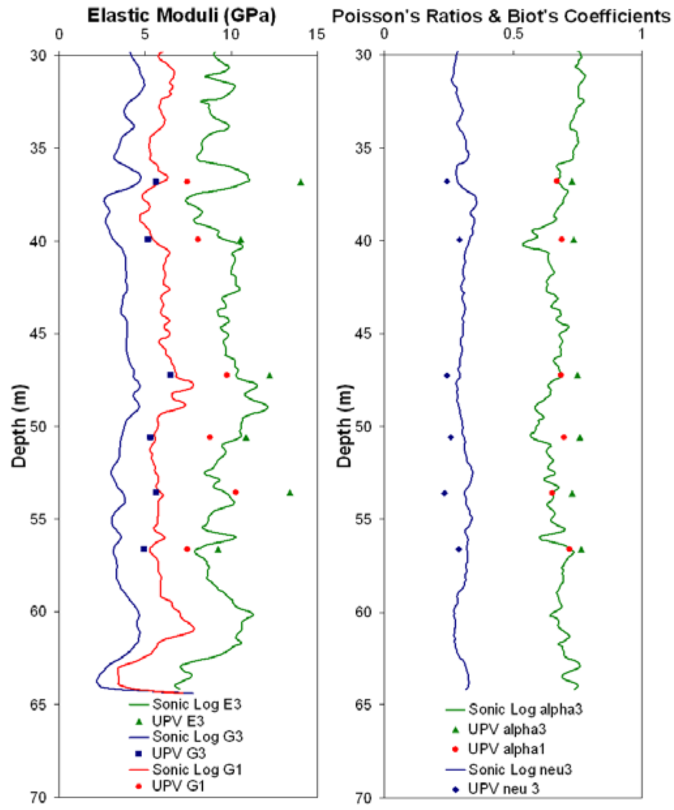


Figure 3. *Sonic scanner log results and UPV measurements showing the anisotropic nature of Woodford Shale.*

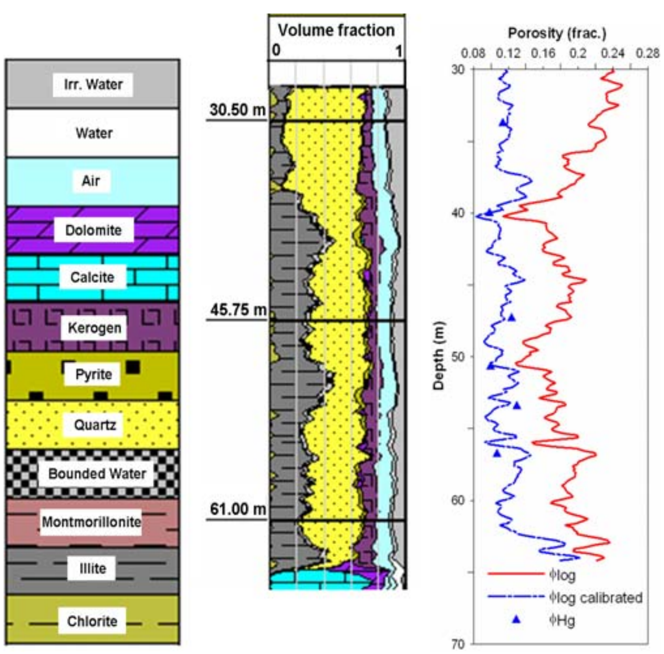


Figure 2. *Log-based Woodford Shale mineralogy composition and porosity (adapted from Abousleiman et al., 2009).*

An upscaling model has been implemented into a simulator that is capable of importing real-time log data and estimating anisotropic elastic and poroelastic properties of the shale formation. In what follows, the mineralogy composition defined by the ECS log and calibrated log porosity $\Phi_{log\ calibrated}$ were used as input in the algorithm. The simulated anisotropic Young's moduli, Poisson's ratios, shear moduli, and Biot's pore pressure coefficients showed good qualitative and quantitative agreement to the ones derived from sonic scanner log response and laboratory UPV measurements, as illustrated in ***Figure 4.*** However, the Young's modulus and Biot's pore pressure coefficient in direction parallel to bedding, E_1 and α_1, which are crucial for a complete mechanical characterization of the transversely isotropic Woodford Shale could not be obtained by the sonic scanner.

Nano-indentation on Woodford Drill Cuttings

Woodford Shale drill cuttings of different sizes were mixed with epoxy to form small blocks (1cm × 1cm × 1cm) for nano-indentation testing and mechanical characterization as shown in Figure 5a. In addition, pure epoxy cubes were also prepared to calibrate the nano-indenter response when indenting on pure epoxy phase. Nano-indentation testing conducted on pure epoxy blocks

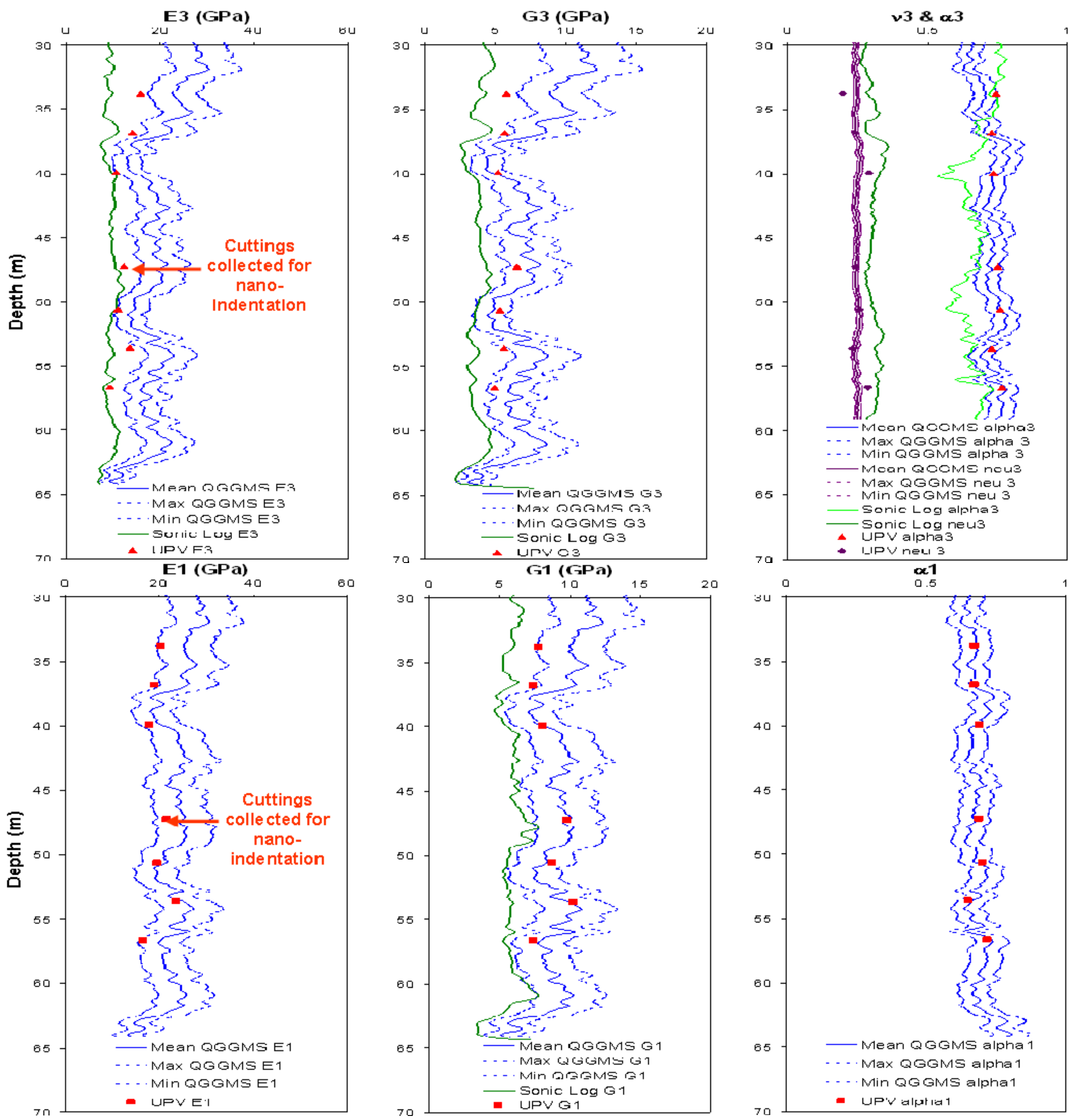


Figure 4. *Comparison between GeoGenome simulated results, sonic scanner log results, and UPV measurements. Monte Carlo simulations were performed to estimate the impacts of log porosity and ECS mineralogy uncertainties on the simulated results (shown as dash lines). The depth where Woodford cuttings were collected and mixed with with epoxy for nano-indentation tests is also indicated (Abousleiman, et al, 2009*

and on preserved Woodford Shale not mixed in epoxy showed that the epoxy and clay form two separate domains of indentation modulus and hardness, as illustrated in ***Figure 5c.*** This observation formed the basis for the extraction of shale mechanical properties from indentation tests performed on shale drill cuttings mixed in epoxy.

An SEM image of the indentation imprints on the Woodford samples embedded in epoxy is shown in ***Figure 5b***. A total of 1,350 indentation tests and corresponding force and displacement curves were obtained for each prepared block. Prior to analyzing the nano-indentation testing data it was necessary to investigate whether epoxy can affect the mechanical properties of porous clay phase. When casting rock chips in epoxy for indention tests with a 1mm flat indenter, Uboldi et al. (1999) reported epoxy could intrude into rock pores and influence the results. Consequently, they selected a highly viscous epoxy in an attempt to minimize epoxy intrusion. Unfortunately, the method was not always effective even when applied to low-permeability and

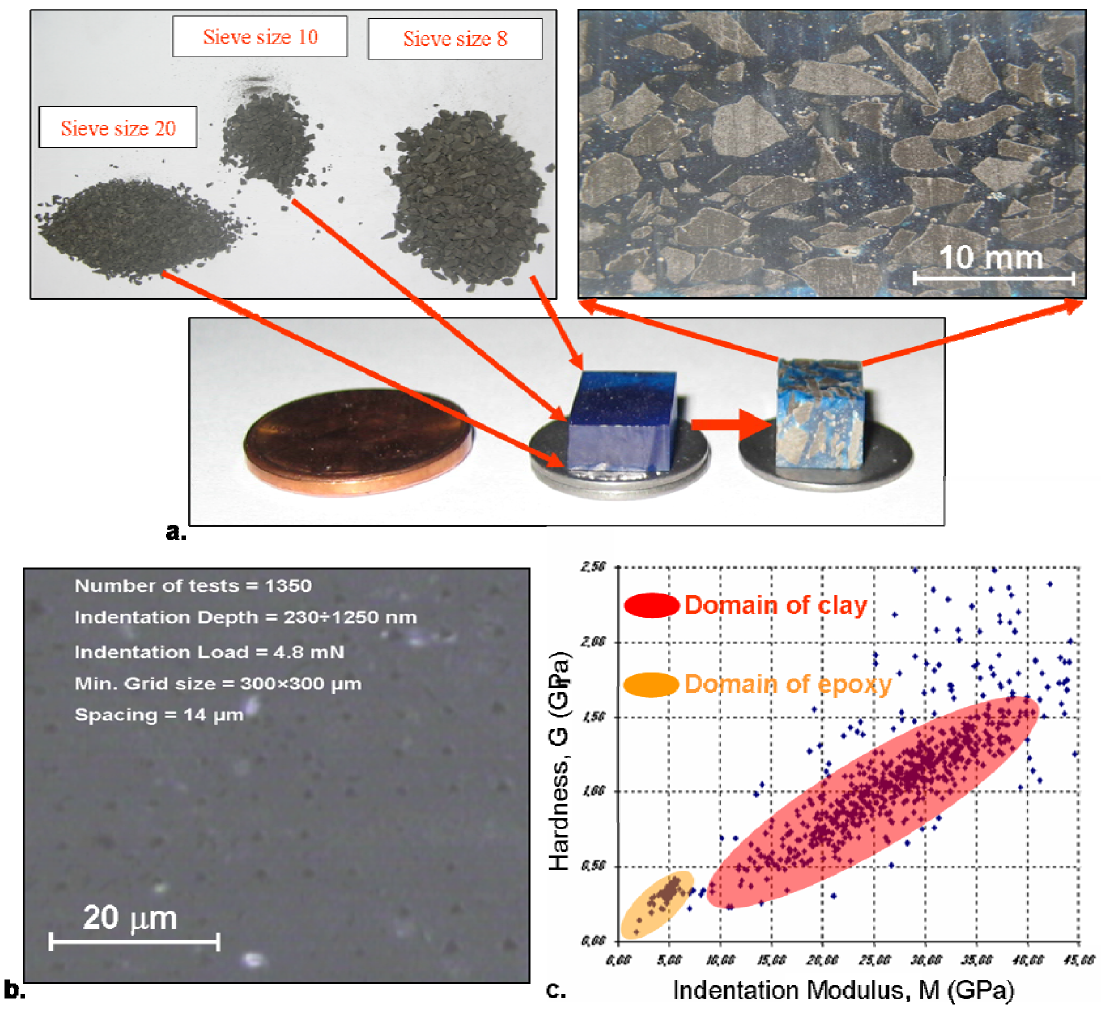


Figure 5. a) *Woodford drill cuttings before and after mixing with epoxy for nano-indentation tests,* b) *Array of nano-indentation imprints on a Woodford Shale drill cutting embedded in epoxy,* c) *Hardness and indentation modulus domains of clay and epoxy (Abousleiman et al., 2009)*

low-porosity shale samples. Wang et al. (2001) conducted UPV measurements on clay powder mixed in epoxy to determine the elastic properties of the solid clay. They also observed that the measured elastic properties of the solid clay were higher than published literature data. A similar clay phase stiffening phenomenon was also observed when indenting on Woodford cuttings embedded in epoxy as illustrated in **Table 1**.

Epoxy Type	Indentation Modulus (GPa)	
	Mean	Standard Deviation
Without Epoxy	9.5	2.9
Devcon Epoxy	18.8	3.0
Devcon Epoxy	18.7	2.0
E90-FL	15.4	3.0
5-min Epoxy	17.3	5.0
2-ton Epoxy	19.5	2.0

Table 1. *Indentation modulus obtained from nano-indentation tests on Woodford drill cuttings mixed in epoxy (reproduced from Abousleiman et al, 2009).*

The stiffening of the Woodford clay phase could be the result of epoxy intrusion into pores during the mixing. Also, Woodford Shale has relatively large kerogen content as part of its porous clay phase. An affinity of kerogen to epoxy chemistry could exist that led to the stiffening of the total clay phase. Other mixing glues or materials could replace epoxy in future testing. In this study, the following scaling was applied to the measured indentation modulus to account for the stiffening of the clay phase:

$$M_{scaled} = M_{indentation} \frac{M_S}{M_{polymerized}}, \qquad (7)$$

where M_{scaled} is the clay phase indentation modulus adjusted for epoxy effects; $M_{indentation}$ is the indentation modulus measured by nano-indentation; M_S is the indentation modulus of the solid clay reported by Ulm and Abousleiman (2006); and $M_{polymerized}$ is the Voigt average of the solid clay indentation modulus calculated using the stiffness data reported by

Wang et al. (2001) and sample volume fractions of clay and kerogen from XRD analysis. For the particular depth where the shale cuttings were collected, the estimated $M_{polymerized}$ was approximately 45 GPa.

The upscaled Young's modulus of Woodford Shale samples mixed in epoxy is compared to those from nano-indentation testing and UPV measurements in ***Figure 6.*** The agreement between these results is promising as a future cost-effective technique for shale mechanical characterization.

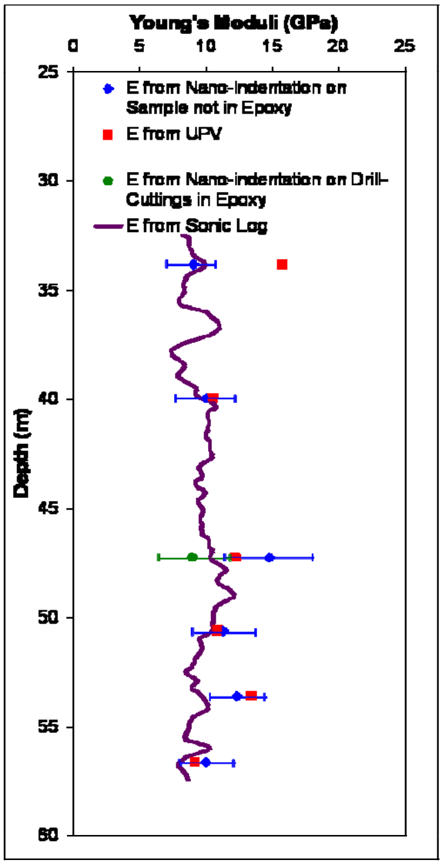


Figure 6*. Comparison between Young's moduli from UPV measurements and nano-indentation tests*

Barnett Shale characterization
A similar study was conducted on a deep vertical well (2500 m) drilled in the Barnett Shale formation. ECS mineralogy composition and calibrated log porosity showed that the Upper Barnett and Lower Barnett are separated by the Forestburg formation, as illustrated in ***Figure 7.***

The GeoGenome-simulated Young's modulus and shear modulus, E_3 and G_3, in the direction perpendicular to bedding were in excellent agreement with those derived from sonic log data, as shown in ***Figure 8.*** Moreover, the GeoGenome model also provided estimates of Young's modulus and shear modulus, E_1 and G_1, in a direction parallel to bedding which could not be obtained using sonic logging tools. The results demonstrate the applicability of the GeoGenome upscaling model to predict anisotropic mechanical properties for Barnett Shale formation.

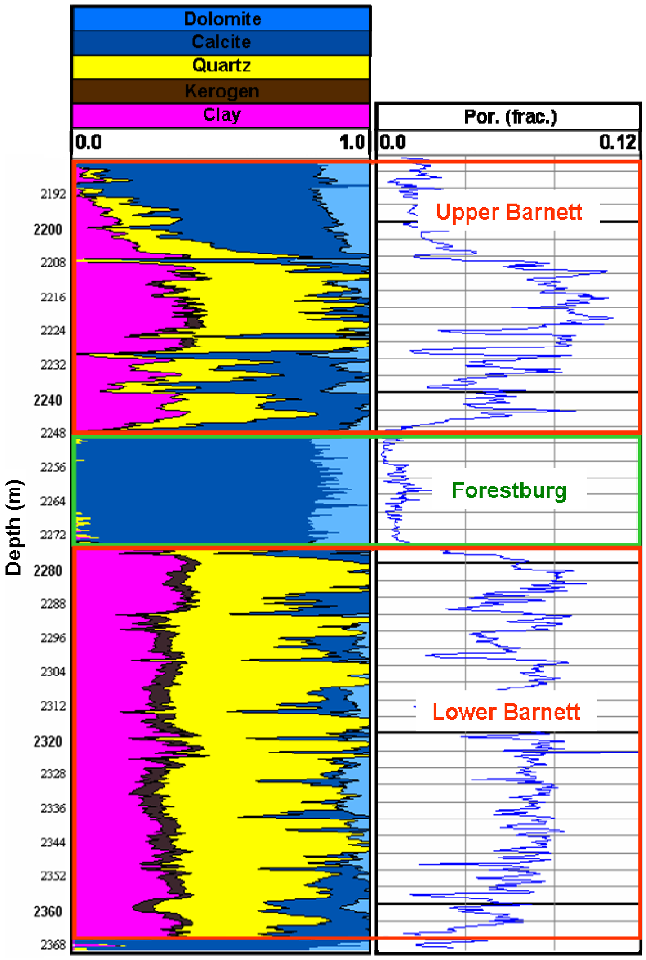


Figure 7. *Mineralogy and porosity of the Barnett formation (reproduced from Abousleiman et al, 2009)*

Conclusions
In this work, wells in the Woodford and Barnett formations were cored and logged. Anisotropic elastic and poroelastic properties of these formations were estimated from thousands of nano-indentation tests and mineralogy and porosity logs using the GeoGenome model. The results agreed with laboratory UPV measurements and sonic log results for properties in direction perpendicular to bedding. The GeoGenome upscaling model also provided estimates for properties in direction parallel to bedding, which cannot be easily obtained from logs. Nano-indentation tests on drill cuttings embedded in epoxy showed very promising results for a cost-effective technique for shale mechanical characterization.

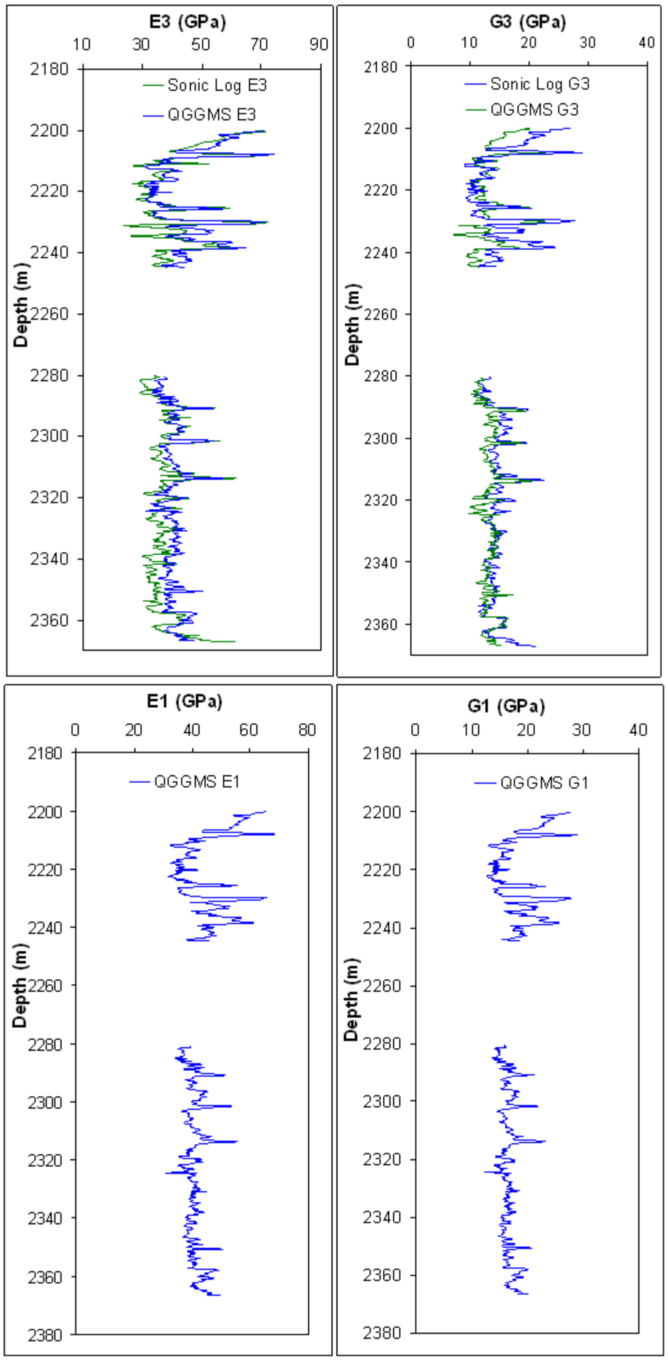


Figure 8. *Comparison between sonic log responses and GeoGenome-simulated results.*

Acknowledgements
The authors would like to thank Schlumberger and Devon Energy for sharing their log data. This work is partially funded by the Geo-Genome Industrial Consortium (G2IC) at the University of Oklahoma and the Massachusetts Institute of Technology.

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More "In-Progress" Photos of New Camp

Front view of the grand Dining Hall with Study Hall behind

Overview of the main campus

State-of-the-art kitchen

2010 Freshman Field Trip

GAIL HOLLOWAY, Instructor/Recruiter, ConocoPhillips School of Geology and Geophysics

Dr. Barry Weaver explains the geology at Capulin Volcano.

Dr. Madden discussing issues at the uranium processing plant.

Dr. Elmore and students outside Cañon City, Colorado

On Saturday, May 15, 2010, three vans left from the Sarkeys Energy Center parking lot bound for Texas, New Mexico, and Colorado. Led by Dr. Barry Weaver, eighteen first-year Geology and Geophysics majors experienced a week of world-class geology.

The Freshman Field Trip is run for students just starting out in the major. In order to attend, students must be a declared Geology and Geophysics major and must have taken at least one introductory geology class, but no higher-level geology classes. The trip is designed to reinforce the concepts taught in introductory geology and to introduce new aspects of geology that students will be studying in future classes. However, learning about geology is only one aspect of the trip. Equally important is the chance to create connections with fellow students. Since these students are all at the same point in their academic career, they will have many classes together before graduating from OU. By creating connections now, they will have a stronger future support network.

This was the third trip taken since the program was reintroduced in spring 2008. Students from the previous trips formed very cohesive groups and met regularly throughout the following semesters, both academically and socially. This has strengthened their performances in later classes – definitely one of the goals of the trip. For the second year, Dr. Barry Weaver was the principle professor leading the trip, assisted by staffer Gail Holloway. Dr. Doug Elmore and Dr. Andy Madden joined the trip for the two days spent in the Cañon City/Colorado Springs area. Rounding out the group were three undergraduate students from last year's trip, Dan Ambuehl, Jesse Blumenthal, and Rebecca Johnson.

This year's trip concentrated primarily on New Mexico and Colorado, with one stop in Texas. Geologic highlights of the trip included: Palo Duro Canyon, the Sandia Peak Tramway, Soda Dam, the Rio Grande Rift, Valles Caldera, Tent Rocks, dinosaur footprints along Skyline Drive, structures outside of Cañon City, a tour at a uranium processing plant, Garden of the Gods, the Mollie Kathleen gold mine, Spanish Peaks, and Capulin. In addition to the purely geological aspects of the trip, cultural/historical stops were also included, many of which also showed wonderful geological features/concepts including Bandelier National Monument and Old Town Santa Fe. The group was also excited to see OU's new field camp in Cañon City. It is still a work in progress, but it looks to be a great facility.

From comments received, the students not only learned a lot on the trip, but they also had a great time while doing so.

Preparing to go 1,000 ft. down into the Mollie Kathleen gold mine.

The group at Capulin National Monument. Front from left to right: Jesse Blumenthal (TA), Jason Li, Nathan Hasbrook, Mallory Irwinksy, Ellen Rosencrans, Jeff Westrop, Jen Digiulio, Scott Hasbrook, and Brooke Morris. Back from left to right: Hoang Bui, Thang Ha, John McMican, Kima Gore, Daniel Parizek, Tuan Nguyen, Rebecca Johnson (TA), Dan Ambuehl (TA), Shelly Wernette, Huong Dang, Dr. Barry Weaver, Uyen Nguyen, and Hung Nguyen.

Probabilistic Neural Network Inversion for Characterization of Coalbed Methane

***Malleswar Yenugu**, Jeremy C. Fisk and Kurt J. Marfurt, ConocoPhillips School of Geology and Geophysics, The University of Oklahoma*
Dennis Cooke, Santos Ltd, Australia

Malleswar "Moe" Yenugu
PhD Candidate
Geophysics

Summary

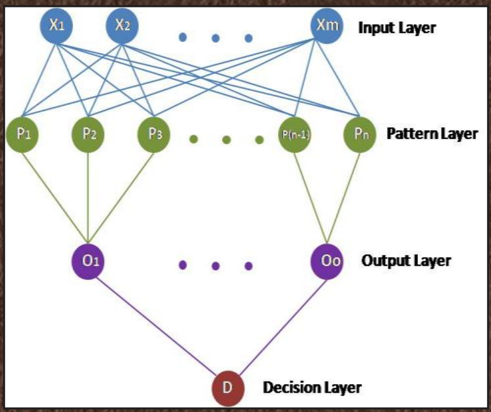
The seismic guided estimation of reservoir properties away from wells is a common problem that geophysicists, geologists and reservoir engineers face every day. This problem is due to low resolution of seismic data as well as the lack of proper models that link seismic data to borehole data. Geostatistical methods help resolve this problem, but these methods rely only on a linear fit between seismic attributes and reservoir parameters. Artificial neural networks are the best method to relate the non-linear fit between the borehole parameters to seismic volume parameters to better understand the heterogeneity of the reservoir properties. Probabilistic neural networks (PNN) are used to invert the seismic data of a coalbed methane (CBM) field from northeast Australia to better understand the reservoir properties of the coals sandwiched between sands and shales. PNN has not only helped to improve the vertical resolution but also the lateral variation of this heterogeneous reservoir.

Introduction

The contribution of production from the unconventional reservoirs like shale and coal is increasing everyday to meet the energy needs of the world. These reservoirs have low permeability often act as both the primary source rock as well as the reservoir rock. These are not only thin but widespread in the basin. The characterization of these reservoirs is a challenge to geoscientists in terms of resolution and distribution in an area. The calibration of well logs (high resolution) with 3D seismic data (low resolution) is a challenge when building comprehensive geological models.

Artificial Neural Networks (ANN) were introduced to the geosciences community in 1980's. ANNs have the ability to recognize complex, non-linear relationships between seismic attributes and petrophysical data. These relationships are applied to seismic data to predict inter-well reservoir properties. However, there is the danger that the neural network can become "over trained". That is, the fit at the wells is excellent, but the underlying model is too complex and does not lead to physically meaningful results away from the well. This problem is addressed by using the technique of cross-validation, in which we remove wells from the training stage and then 'blindly' predict these wells in the validation stage (Herrera et al., 2006). The objective of this paper is to apply probabilistic neural networks (PNN) to invert the seismic data volume to impedance by training and validating the acoustic impedance logs at the wells.

***Figure 1.** Basic design of a Probabilistic Neural Network*



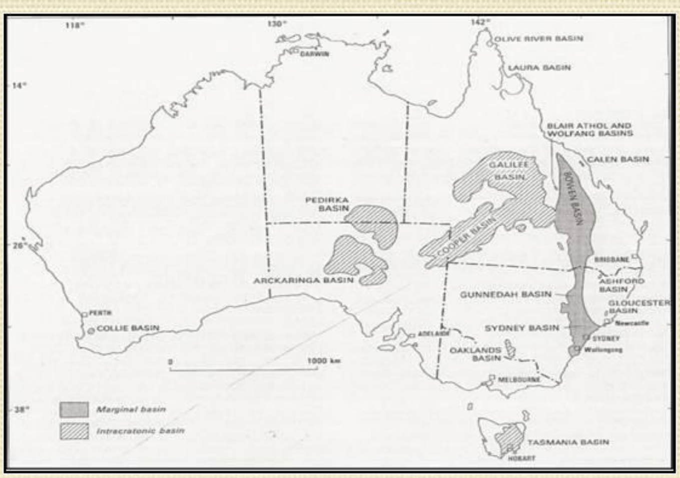
Probabilistic Neural Networks

The ability of ANNs to detect and recognize data patterns and to exploit functional, complex non-linear relationships between multiple data inputs provides for a powerful exploration tool. ANNs are robust in noisy or missing data sections and can solve ambiguities or differences between data inputs. ANN results are developed through repeated training. An input model may not be required to be successfully applied.

Since the 1980's many different artificial multi-layer feed-forward neural networks have been successfully applied to various geophysical problems. With good quality seismic and well log data, the PNN is favored. The PNN does not depend on an input forward model and does not require knowledge of the seismic wavelet. It has less of a 'black box' approach associated with it and tends to be more stable than the traditional multi-layer feed forward neural network (Hampson et al., 2001). A PNN is a mathematical interpolation method implemented via a 3-layered feed forward neural network architecture. Training involves only one pass through each training node. The output target log values are assumed to be a linear combination of the log values available in the training data. **Figure 1** shows the basic design of a Probabilistic Neural Network.

The PNN uses Gaussian weighting functions which fit the seismic attributes to the training samples by a generalized nonlinear regression approach. The key parameter in the PNN method is the sigma factor, which controls the width of each Gaussian function. The sigma factor is allowed to vary for each input attribute (Hampson et al., 2001). The main advantages of PNNs are that they are not dependent on an initial set of weights. Second, the weights are determined entirely from the data, and there is no problem with convergence to a solution. Cross validation systematically removes each well used in the training process from the training set. The multiattribute transform is recalculated with the well absent, or hidden, from the training process. The average predictive error of all the hidden wells is referred as the validation error. The validation error is the error associated with applying the PNN to the entire seismic data volume. Multiattributes, used as PNN inputs, may be geologically disconcerting; many attributes may be statistically significant but do not have theoretical explanations (Leiphart and Hart, 2001). Multi-attributes must be interpreted within a geologic framework, not a statistical one. Geologically plausible and physically realistic results are necessary to be confidently used for exploration and exploitation purposes.

Figure 2. *The geographic location of the Bowen basin in Australia (after Hunt et al., 1989)*



Example

The principles of PNN are applied on a coal bed methane reservoir to invert the seismic data to acoustic impedance volume to characterize the reservoir. This field is located in the Bowen basin, Northeast Australia. The Bowen basin is Permian-Triassic and a major economic coal basin that extends approximately 900 km in a generally north to south direction in the eastern portion of Queensland, Australia**.** **Figure 2** is a map of Australia which outlines the approximate geographical limits of the Bowen basin in Queensland. The Bowen basin is considered a marginal basin due to its location being marginal to the cratonic platform. Deep troughs on the eastern side of the basin developed because of the New England orogen thrusting and crustal thickening. These troughs were subject to high rates of subsidence in the late Permian. Toward the end of the Permian, the coal measures formed in environments described as fluvio-deltaic with fluvial elements transitioning to paludal. Marginal basins in Australia tend to be characterized by a thicker sequence of coals broken into numerous coal seams and generally contain a lower coal to sediment ratio than intracratonic basins (Hunt et al., 1989).

In this study, we used five wells which have seismic to well ties from synthetic seismograms. Impedance logs were generated using the P-wave and density logs at the well locations and these logs were trained using probabilistic neural networks. An impedance model was built initially by using horizons of interest. This initial model along with amplitude envelope and amplitude weighted cosine phase of seismic data have been used as seismic attributes along with the impedance logs to predict the impedance logs at the well locations. **Figure 3** shows the actual and predicted impedance logs of the wells. A total of 25 sigmas have been used for training with the value of sigmas ranging from 0.1 to 3, with the global sigma of 0.825 used.

A crossplot of actual and predicted impedance values using points from the analysis windows of all five wells is shown in **Figure 4.** The correlation coefficient for the linear regression using 3 attributes is 0.8287 with an average error of 3440.42 [(ft/s)*(g/cc)]. However, the validation results of PNN show a cross correlation coefficient of 0.7012 with an average error of 4152.23 [(ft/s)*(g/cc)] **(Figure 5).** PNN based prediction of impedance logs retains more of the dynamic range and high-frequency content as can be seen at the well locations, because the PNN result is a nonlinear function and closely follows the training or control data.

The training values that we computed are applied to the whole seismic data volume to invert it into impedance volume. **Figure 6** shows the line that intersects well-A extracted from the impedance volume. The vertical as well as the lateral resolution of the volume has been increased.

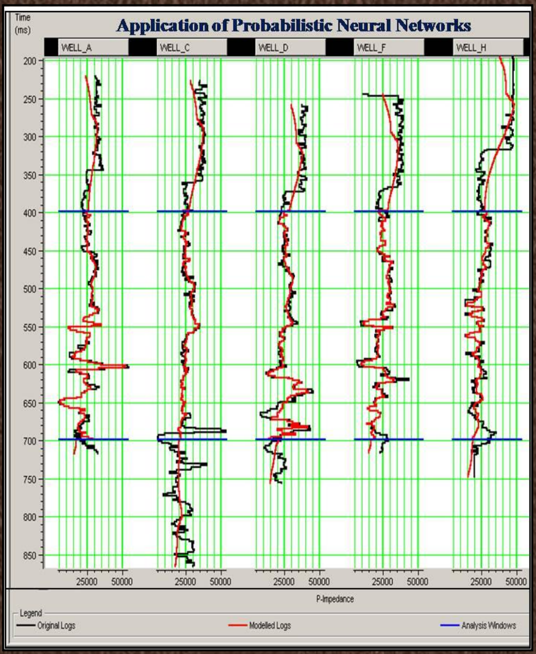


Figure 3. *Application of the probabilistic neural network (PNN) comparing the predicted impedance logs and the impedance logs that were used in the training.*

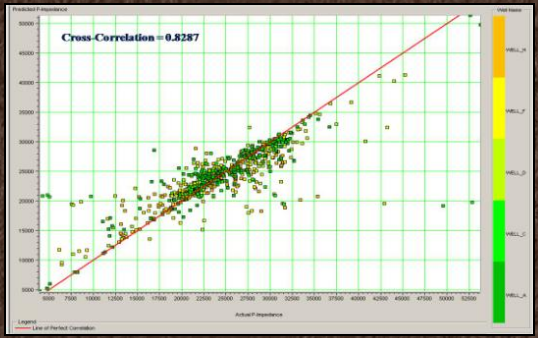


Figure 4. *Cross-plot between actual and predicted impedance logs of all the wells.*

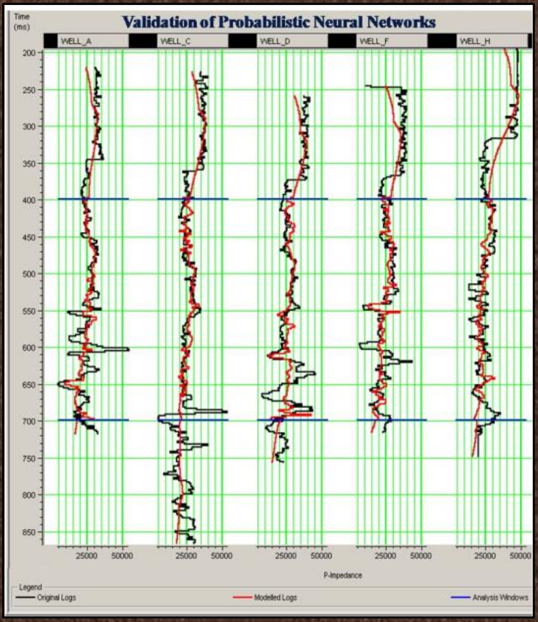


Figure 5. *Validation of the PNN using the predicted and actual impedance logs*

This figure clearly shows the distribution of high impedance shales with moderate to low impedance coals. The impedance volume has been viewed by extracting impedance values along the horizons between the horizons and horizontal time slices to understand the deposition of coalbed methane reservoirs. **Figure 7** shows a horizontal data slice extracted from the impedance volume. It clearly brought out the distribution of different lithofacies with lateral variation of impedance values.

Conclusions

The main advantages of the probabilistic neural network inversion of seismic data are not only improved vertical and lateral resolution but it also uses cross-validation as a quality assurance tool. The tie between seismic and well logs is very important especially in thin bed reservoirs. We used PNN to invert the seismic data to exploit the thin-bedded coalbed methane reservoir. PNN also gave better results when compared to other methods like band-limited, colored, sparse-spike inversion techniques.

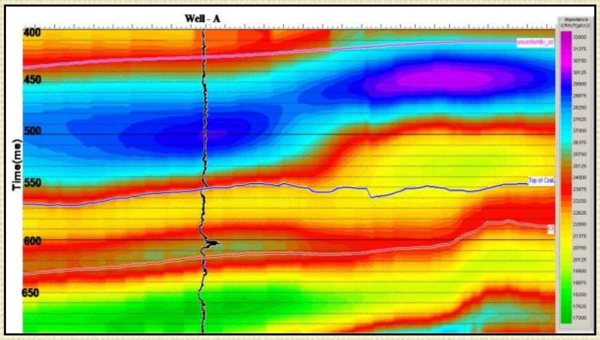


Figure 6. PNN impedance cross section along the well-A

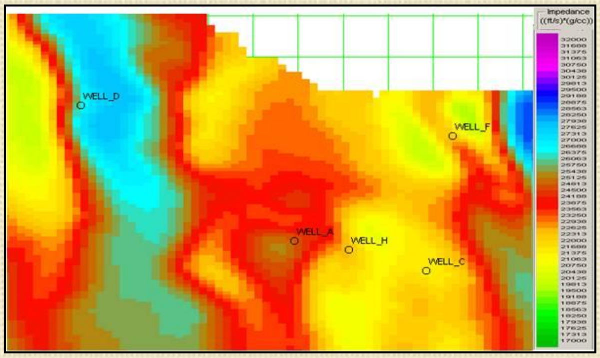


Figure 7. Data slice from the PNN impedance volume

Acknowledgements

Thanks to Santos Ltd, Australia for giving permission to use their data set. Thanks also to Hampson-Russell software Ltd for providing academic license.

Research in Scotland: Paleomagnetic Dating of Fracturing Using Breccia Veins in Durness Group Carbonates and the Paleoplumbing of Scotland

R. Douglas Elmore, Director and Eberly Family Chair Professor, ConocoPhillips School of Geology and Geophysics

For the last fifteen years or so Mike Engel, John Parnell (University of Aberdeen), and I have been conducting research in Scotland. We have recently focused on investigating if the faults in Scotland were conduits for fluids in Scotland and diagenetic alteration **(Figure 1)**. Numerous students have been involved doing M.S. theses (Lisa Plaster-Kirk, Mica Davidson [now Feinstein], and Sharon Woods, Raleigh Blumstein), undergraduate theses (Shannon Dulin), or helping collect samples (Scott Imbus, Glen Bixler, Michelle Abraham, Mat Elmore, Dan Engel, and Stacey Evans). Scotland is a great place to visit, particularly when the weather is good, with lots of classic geology **(Figures 2 and 3)**. I will first describe our most recent project and then provide a summary of what we have done over the last fifteen years.

Figure 1: *Map of Scotland with the major faults and locations where we have conducted studies.*

Paleomagnetic Dating of fracturing using breccia veins in Durness Group carbonates, NW Scotland (Journal of Structural Geology)

Clastic veins or breccias are becoming recognized in numerous geologic terranes (e.g., Wright et al., 2009; Wilson et al., 2010) and some con-tain sediment infills (e.g., Beacom et al., 1999). Most of these breccias are interpreted to be related to faulting (e.g., Woodcock et al., 2006) and they can also be sites for precipitation of hydrothermal minerals (e.g., Sibson 1986). Determining the timing of movements on such faults is frequently problematic. Paleomagnetic analysis is one approach that can provide constraints on the timing of faulting events (e.g., Dulin et al., 2005).

Fault-related breccias occur in the Cambro-Ordovician Durness Group carbonates in northwest Scotland, adjacent to the Moine Thrust Zone (MTZ) **(Figure 3)**. These breccias cut through the carbonates of the Durness Group and display evidence that they were conduits for the migration of fluids that caused diagenetic alteration (e.g., hematite authigenesis, calcite cementation). In addition to determining the timing of faulting and diagenetic alteration in the veins, the study should provide information on fluid migration pathways and possible connections between the fluids and orogenic or other geological events.

Figure 2: *Picture of Hutton's angular unconformity at Siccar Point on the east coast of Scotland. Vertical Silurian sandstone is below the unconformity with gently dipping Upper Devonian sandstone above. This is a classic location in geology.*

The veins contain brecciated fragments of the host Durness Group and strike either east-west or north-south. Clasts of breccia cemented by calcite suggest multiple brecciation events. The host Durness Limestone is a gray dolomite and contains a Devonian chemical remanent magnetization (CRM) that resides in magnetite The veins contain CRMs that reside in hematite. The breccias in north-south veins contain a Triassic CRM whereas the veins with east-west strikes contain a Jurassic CRM. Authigenic hematite is common in the breccias along growth planes in the calcite cements. The two CRMs within the veins are interpreted as dating two separate brecciation and fluid flow events that precipitated authigenic hematite. The brecciation and fluid flow events are interpreted to be related to extension in the Mesozoic which is consistent with the extensional history of the northern Atlantic margins.

Dating Fluid Flow Events in Scotland

Our studies suggest that there were multiple fluid flow events along faults in Scotland **(Figure 1)**. We have dated a Permian-Triassic fluid-flow event associated with dolomite veins in the Dalradian Schist in the Southern Highlands (Parnell et al., 2000) and a Permian event along the Highland Boundary Fault (e.g., Elmore et al., 2002). Blumstein et al. (2005) reported that four fluid flow events (Devonian, Permian, Mesozoic, and Early Tertiary) occur in different lithologies along the MTZ from Skye to Durness, and can be related to specific geologic events such as hydrothermal fluids associated with Devonian and Tertiary igneous activity. Elmore et al. (2006) report that fluid flow events that caused hematite precipitation occurred along different segments of the Great Glen Fault in the Permian and the Cretaceous. Woods et al. (2000) describe how hydrothermal fluids and heat caused diagenetic alteration on Skye.

These studies provide evidence that dormant faults or fault systems can be conduits for localized fluid flow events at different times. Since the magnetizations are younger than the Caledonian orogeny, they are not necessarily related to major orogenic events (i.e. continent-continent collision) but can be related to more localized igneous and tectonic activity. The fluid flow events caused hematite mineralization, other diagenetic features, and the faults may have provided the paleoplumbing for diagenetic fluids in Scotland.

Figure 3: *A breccia vein (E-W) in the center of the photo at the Balnakeil location. The vein is ~20cm thick.*

Prior to the summer of 2009, we had found that three (MTZ, Highland Boundary, and Great Glen) of the four major faults in Scotland were conduits for fluids. We sampled the fourth major fault, the Southern Upland Fault **(Figure 1)**, in southern Scotand, during the summer of 2009 for Stacey Evans' M.S. thesis. Stacey did a good job sampling around the fault but unfortunately, the carbonate rocks we sampled had very weak and unstable magnetizations. As a result, Stacey has moved on to another project. We are still thinking about the significance of the negative result from the fault.

Locating a Historic Norman Gravesite with Geophysical Methods

John Leeman, *B.S. Candidate, Geophysics/Meteorology, University of Oklahoma*
Katie Keranen, *Assistant Professor, ConocoPhillips School of Geology and Geophysics*

The worst fire in Norman history occurred on April 14, 1918. It is believed an electrical fault started a fire in the early morning hours at the Oklahoma State Hospital for mental patients. As patients were evacuated the firefighters rushed into the structure to attempt more rescues. Two buildings were destroyed and others damaged. The first floor ward, which contained 48 male residents 10-15 years old, reported 38 deaths. Some of the deaths were attendants, but all of the bodies were burned beyond recognition and placed in one grave in the IOOF (Independent Order of Odd Fellows) Cemetery near Rock Creek Road.

Over 90 years later, the University of Oklahoma's Principles of Geophysics class went to the IOOF cemetery to attempt to locate the gravesite in collaboration with the Oklahoma Archaeological Survey. The location was specified in historical documents as the northeastern portion of the cemetery, but the exact location had been lost. Armed with ground penetrating radar, seismic gear, magnetometers, and an electrical resistivity apparatus, the students, headed by Assistant Professor Dr. Katie Keranen, spent a Saturday in the field.

Title Photo: Students collect data at the IOOF cemetery located off Rock Creek Road in Norman (left to right) Ahmed Awami, Brittany Pritchett, John Leeman, and Brandon Guttery. (Photo: J. Chang)

While the GPR, seismic, and magnetic methods were carried out with commercial equipment, the electrical resistivity measurements were attempted with a new homemade demonstration device. The device, built by John Leeman and loosely based on a design by Herman (2001), consisted of a deep cycle battery, electrical inverter, two digital multi-meters (DMM), copper grounding rods, and a simple control box **(Figure 1)**.

The basic principle of operation is to place a current across two electrodes and measure the potential difference across the pair of electrodes. While the geometry of the electrode spacing can vary, the general idea is that increasing electrode spacing systematically obtains a vertical sounding of apparent earth resistivity. Commercial units use large arrays of electrodes and computerized switching to collect a greater number of data points with great speed, but this method was much more hands-on.

Students set up the electrodes and then took readings of current and voltage in various array configurations by manually plugging electrodes into different metering ports on the control box. Then the power was turned off, the electrodes were moved, and the process repeated. This was done in the two areas likely to contain the grave. In one of the areas, two different electrode configurations were tried, including a square, which allows the electrical anisotropy of the material below to be examined.

Figure 1: The simple equipment needed for a resistivity survey. Inverters (left), control box, meters, charger, and electrode solution (center), and copper rods/battery (right). (Photo: J. Leeman)

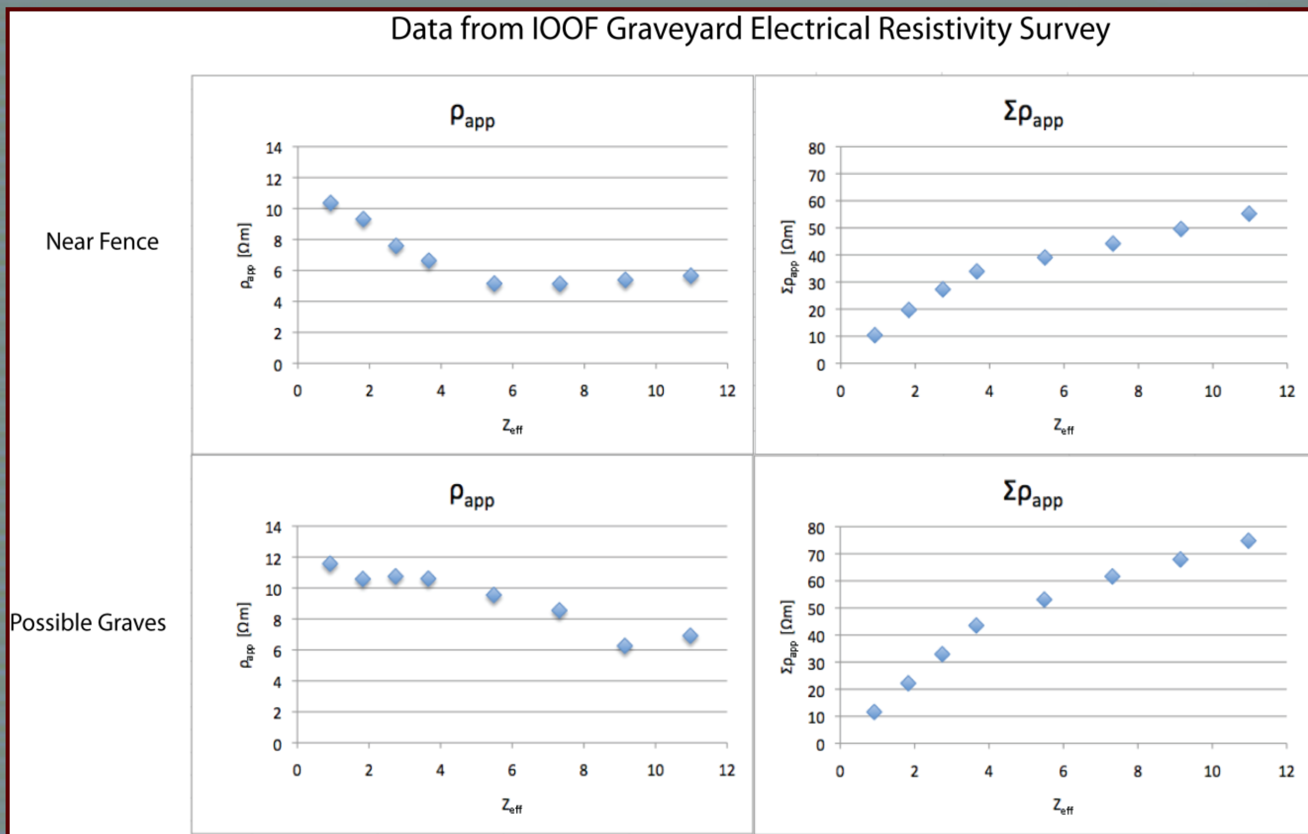


Figure 2: Data collected at the IOOF cemetery near the fence (top) shows a basic two layer structure, but the data collected over the believed gravesite (bottom) shows an anomaly 2-4 m deep which is the expected depth of the graves. This is most easily viewed on the graph of ρ_{app}.

A simple spreadsheet allowed the data to be plotted in real time so areas of interest could be determined and examined in more detail by using finer electrode spacing. **Figure 2** shows the results of the experiment. Data is plotted with effective depth on the x-axis (Z_{eff}) and either apparent resistivity (ρ_{app}) or the sum of apparent resistivity ($\Sigma\rho_{app}$) on the y-axis. The top row examines an area near the corner of the cemetery by the fence. The bottom row is what we believe to be the most likely location of the graves. Notice the anomaly 2-4m below the surface. This could be the graves as it is the correct depth and shows up on all array configurations. This particular data set was collected in the Wenner β configuration.

This experiment allowed students to have a more hands-on experience with the electrical resistivity method and resulted in a deeper understanding than would have been gained by using a commercial instrument that would automatically switch out all settings and easily plot the data. In addition, this setup can be easily used in a classroom environment as a tabletop demonstration of the method, as it can easily resolve the difference between soil, a plastic container, and the table.

John Leeman

John Leeman, *B.S. Candidate, Geophysics/Meteorology, University of Oklahoma*
Megan Elwood Madden, *Assistant Professor, ConocoPhillips School of Geology and Geophysics*

COLLABORATIVE GAS HYDRATES RESEARCH AT OU

Gas hydrates (clathrates) are cages of water molecules surrounding guest molecules such as methane or carbon dioxide. Sir Humphry Davy first characterized hydrates in the early 1800's, but many things about the structure, formation, and dissociation of hydrates are not well understood. Hydrates have always been a concern to industry from a drilling safety standpoint and have even caused problems in pipelines by forming clathrate 'plugs' resulting in downtime. Gas hydrates also represent a massive reserve of methane, an estimated 6.4 trillion tones of methane (Buffett and Archer, 2004). This stored gas has inspired the 'Clathrate Gun Hypothesis' which suggests that a climate shift could destabilize gas hydrates releasing more greenhouse gas into the air in a positive feedback cycle (Kennett et al., 2003). Hydrate could also be an energy source as shown in the Prudhoe Bay and North Slope tests of recent years (Boswell, 2007). Dissociating one liter of clathrate will yield about 164 liters of gas!

Students and faculty at the University of Oklahoma are currently conducting clathrate experiments on a variety of scales to better characterize and monitor hydrates. At OU experiments are taking place in Dr. Megan Elwood Madden's lab using small (<1L) pressure vessels to study the rate at which hydrate forms and decomposes under various temperature and pressure conditions. These experiments are being performed with carbon dioxide as well as methane to allow application of the results from Earth to other planets (Leeman and Elwood Madden, 2010).

In collaboration with Oak Ridge National Laboratory, John Leeman has been working with the 72L Seafloor Process Simulator (SPS) for two years as a summer intern. This large pressure vessel is made of corrosion-resistant Hastelloy and cooled in a commercial cold room with an explosion-proof gas evacuation system. The SPS allows hydrate to be formed in an ocean floor environment under thousands of pounds per square inch pressure and just above the freezing point of water (Phelps et al., 2001). A sediment column is built within a PVC bucket, fit with instrumentation, and lowered into the SPS. The vessel is cooled and pressurized to form gas hydrates within the sediments.

Title Figure: Sealing the lid of the SPS with a hydraulic torque wrench.

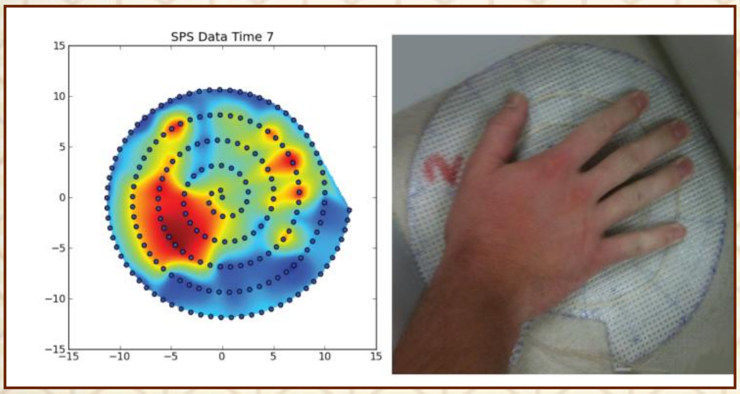


Figure 1 – A hand placed on a spiraled DSS fiber is easily resolved with the fiber optic sensing system.

Leeman and Dr. Elwood Madden have worked with ORNL colleagues to develop a unique instrument to monitor hydrate formation and decomposition within the SPS. Fiber optic cables with Bragg gratings embedded every 1cm along their length are spiraled in the sediment. By sweeping a laser optical backscatter reflectometer through a range of wavelengths each grating is interrogated for changes in its characteristics. From this a 'Temperature Strain Value' (TS value) can be calculated and used as a combined proxy for temperature and physical forces at that location on the fiber (Hill and Meltz, 1997). John Leeman has developed software to estimate the position of each sensor in space given the orientation and vertical distribution of the fibers, grid the TS data, and show areas of high and low TS value (Leeman et al., in preparation). Shown in **Figure 1** is an experimenter's hand placed on a fiber and the output of the in house software.

A variety of experiments have been conducted in the SPS. A split column experiment has been conducted with sediment split vertically with a plastic mesh and filled with sand and silt. This experiment was conducted to investigate the effect of grain size on hydrate formation and to determine if the instrumentation in the sediments provided a pathway along which the gas was flowing**.** **Figure 2** shows the results of the experiment in which it is clear that the areas of hydrate (hot colors) are in the sand. In addition, a heat induced production test is currently underway. Hydrate is synthesized within a sand column; the hot water is pumped through a heat exchanger deep in the column to dissociate the hydrate and free the gas. Hydrate dissociation is endothermic, so it becomes colder leading to self-preservation. The effect of continuous heat flow on hydrate production rates will be determined by constantly pumping hot water through the system.

Experiments are also underway to determine fundamental properties of hydrates such as the bulk modulus. Claudia Rawn, an ORNL materials scientist, obtained beam time on a neutron diffractometer at the High Flux Isotope Reactor (HFIR). Hydrates were synthesized in the lab using deuterium and CO_2. The clath-rate was then cold loaded into a TiZr cell and neutron diffraction experiments conducted up to 100,000 psi. Samples were also taken to ORNL's Spallation Neutron Source (SNS) for analysis. Other samples were also loaded onto a computer controlled cold stage in a PANalytical X-ray diffractometer. With the Xcelerator detector diffraction patterns can be detected up to 100 times faster than conventional instruments allowing the evolution of the diffraction pattern to be examined increasing temperature of the sample stage decomposes hydrate.

Through collaboration with ORNL we are continuing to learn new things about clathrate formation and hazards. This research impacts natural gas production technology, climate modeling, risk assessment, and even planetary research.

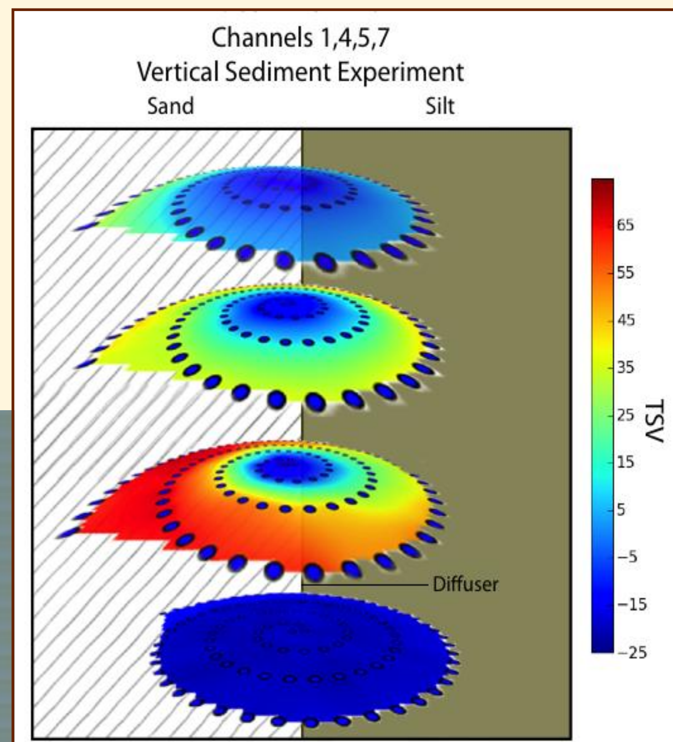


Figure 2 – Clathrate shows a clear formation preference in the sand, indicated by hot colors. The silt has some hydrate forming along the edges of the sediment column.

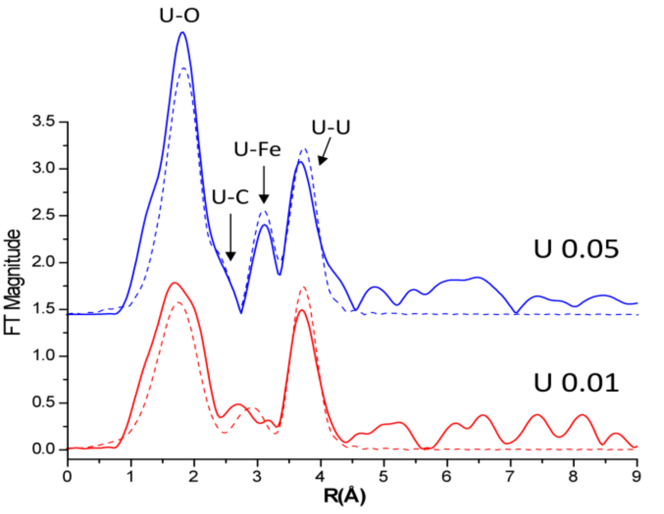
Long-term Fate of Ferric Oxyhydroxide Associated U(VI) During Biological Magnetite Formation

Andrew L. Swindle[1], Andrew S. Madden[1], Melanie J. Beazley[1], Ji-Won Moon[2], Bruce Ravel[3], Tommy J. Phelps[2]
[1]University of Oklahoma, [2]Oak Ridge National Laboratory, [3]Brookhaven National Laboratory

Uranium is a groundwater contaminant at a number of sites across the country, including many managed by the U.S. Department of Energy (DOE). The metal is both toxic and radioactive and is typically encountered in the environment as either mobile hexavalent uranium (U(VI)) or relatively immobile tetravalent uranium (U(IV)) (Ilton et al., 2010). One potential uranium remediation technology being investigated involves using iron-reducing bacteria to reduce mobile U(VI) to immobile U(IV) thereby sequestering the uranium within the aquifer solids (Schofield et al., 2008). However, the fate of uranium co-reduced with ferric iron has not been resolved. Previous investigations have provided distinct possibilities including: 1) incorporation into the magnetite structure as U(VI), 2) incorporation into the magnetite structure as U(IV), 3) sorption onto iron oxides as uranyl ions (UO_2^{+2}), 4) separate iron and uranium precipitates (Duff et al., 2001, Nico et al., 2009). Each of these possibilities has implications as to the long-term stability of co-reduced uranium and the ultimate viability of in-situ microbial metal reduction as a uranium remediation technology.

Utilizing uranium-doped bacterial culture-mineral slurries, the fate of uranium during biological magnetite formation was investigated by U L_{III}-edge X-ray absorption near edge spectroscopy (EXAFS) performed at the Advanced Photon Source (APS), transmission electron microscopy (TEM) performed at the Samuel Roberts Noble Electron Microscopy Laboratory, and X-ray diffraction (XRD) performed at the Devon Energy NanoLab. Uranium-doped culture-mineral slurries contained 0.4 M of metals, with the exact concentrations of Fe and U dependent on the desired cation mole fraction of uranium desired (Moon et al., 2007). For these experiments, the cation mole fractions of $U_{0.05}Fe_{0.95}$ (0.05) and $U_{0.01}Fe_{0.99}$ (0.01) were investigated. Culture-mineral slurries were prepared in August 2007, with EXAFS analysis conducted shortly after incubation. TEM and XRD analyses were completed November 2009 through June 2010 providing the opportunity to investigate the long-term results of the experiment as well as the ability to compare short- and long-term data.

EXAFS fittings indicate that the predominant form of uranium in the culture-mineral slurries is uraninite **(Fig. 1).** Theoretical model fittings indicate a U-U coordination number of 5-6, indicative of particles in which atoms at the surface dominate the signal, which is typical of nano-particles. In addition, the modeled U-U bond length of less than 3.87 Å indicates uraninite particles of approximately 2-3 nm (Bargar et al., 2008, O'loughlin et al., 2003, Schofield et al., 2008, Suzuki et al., 2002). The 0.05 uranium slurry also indicated a U-Fe and U-C association, though they represent a small volume of the total uranium in the slurry. Based on modeling, the U-Fe association is indicative of a sorption scenario rather than an incorporation of uranium into an iron mineral structure, while the U-C signal is likely the result of uranium that has associated with organic carbon from the slurry.



Sample	Atoms	N	R (Å)	σ²
U 0.05	U-O	6.5 (1.2)	2.33	0.013
	U-U	6.0 (2.2)	3.85	0.010
	U-C	1.8 (0.2	2.92	0.003
	U-Fe	0.35 (0.35)	3.52	0.005
U 0.01	U-O	9.3 (2.8)	2.32	0.027
	U-U	5.0 (1.8)	3.85	0.009
	U-Fe	1.7 (2.5)	3.41	0.015

Figure 1 *– EXAFS fittings of culture-mineral slurries. Note the U-U coordination numbers of 6.0 and 5.0, indicative of atoms at the surface dominating the signal, typical of nano-particles. The U-U coordination number for bulk uraninite is 12.*

TEM analysis revealed four dominant crystal morphologies in both culture-mineral slurries **(Fig. 2).** Utilizing electron diffraction patterns and Energy Dispersive Spectroscopy (EDS) the minerals associated with the various crystal morphologies were identified as magnetite, akaganéite, goethite, and uraninite **(Figs. 3 and 4).** The uraninite particles identified in the TEM samples ranged in size from ~50 to ~100 nm, approximately one order of magnitude larger than indicated by the EXAFS fittings (Figure 4). EDS spectra collected from magnetite and uraninite in the 0.05 culture-mineral slurry confirmed the U-Fe and U-C associations indicated in the EXAFS fittings **(Fig. 5).** XRD analyses of the culture-mineral slurries confirmed the mineralogies identified in the TEM **(Fig. 6).**

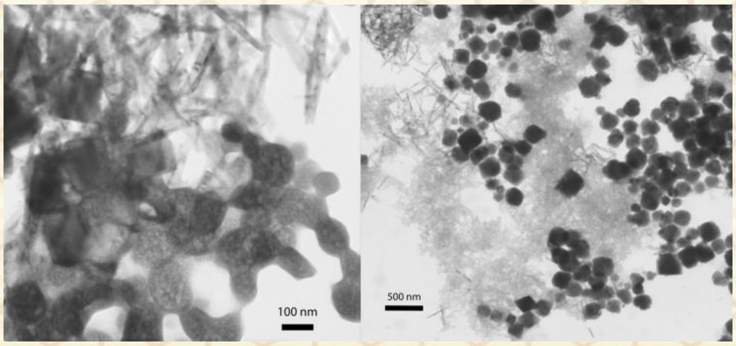


Figure 2 *– General morphologies of the culture-mineral slurries. Left = 0.05 U slurry. Right = 0.01 U slurry. Dominant morphologies in each slurry consisted of octahedra, small and large rods or laths, and spherules.*

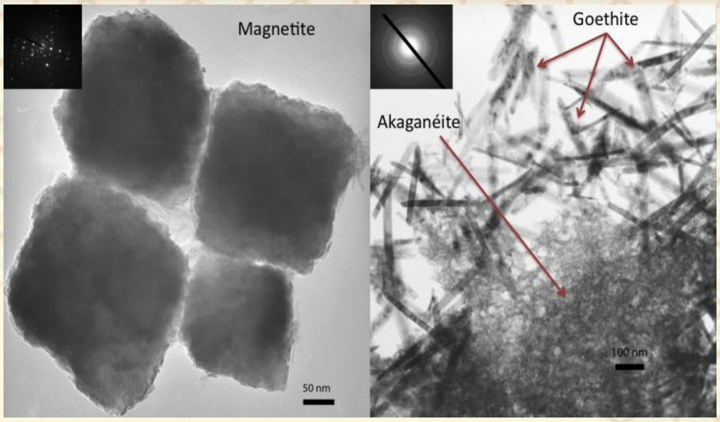


Figure 3 *– Displays the various morphologies identified as the iron-bearing minerals magnetite (left), goethite, and akaganéite (right). Unreduced FeOOH can be seen covering the edges of magnetite. Electron diffraction patterns used to verify mineralogy are inset in the upper left corner of each image.*

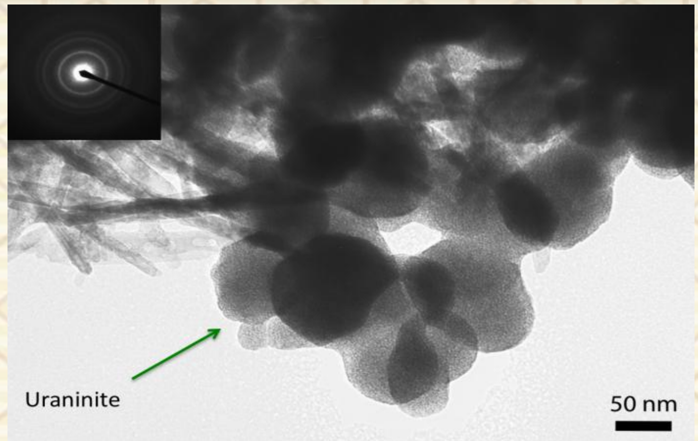


Figure 4 *– Displays the morphology identified as uraninite. Electron diffraction pattern used to verify mineralogy is inset in the upper left corner of the image.*

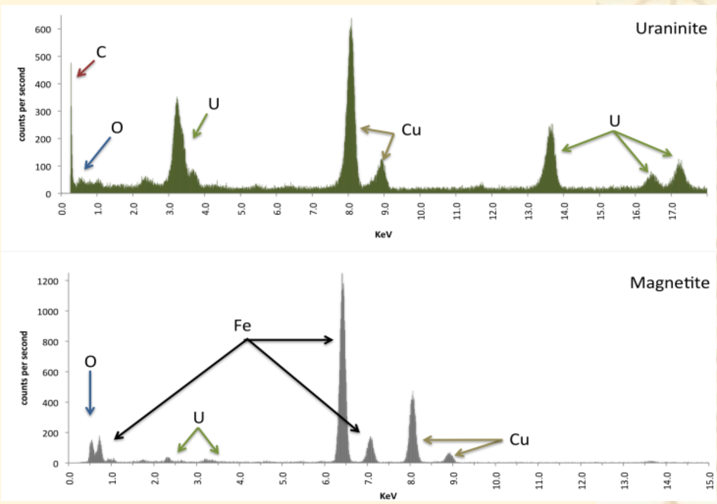


Figure 5 *– EDS spectra collected from the uraninite (top) and magnetite (bottom) particles in* ***Figures 4*** *and* ***3****, respectively. Collected spectra verify composition of the identified mineralogies. Indicated U-C (uranin-ite) and U-Fe (magnetite) associations are consistent with EXAFS fittings. Cu in both spectra is from the detector housing.*

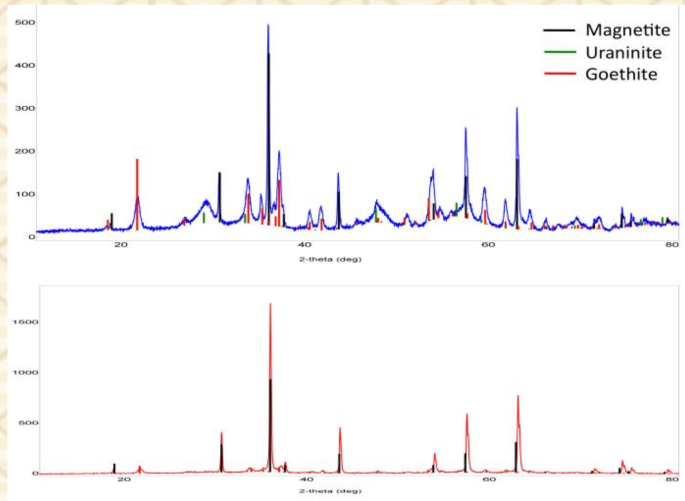


Figure 6 *– XRD data verifying mineralogies identified via EXAFS and TEM. Smaller goethite and uraninite peaks in the 0.01 U culture-mineral slurry indicate that those minerals constitute a smaller percentage of the overall sample compared to the 0.05 U culture-mineral.*

As previously discussed, EXAFS fittings indicated that in both slurries the predominant form of uranium was uraninite nano-particles approximately 2-3 nm in size, considerably smaller than the uraninite particles observed in the TEM images. Several TEM images show uraninite particles undergoing apparent crystal growth, indicating that crystal growth may be occurring in the slurries **(Fig. 7).** Reactivity and solubility of solids tends to increase as surface area increases; therefore, nano-particles tend to be very active chemically due to their large surface area. The long-term stability of biogenic uraninite nano-particles has been questioned as these particles were thought to be unstable in the environment (Bargar et al., 2008, O'loughlin et al., 2003, Suzuki et al., 2002). Our experiments indicate that under reducing conditions nano-uraninite crystals may grow, thereby becoming more resistant to dissolution or reoxidation.

ANDREW SWINDLE
M.S. in Geology

ACKNOWLEDGEMENTS

We would like to thank the U.S. Department of Energy (DOE) for providing financial support for this investigation. Additional financial support was provided by the Oak Ridge Associated Universities Ralph E. Powe Award to ASM.

We would also like to acknowledge technical support provided by Greg Strout at the Samuel Roberts Noble Electron Microscopy Laboratory, and the scientists and supporting staff at the APS BM20.

MICHAEL SOREGHAN, Assistant Professor, ConocoPhillips School of Geology and Geophysics

Dr. Soreghan talking to students in the Wichita Mountains.

Students hiking to a spring in the Arbuckle Mountains.

Students conducting an experiment about solar radiation.

Excitedly hopping onto a large boulder and gazing around in a full circle at the landscape of the Wichita Mountains under a June noonday sun, the petite seventh grader ignored the heat and bugs she had been complaining about moments before and shouted for all to hear, "Wow, I've never been on the top of a mountain before!" The reaction of the kids during the "hike to „Little Baldy' " as part of one of two field trips we run during the ExxonMobil Bernard Harris Summer Science Camp at the University of Oklahoma is one of my favorite times as academic director for the camp. The Summer Science Camp is in its fourth year at the University of Oklahoma and is run by The ConocoPhillips School of Geology and Geophysics and Precollegiate Programs, part of OU's College of Continuing Education. The camp is part of a national program sponsored by ExxonMobil and the Bernard Harris Foundation to serve middle-school students from historically underserved and underrepresented groups in highlighting the critical importance of science, technology, engineering and math (STEM) in a fun, engaging way. OU has been a part of this expanded network since the program expanded from two schools in 2006 to thirty universities across the nation this summer and the OU camp has now "graduated" almost 200 students from all over Oklahoma.

The theme for our camp is "Earth Cycles" and students focus on the natural cycles of rock, water, weather and carbon. Within this broad canvas of Earth Science we touch on a number of interactions and connections among Earth processes. For example in our hike to Little Baldy, the students identify outcrops of rock and "map" a change from gabbro to granite and then are asked to describe the attendant change in vegetation from scrub oak (underlain by gabbro) to grasses and annuals (underlain by granite). Also, we study how weathering of soil and rock can change the composition of the groundwater as it passes through soil and rock, and then experience this directly during a fieldtrip to the Arbuckle Mountains when we compare the taste of spring water around

Sulphur, OK. Another example is how the carbon cycle is related to each of the other cycles, as the students pretend to be a carbon atom and track their movement among the different reservoirs for carbon, including the atmosphere, biosphere, soil, rock and ocean. Students learn that affecting one part of the cycle certainly impacts other components of this system. The group of teachers that worked with us was fantastic in keeping student interest high and in running the lessons in a fun, engaging way.

We also focus on how STEM fields are critical for solving problems caused by human's impact on these natural cycles, such as looking at alternative energy sources, designing simple water filters and building solar cookers. This latter project took on added excitement because we have arranged to bring the student built solar cookers to Tanzania and donate them to TACARE (Lake Tanganyika Catchment Reforestation and Education Project) located in Kigoma, Tanzania along the shore of Lake Tanganyika. One of the charges of this community-based conservation program is to alleviate the rapid deforestation of indigenous forests in the regional lake catchment which has impacted the lake itself (see related article on Dr. Soreghan's recent research award). Most of the deforestation occurs to provide cooking fuel in order to boil water, and thus alternative means of heating water will not only save the forests, but also the time invested in harvesting the fuel wood. The program coordinator for TACARE will take the students' solar cookers into the surrounding villages and track their use.

Students constructing a floating raft from foil and straw. Contest was held to see which raft could hold the most pennies before sinking.

Dr. Bernard Harris and ExxonMobil geologist with teaching staff of Earth Cycles Camp.

The two-week camp incorporated tours as well to see how scientists and engineers work. We visited the The ExxonMobil Lawrence G. Rawl Engineering Practice Facility where the students were greeted by Dean Larry Grillot and then met Dr. Bernard Harris, the foundation head, medical doctor and former NASA astronaut who flew on two shuttle missions in the 1990's. He was also a highlight for the students, because he is such an engaging speaker. He spoke to them about his space travel, but also about attaining their goals and not to be afraid of working hard in school. A geologist from ExxonMobil also discussed career opportunities with the campers. The students also toured the National Weather Center and the Sam Noble Museum of Natural History.

Between all of the in-class activities, field trips, tours and discussions, the student groups were given time to prepare a Powerpoint presentation on an assigned aspect of Earth Cycles and then on the last day they presented what they learned to their families in a closing ceremony. It was fun to watch each student get up on a stage in front of more than 400 people and proudly discuss what they learned. So many of them conveyed their excitement of science and engineering to their families; it was gratifying to see and hear. But, for me, one of the most crystallizing comments came as two students walked along a path in the Chickasaw National Recreation Area—as they discussed the camp one said to the other "I wish our science classes in school were like this--here we get out and DO stuff." Isn't that why we all love science and engineering?

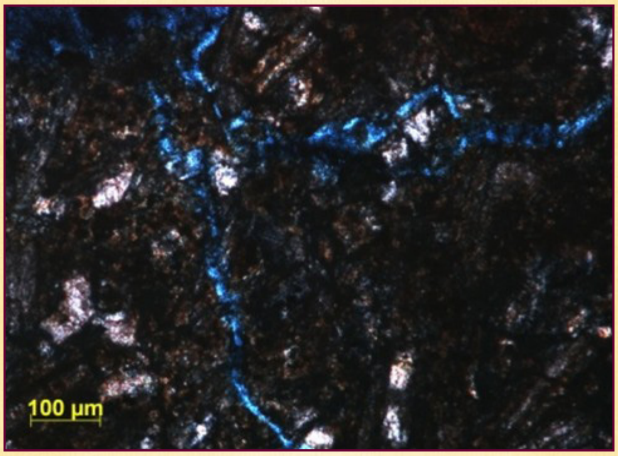
Effect of Volcanic Bodies on Hydrocarbon Reservoirs in the Northeastern Part of Chicontepec Foredeep, Mexico

Supratik Sarkar, Ph.D. Candidate in Geology, ConocoPhillips School of Geology and Geophysics

Foredeep basin turbidite systems develop in elongated highly subsiding troughs in front of fold-thrust belts associated with plate convergence or collision. Deepwater sedimentation in the Chicontepec foredeep is an example of such a turbidite system in front of the Sierra Madre Oriental fold-thrust belt. The reservoirs here are primarily formed by submarine fans although large portions of the systems are dominated by mass transport complexes (MTCs). These MTCs along with poor grain sorting, grain maturity, diagenesis, and tectonic effects make the reservoirs highly complex and compartmentalized. Intrusive and extrusive volcanic events in this convergent tectonic margin add to the complexity of the reservoir.

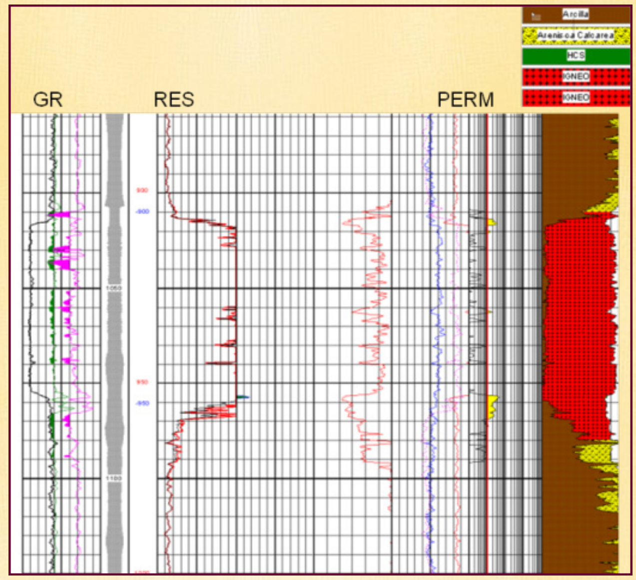
Previous studies indicate that the majority of the volcanism in this region took place from pre-Oligocene to Quarternary. Age of the turbidite reservoirs at Chicontepec is predominantly Paleocene-Eocene. As part of a comprehensive reservoir characterization process, our goal is to identify the effects of the large scale volcanic intrusive and extrusive bodies on the reservoir. The eastern part of the Amatitlan 3D seismic survey includes four separate oil fields. Spectral decomposition and other attribute stratal slices indicate that the main reservoir interval in all the four oil fields is part of a large submarine fan system. A large volcanic body and several smaller intrusive and extrusive volcanic features predominantly overlay the 'Coyotes' field, which is one of the four fields. Ant tracking and most positive curvature attributes indicate the presence of natural fractures in the reservoir interval with a greater concentration in 'Coyotes'. Furthermore, the permeability and net-to-gross ratio in 'Coyotes' is higher than that in the adjacent fields where the volcanic features are less obvious or nonexistent. One hypothesis is that the intrusive volcanic bodies created fractures or secondary porosity in its close proximity and it was emplaced before the migration of hydrocarbons into the reservoir. Outcrop studies we conducted in Chicontepec basin and preliminary rock physics based studies validates our seismic amplitude and attribute based hypothesis. Well logs from only a few wells encountered the volcanic interval, which show spikes of low gamma ray, high resistivity, variable density and low velocity at the volcanic layers. The velocity anomaly might be indicative of fractures within the volcanic bodies.

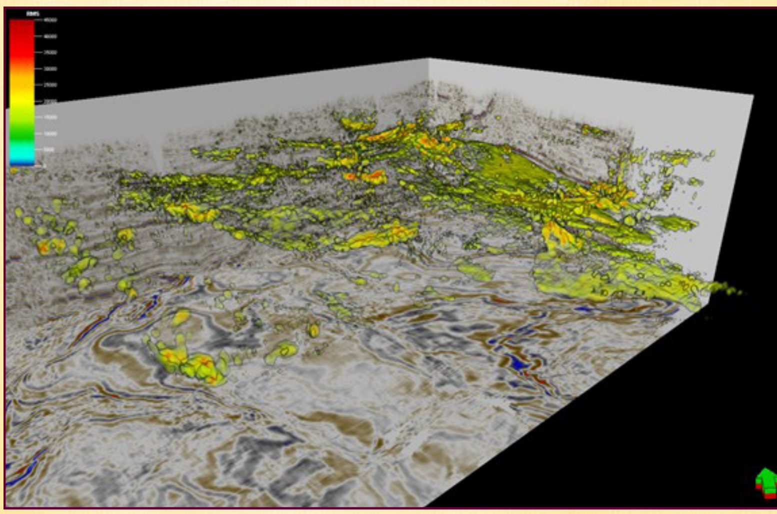
Igneous dike, coulumner basalt and sill within deepwater Chicontepec outcrops, Mexico. White rectangle indicates the 3D seismic area.



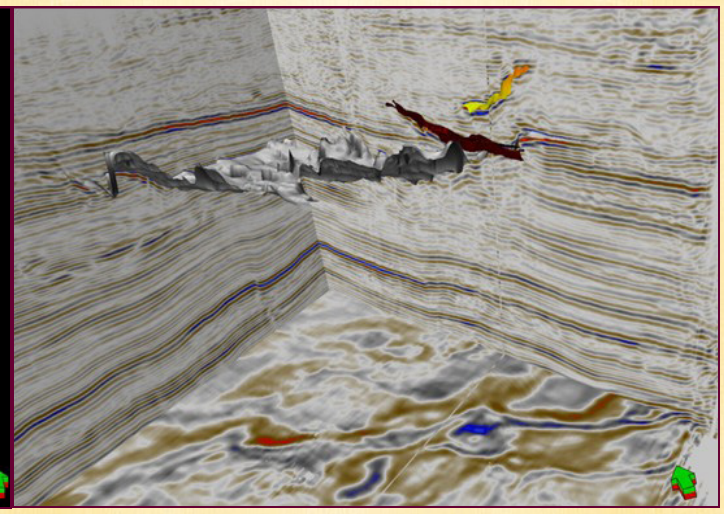
Thin section near the contact zone of igneous sill and Chicontepec Sandstone.

To the Right: *Typical well log response of a volcanic intrusive at Chicontepec. permeability increasing at the contact zone.*



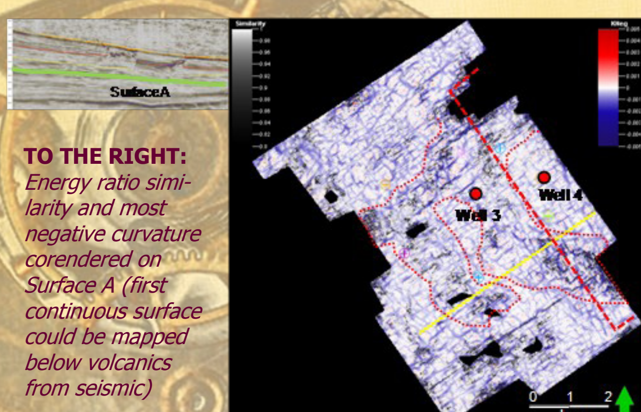


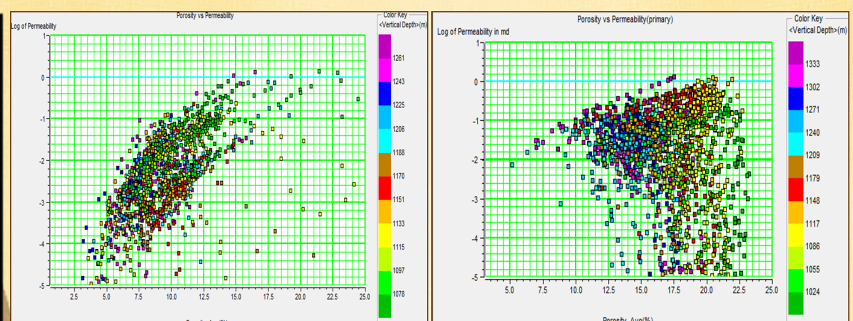
Igneous geobodies shown by rms amplitude.



Mapped igneous bodies from seismic.

TO THE RIGHT: *Energy ratio similarity and most negative curvature corendered on Surface A (first continuous surface could be mapped below volcanics from seismic)*





Porosity vs. Permeability plot from two wells, one within the mapped zone affected by volcanics (well 3) and other outside the mapped zone (well 4).

AAPG STUDENT CHAPTER

ConocoPhillips School of Geology and Geophysics
The University of Oklahoma

2009—2010 OFFICERS

Jonathan Funk, President
Brett Schlichtemeier, Vice President
Nabanita Gupta, Secretary
Fuge Zou, Treasurer
Elisheva Patterson, Field Trip Chair
Bagdat Toleubay, Social Chair
Jorge Gonzalez, Event Planning Chair
Malleswar (Mo) Yenugu, Marketing Chair
Dr. John Pigott, Faculty Advisor

Year-End Report

Prepared by President Jonathan Funk

The 2009-2010 academic year was a very busy year to say the least for our AAPG student chapter. We focused on 3 core areas: 1) technical growth, 2) career development and 3) social activities. With technical growth, our chapter hosted various geoscientists for short courses and technical presentations. This included Quinn Passey from ExxonMobil with multiple courses on Shale Petrophysics and Thin Bed Evaluation. Additionally, Stan Cunningham taught us a course on Prospect Evaluation for Oil and Gas. We also entertained varying talks from Asteroid Impacts to Naturally Fractured Reservoirs to Turbidite Channels. Internally, we had a student talk exchange where students presented their research or skills that they have picked up to broaden our members' exposure with the exchange of ideas. This was very informative for both the presenters and audience and helped lead to future collaboration.

Shale Petrophysics short course with Quinn Passey

In terms of career development, we hosted several activities to help prepare our members for the oil and gas industry. These include a short course from Dr. John Pigott on the Interviewing Game to prepare our members for the recruiting season. Additionally, we hosted Janine Helmich from Marathon Oil for a talk on the "Role of Geoscientists in the Petroleum Industry." One of our cabinet members, Jorge Gonzalez, also set up a rig visit with Devon Energy to show our members what life is like out in the field and how geologists contribute to oil and gas development.

We also had various social events throughout the year including pool, bowling, and a new annual event of AAPG/SEG versus SPE, a petroleum engineering organization at OU. These were very successful events and helped build the fellowship between our members of varying backgrounds from undergraduate to graduate studies with both domestic and international students.

Day out on the rig with Devon Energy

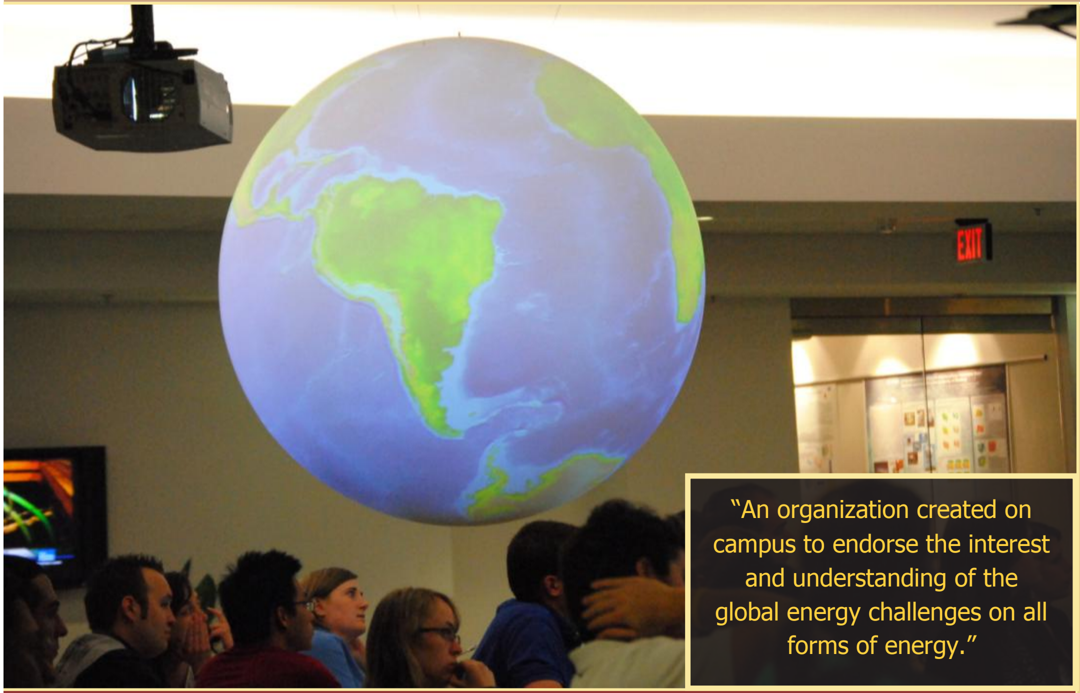
The year concluded with a trip to New Orleans for AAPG's annual convention. Thirty-three students were able to attend, with nine presenting their research in either poster or oral sessions. **Towards the end of the convention, our chapter received recognition of the Best Student Chapter in the United States.** This award completely reflects our chapter's active participation and dedication to being the best.

It has been such a pleasure to serve as AAPG President over this past year. Our members are the best in the world and made this such a successful year. With a great cabinet of Fuge Zou, Brett Schlichtemeier, Nabanita Gupta, Mo Yenugu, Jorge Gonzalez, Elisheva Patterson and Bagdat Toleubay, we had the opportunity to try some new ideas in addition to adding to the successful cabinet from the year before, led by Carlos Santacruz. AAPG has a fantastic cabinet coming back next year, led by Brett Schlichtemeier, the new president, and will continue to have a very bright future with your support!

THE OKLAHOMA ENERGY CLUB

By Andrea F. Cadena[1], David B. Grantham[2], Juan R. Torres[3]

[1] School of Geology and Geophysics, Liaison OEC for The Earth and Energy College; [2] Graduate College VP, External Relations OEC; [3] Department of Botany and Microbiology, President Oklahoma Energy Club



"An organization created on campus to endorse the interest and understanding of the global energy challenges on all forms of energy."

According to the U.S. Energy Information Administration, Oklahoma is rich in energy resources, as it is one of the top natural gas producing states in the country and a substantial producer of oil and coal (U.S. EIA, 2010). But, the source of energy in Oklahoma is not limited to fossil fuels. The state is leading important programs, such as the Oklahoma Wind Power Initiative, and the Oklahoma Biofuels Initiative and has adopted various incentive programs to support renewable energy-related projects.

All these energy topics have been investigated separately by various schools at the University of Oklahoma without much awareness within the community. However, the energy fields have gotten together – like the electrons around the atom – and are now available to students on campus and the Oklahoma community since the Oklahoma Energy Club was founded and held its first meeting on February 21st, 2010. At this meeting, Chairs and Liaisons were designated, and we started to work on developing our agenda for future events and meetings. The Club has five energy chairs corresponding to five energy spheres: climate and environment, hydrocarbons, renewables, 21st century energy applications, and markets and economics. Aware of the natural advantages of Oklahoma in terms of its energy resources, the Club strongly believes that the State can become a model for energy autonomy and security with the proper vision and leadership.

The Mewbourne College of Earth and Energy will host a program in early November, and we are planning to have the participation of some of the companies that are directly investing in Oklahoma, in conventional or unconventional reservoirs. For next year, The College of Atmospheric and Geographical Sciences and Price College of Business are planning a technical activity for our members. We are also planning an interdisciplinary program that addresses the development of shale gas from the view of geology, petroleum engineering, business and law. We also have some non-technical activities that are being planned. Energy Nights are coming, which will feature opportunities to join with members from other colleges in a relaxed environment outside of campus.

If you would like to join the Oklahoma Energy Club at OU, please send your contact information or any questions to Andrea Cadena (student liaison for the Mewbourne College of Earth and Energy) at: acadena@ou.edu.

After its first meeting, the Club helped to improve the knowledge of its members in different topics with direct or indirect participation through talks and other activities during last Spring semester. Some of them were:

- **February 26th**: The Club was presented officially to the members of the Student Chapters of the AAPG and SEG at the AAPG-SEG Exchange talk
- **March 20th**: Exxon Mobil talked about career paths available to finance majors at Exxon, how hedging plays a part in their strategy and their company outlook going forward.
- **April 27th**: Tristan Adler, a BOK employee and OU MBA student, spoke about lending practices for the oil & gas industry.
- **April 29th**: Talk given by Dr. Young Wang, of Pacific Northwest Laboratory about the DOE perspective on biofuels from biomass.

We would also like to thank the deans and faculty from the following colleges and look forward to their continued support:

Mewbourne College of Earth & Energy
Michael F. Price College of Business
College of Architecture
College of Arts and Sciences
College of Atmospheric & Geographic Sciences
College of Engineering
College of Law
Graduate College

CANDIDATES FOR DEGREES

Master of Science in Geology

Nathan Travis Cless
Aslihan Deliktas
Jonathan Funk
Austin Heape
Veronica Liceras
Sumudu Munasinghe
Jessica Michelle Pack
Alisan Templet
Dwain Veach

Master of Science in Geophysics

Oswaldo Davogustto
Jeremy Craig Fisk
Yanxia Guo
Bryce Evan Jensen
Victor D. Pena
Xavier Refunjol
Christine M. Worthington

Bachelor of Science in Geology

Ahmed Mansour Al Shafei
Simon R. Anzaldua
Sarah Elaine Farzaneh, SCL
Brandon Michael Guttery, WSD
Vanessa Nicole Harvey
Matthew Ryan Kendall, WD
Tiffany Amelia Legg
Michael Phillip Merrell, WSD
Matthew Allan Miller, WSD
Noah Steven Morris
Rami Aran Nyanat
Brittany Nicole Pritchett
Michael Alan Rhea
Jennifer Rae Scott
Austin Shock

Bachelor of Science in Geophysics

Hani Ataiq Alzahrani, WD
Toan N. Dao, WD
Tung T. Nguyen, WD

Doctor of Philosophy in Geology

Shamik Bose
Seth A. Busetti
Devin Dennie
Matthew S. Zechmeister

Doctor of Philosophy in Geophysics

Kui Zhang

Awards and Recognition

Regent's Alumni Award

Gene Van Dyke

After graduating from OU in 1950 with a Bachelor of Science degree in geological engineering, Van Dyke began a 60-year career in oil and gas exploration, exploring frontiers ahead of the game, first in Texas and Louisiana and then in the North Sea and deepwater West Africa. Today, his company, Vanco Energy, has operations offshore of the Ukraine and four countries in West Africa and has been one of the largest license holders in deepwater Africa for more than ten years.

Van Dyke has maintained close relations with and is a generous benefactor to the University. His company sponsors the Houston radio broadcast of OU football games each year; and in association with the OU President's Associates program, he opens his home for the OU-Texas A&M pre-game celebration every other year. He has made generous gifts for the renovation of the Sarkeys Energy Center Plaza, now known as the **Gene Van Dyke Plaza,** which will house the new computer labs and meeting space for the Mewbourne College of Earth and Energy. He also has made gifts to the Victor E. Monnett Chair, named in honor of the longtime director of OU's School of Geology and Geophysics, whom Van Dyke credits with having influenced him to pursue studies and a career in the oil business.

Van Dyke was nominated for the Regents' Alumni Award by Larry Grillot, dean of Mewbourne College of Earth and Energy. His name will be engraved on a permanent plaque that hangs in the Oklahoma Memorial Union.

Schlumberger Awards Scholarship to AAPG's Outstanding Student Chapter at OU

The University of Oklahoma's **AAPG student chapter** was the award recipient for **"Outstanding Student Chapter"** among United States-based chapters. The $1,000 scholarship check was contributed by **Schlumberger** and presented to OU at the annual meeting in New Orleans last April, 2010.

The Lunch Club Bunch

The **Lunch Club**, formed last year by alumni **Dave Campbell, Bill Reed, Bob Davis,** and OU Professor **Roger Slatt,** enjoy a leisurely lunch at the newest hot restaurant in Norman, FANCY THAT, to exchange ideas. When together, they certainly encompass the full range of professional, social, and political wisdom!

2009 Trailblazer Award Recipient

LEW O. WARD, III

On Nov. 13, **Lew O. Ward III** was honored with the Oklahoma Trailblazer Award at a dinner held in Oklahoma Memorial Union at the University of Oklahoma. Established in 2003, it is presented annually to honor the exceptional individuals in the energy industry who blaze a trail for others to follow. Ward, founder and chairman of Ward Petroleum, was joined by his wife, Myra, and family members. Myra, who was among the first cohort to attend the geology field camp, also was recognized for being a trailblazer when she was presented with an engraved rock hammer by CPGG director, R. Douglas Elmore. The event was sponsored by Crawley Petroleum, Panhandle Oil and Gas, Inc.; Vanco Energy Company; Legends Exploration--J. Denny and Dixie Bartell; Doug and Peggy Cummings; Harold Hamm; Donald G. and Jo Spindler and OU's Office of University Development. Hosts for the evening were the Mewbourne College of Earth and Energy; the Mewbourne School of Petroleum and Geological Engineering; the ConocoPhillips School of Geology and Geophysics and the Oklahoma Geological Survey.

AAPG 2010 Grants-in-Aid Awards

Brett Schlichtemeier

Shanshan Liu

Malleswar Yenugu

AAPG Mid-Continent Section Meeting Full of Achievements for Sooners

Oswaldo Davogustto

Rachel Barber

Kui Zhang

(Above) On October 11—13, Tulsa hosted the 2009 Mid-Continent Section Meeting. The OU student chapter of AAPG was represented by thirteen members who either presented posters or attended short courses at the event.

Oswaldo Davogustto took home 1st Place with his poster, while **Rachel Barber** and **Kui Zhang** walked away with 2nd and 3rd Places.

Supratik Sarkar, PhD candidate at OU, received second place award in the 2010 AAPG Student Oral Awards Competition for his oral presentation entitled, *"Effect of Volcanic Bodies on Hydrocarbon Reservoirs in the Northeastern Part of Chicontepec Foredeep, Mexico."*

(Above) For 2010-2011, **"Moe" Malleswar Yenugu** was awarded research grants from the Kansas Geological Foundation and the Society of Petrophysicists and Well Log Analysts Foundation for his research on the reservoir characterization of fractured Mississippian reservoirs in northeast Oklahoma. Moe was also awarded a scholarship from the Permian Basin Geophysical Society and the Sooner Heritage scholarship from the University of Oklahoma.

SPRING PICNIC AWARD CEREMONY

Ben Hare Award for Excellence in Geology and Geophysics: **Matt Zechmeister, PhD recipient**
Fuge Zou, Masters recipient

David Stearns Award for
Outstanding Geology Student

Michael Merrell

Alan Witten Award for
Outstanding Geophysics
Student

Sarah Farzaneh

Estwing Hammer Award for
Outstanding Senior

Brandon Guttery

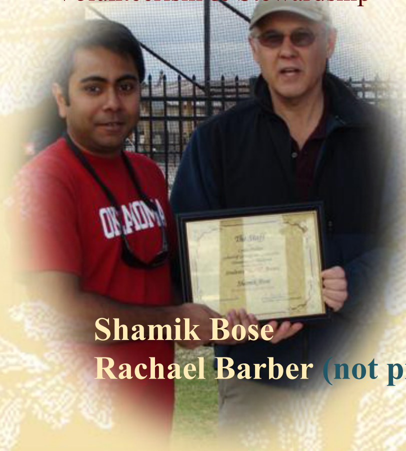
Charles N. Gould Award for
Outstanding Senior

Matthew Kendall

Stan Cunningham Award for
Excellence in Teaching

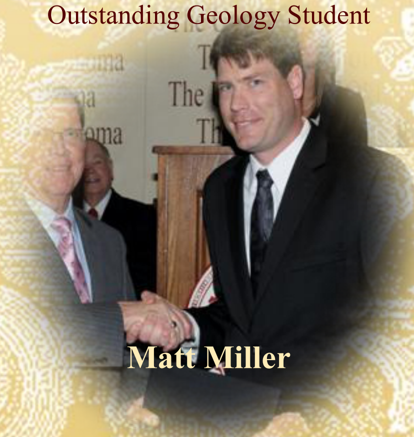
Stacey Evans

Rock Award for Outstanding
Volunteerism & Stewardship



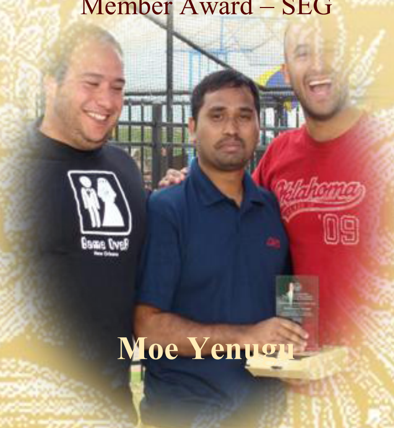
Shamik Bose
Rachael Barber (not pictured)

David Stearns Award for
Outstanding Geology Student



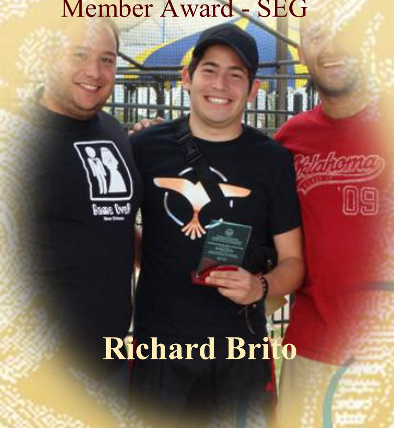
Matt Miller

Outstanding Graduate
Member Award – SEG



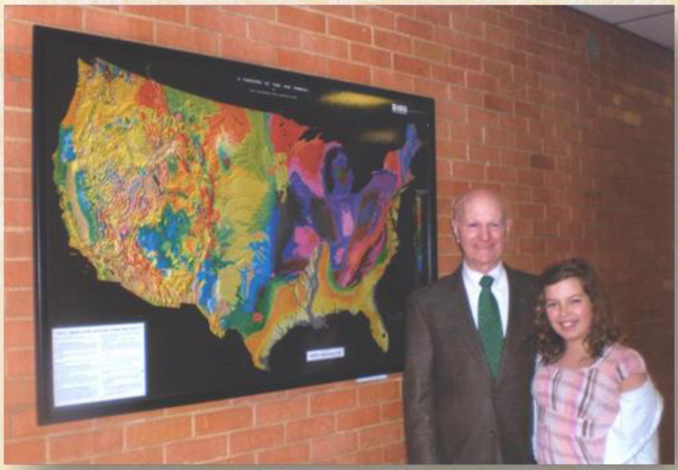
Moe Yenugu

Outstanding Undergraduate
Member Award - SEG



Richard Brito

GEOLOGY EDUCATION: MAP DONATED TO MONROE ELEMENTARY



Jon R. Withrow, an alumnus of OU's ConocoPhillips School of Geology and Geophysics, is pictured here with his granddaughter, Jessica Riley, standing in front of a surface outcrop map with a geological time chart. The map was donated in October, 2009 to the fifth graders of Monroe Elementary by the Society of Independent Professional Earth Scientists (SIPES) as an educational tool. Mike Pollok, an independent geologist representing the organization and the current chair of CPSGG's Alumni Advisory Council, made the presentation; and **Withrow**, also a member of SIPES, sponsored the event. The map hangs in the fifth grade wing of Monroe Elementary. *(Photo provided by Jon R. Withrow)*

PROFESSOR DAVE LONDON RECEIVES AWARD FOR BEST PAPER

London received the Hawley Medal of The Mineralogical Association of Canada at their annual meeting in Calgary, Edmonton, in May 2010. The Hawley Medal is awarded to the authors of the best paper to appear in The Canadian Mineralogist in a given year. The award is named in honor of Dr. J.E. Hawley (1897-1965) who was distinguished professor of mineralogy at Queen's University. The paper is selected by a committee of three members selected by the Chair of the Nominating Committee. The paper for which London received the award was entitled *"The origin of primary textures in granitic pegmatites"* and published in 2009.

2010 Tulsa Geological Society Outstanding Student Award

Katie Hulsey

Katie is currently working on her Master's thesis on the Horn River Gas Shale in British Columbia, Canada. She is interpreting the high frequency stratigraphic framework of the Horn River Shale which, when completed, will be a significant contribution to the understanding of this newly emerging shale gas play.

Robert W. "Bob" Allen, an OU alumnus and steadfast supporter of the university, was honored with a 2010 Special Award from the American Association of Petroleum Geologists (AAPG) at their annual convention in New Orleans in April. Bob also received a Legends Award from the Oklahoma City Geological Foundation at a recognition dinner on November 4, 2010 in Oklahoma City. The Foundation established the award in 2007 to honor outstanding geologists in the oil and gas business.

At the April AAPG annual convention**, J. Denny Bartell** (left)**,** Larry Bartell, and John J. Amoruso from Legends Exploration were presented with the Outstanding Explorer Award in recognition of distinguished and outstanding achievement in exploration for petroleum or mineral resources, with an intended emphasis on recent discovery – in this case, the Amoruso Field in east Texas.

2009 Back-to-School Mixer

Thunderbird Lake, Clear Bay Café

2009 Oktoberfest

Sarkeys Energy Center

PUMPKIN CONTEST WINNERS
1st Place—Allison Stumpf
2nd Place—Roderick Perez
3rd Place—Vanessa Harvey

CHILI COOK-OFF WINNERS
1st Place—John Hooper
2nd Place—Rachel Barber
3rd Place—Vanessa Harvey

COSTUME CONTEST WINNERS
1st Place—Vincent Heesakkers
2nd Place—Stacey Evans
3rd Place—Roderick Perez

2010 Spring Break Student Expo

March 11—12, 2010

POSTER CONTEST
Geophysics

Oswaldo Davogustto
1st Place WINNER

JUDGES
Dave Campbell
Sharon Woods
Tom Rowland
Phil Withrow
Joe Vaughn
Jeff Kelley
Steve Carlson
Bob Ehinger
Peter Duncan
Larry Lunardi
Bill Keller

We hosted the 2010 Spring Break Student Expo on March 11-12, and I'm happy to report that it was very successful. Employment is on the rise in the oil and gas industry; therefore, there was a lot of interviewing and networking going on! Which was 120% better than last year's Expo when the industry had taken a nose-dive into despair! Not the best stats we've ever had , but still respectable numbers: 198 students attending, 29 sponsors/23 interviewing, 54 posters, and 50 different universities represented.

Thank you to the following sponsors participating at Silver, Gold, Platinum Levels:

Silver
OGS
Dave Campbell
Marlan Downey
Jennifer Eoff
James K. Anderson
EXAD—H.W. Peace II

Platinum
SEG
Samson
Robert L. Stephenson
Chuck Noll, Jr.

Gold
Schlumberger
Continental Resources
ConocoPhillips
Marathon Oil
Devon Energy
Noble Energy
Geosearch Logging
PML Exploration Services
ExxonMobil
Maersk Oil
I H S
Mewbourne Oil
EnCana Oil
Kirkpatrick Oil
Chevron
MicroSeismic, Inc.

SEG Sooner Challenge Bowl WINNERS

Jefferson Chang/Evan Staples

Xavier Refunjol/Jaydeep Ghosh

EVENT SPONSORS

SandRidge Energy
Chesapeake
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Thank You!

SPECIAL WARM THANKS TO: Jenny Cole, SEG, who always comes early to help me set up; Steve Holloway for keeping the Web link running smoothly; Adrianne Fox, Teresa Hackney, Donna Mullins, Nancy Leonard, Gail Holloway, Rachel Renbarger, and Robert Turner—Office Staff.

2010 Picnic

Andy Alligator's Fun Park

May 1, 2010

SOFTBALL SHOWDOWN

1st

GEOLOGY

2nd

GEOPHYSICS

2009–2010 Alumni Obituaries

In Memory of Our Friends Who Have Passed

Olen C. Allen
Karl H. Alt
John W. Benton
Maryl L. Boyer
Douglas Brookins
Carroll D. Brown
Marvin R. Burditt
L. Weldon Calahan
L. W. Cary
John A. Crisholm
Lyndol L. Cole
Jo Ann D. Cook
Bob K. Crumpley
Robert D. Cypert, Jr.
Doyle W. Davis
Robert M. Davis
Wilbur L. Durr
Jay R. Endicott, Jr.
Lt. Col. J.D. Farrar
Frank T. Fleet
Ray E. Fleming
Paul W. Foster
Col. (Ret) Gerald L. Gardner
Dr. John H. George
Kathleen K. Gilmore
Robert S. Gramarossa
LTC (Ret) Judson B. Grubbs, II
Creed T. Huddleston, Jr.
Kay D. Kennedy
Cdr. James L. Kerr
Morris K. King, M.D.
Robert E. Klabzuba
Frank D. Kozak
Joe A. Laird
Mark C. Leach
Gilmer A. Lewis, Jr.
Robert P. McMurtry
Major Edward L. Miller
Dorothy M. Moore
Henry D. Moorman
Jerry L. Nelms
Walter Neustadt, Jr.
Lawrence J. Olson, Sr.
Dr. Elisha A. Paschal, Jr.
Bernard J. Perry
Case R. Petersen
Lloyd Pippin
J. Robert Porter, Jr.
L.E. Redman
June Sandel
Fred D. Smith
William H. Thams
James E. Thomas
Frank R. Walker
Jud R. Waller
Dr. Oscar D. Weaver, Jr.
Vernon L. Williams

Reported as of September, 2010

Mark Conrad Leach, born April 5, 1960, was freed from the pains of cancer on Wednesday, April 14, 2010, in the presence of family and friends whose lives he had touched. Although Mark's time on earth was short, he was humble as he walked quietly through his life. He was strong in stature and gentle in spirit, giving unspoken and sometimes unseen gifts to those around him.

From when he was a young boy until his last breath, he spent his life searching for things. He loved the earth, its nature and especially the hidden treasures it held. He was patient and thorough as he found collection after collection of arrowheads in areas of Texas where he grew up and in Oklahoma where he resided. Throughout Mark's life, he assembled a remarkable collection of museum-quality gems and minerals from around the world.

His interests led him to this career. As a gifted geoscientist, Mark worked over 25 years in the oil and gas industry; making numerous discoveries in the United States, Gulf of Mexico, China, and South America.

He spent weekends on Grand Lake of the Cherokees at his cabin forever searching for that next trophy bass. His most treasured moments were when he could share these special times with his twin brother, Mike.