GEOLOGY at SMU

An occasional newsletter from Earth Sciences for alumni and friends: December 2016

Shuler-Foscue Chair Zhong Lu

Tracking Surface Motion on the Earth

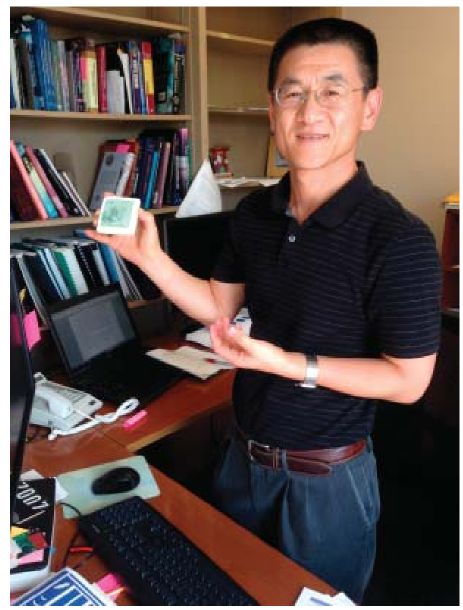
Professor Zhong Lu succeeded the first Shuler-Foscue Chair, the late Eugene Herrin, in 2013. Zhong Lu is a pioneer in radar remote sensing. His preferred technique is Interferometric Synthethic Aperture Radar known as InSAR. InSAR is perhaps the best technique for determining relative motions at the surface of the Earth by comparing radar images taken at different times over the same area. Zhong Lu developed algorithms for processing radar data that result in contours of relative surface movements on top of a geologic map, an aerial photograph or a satellite image.

Interferometry allows estimation of elevation changes that are fractions of a wavelength of the radar wave. The satellite sends and receives radar waves that bounce off the surface; the principle of InSAR is that the satellite position uncertainty is removed by examining the path difference for deforming objects on the surface relative to those that are known to be stationary. The residuals for the tectonically active areas depend upon the phase shift of the returned radar wave that can be measured down to the cm scale. For example, if the *returned* wave from a second image taken during a second pass of the satellite (see page 3), all other things being equal, is 180 degrees out of phase and the wavelength is 6 cm, then the relative displacement is 3 cm divided by 2 (two way travel path) or 1.5 cm.

Zhong Lu

- Peking University, B.S., Geophysics; M.S., Geophysics
- University of Alaska, Ph.D. Geophysics
- Interests-remote sensing & natural hazards
- Principal Investigator on the study of land surface deformation (associated with volcanic, seismic, & hydrogeologic processes)

After completing his PhD at University of Alaska, Zhong Lu became a contractor for the US Geological Survey's Earth Resources Observation and Science Center working with Science Applications International Corporation. His work for the USGS/EROS resulted in a full-time position with the Cascade Volcano Observatory working in the USGS's Volcanic Hazards program.



Professor Zhong Lu holding a 25th Anniversary commemorative cookie (with InSAR image for icing) for the Alaska Satellite Facility for Remote Sensing.

The groundbreaking work in the Volcanic Hazards program spawned a book entitled, *InSAR Imaging of Aleutian Volcanoes: Monitoring a Volcanic Arc from Space*, which he coauthored with USGS colleague Dan Dzurisin; the book's publication coincided with Zhong's arrival at SMU (see page 6). The Alaskan Aleutian Arc is located along major international flight paths between North America and Asia. Volcanic ash is a well known cause of jet engine failure; radar remote sensing provides a mechanism for assessing volcanic hazards in remote and virtually inaccessible areas such as some islands in the the Aleutian Archipelago. The Federal Aviation Administration (FAA) funds the USGS to provide volcanic hazard warnings for airline safety.

By joining the faculty of SMU, Zhong Lu has been able to devote more of his time to a broader list of problems. Radar interferometry is particularly well suited to study areas of active subsidence. The group has undertaken a reconnaissance study of Texas (eg. the Gulf Coast around Houston and in West Texas). These areas were selected because of oil field activity and/or intensive exploi-

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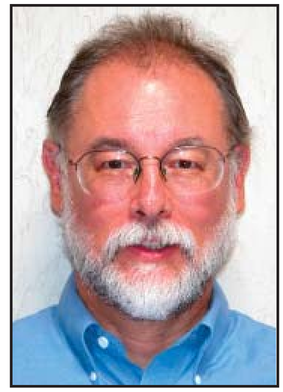
Chairman's Report

Natural and anthropogenic hazards: Finding balance between risk and reward



Robert T. Gregory
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Our department is in the midst of a rebirth. With the passing of Eugene Herrin in 2011, the retirement of Professor David Blackwell, plans for retirements of professors JohnWalther and Louis Jacobs, we are truly seeing a changing of the guard. Our new faculty have energized the department. The cover story is on Shuler-Foscue Chair Zhong Lu who uses radar remote sensing to study differential motion of the ground at the centimeter scale, a technique ideally suited for monitoring natural hazards.

The department now has a seismology group almost made for the recent events affecting the Fort Worth Basin to the west of SMU. The DFW area is now seismically active and has made it on to the US Geological Survey's earthquake hazards map! Heather DeShon, Matthew Hornbach and Beatrice Magnani along with Brian Stump and Chris Hayward have formed a formidable group addressing the issues of induced seismicity.

Heather DeShon and Beatrice Magnani were both recruited from the Memphis Center for Earthquake Research and Information (CERI). Heather is an earthquake seismologist. She has taken the lead on organizing the deployment of a North Texas seismic network consisting of close to 30 seismometers split between Azle, Irving and Venus, all localites with recent seismic activity. Beatrice is an active source seismologist who has imaged the New Madrid seismic zone so that she has experience in differentiating between an active seismic zone and an ancient one. Namely, is the uptick in the frequency of earthquakes part of a natural cyclicity or really anthropogenic?

Matthew Hornbach joined us from the Institute of Geophysics, UT Austin. Cliff Frohlich, also from UT, recommended Matt to us when he was collaborating with our group working on the Cleburne earthquake swarm (Justinic et al., *Bull. Seismol.Soc. Am.*, 2012). Matt's interests are many; he contributed the fluid flow analysis associated with the withdrawal and injection of waste water for the Azle sequence. The *Nature Communications* paper, the so-called "Causal Factors" study, Hornbach and DeShon et al. (2015), changed the regulatory environment for the State of Texas and contibuted to the Legislature establishing a Texas seismic network called TexNet.

Completing our list of new faculty is Rita Economos who came to us by way of UCLA's Ion Microprobe laboratory. Rita is a geologist with a big G in that she combines careful field work (she has training in structural geology) with state-of-the-art laboratory work on instruments such as the large radius secondary ion microprobe. Rita examines the subvolcanic structures associated with the generation, emplacement and storage of silicic magmas, i.e. what are the guts of a potential supervolcano. Her current field areas are in the Italian Alps and their foothills and the Mojave block in Southern California. Supervolcanos have the ability to affect the global climate regime and could be a game changers for human civilization. All of our new faculty fit nicely into the late Claude Albritton's mould of basic research that informs geologic problems with national interest implications.

The fracking revolution presents an interesting problem for society. The technology has expanded the amount of accessible oil to about three times what M. King Hubbert estimated in the 1970's. However, there are consequences for any type of extractive industry. The tight oil and gas reservoirs yield a large amount of byproduct in the form of saline fluid. The practice has been to aggregate the fluid from multiple wells and inject it back into the subsurface. This practice has made Oklahoma the most seismically active region in the continental United States. The question becomes the balance between the rights of the surface property owners and those of the vested mineral rights holders. Additionally, the safety of the general population in an earthquake larger than anticipated in the building practices of a region is a serious economic issue.

Our fold out features archival images (*LA Times)* from the Baldwin Hills, Los Angeles County, water reservoir failure. The reservoir was situated in a geologically challenging area. Water flooding, an enhanced oil recovery technique, was employed in the adjacent oil field accelerating the creep rate on shallow faults that crossed the reservoir and its dam (Hamilton and Meehan, *Science 172*, 1971). My parents owned a business next door to the Rodeo Bowl (picture 4, page 4). During the flood, the fire department rescued them and their customers by boat from the top a parking lot wall over 6 feet high. At the time, the incident was ruled an unfortunate event. My parents were able to get a small business disaster loan which they had to pay off. Whose risk, whose reward?

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tation of groundwater resources. Compaction of materials in the subsurface is a consequence of fluid withdrawal or dissolution of labile minerals (carbonates and evaporites).

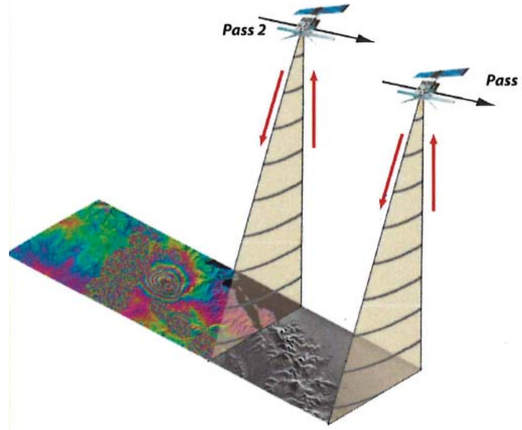
A study published with staff research scientist Jin-Woo Kim and graduate student Kimber DeGrandpre, InSAR images of the Wink, West Texas, area shows that existing sinkholes are still active with vertical rates of subsidence less than 5 cm/yr. Not so obvious are areas where new sinkholes may be forming. The rates of subsidence for nascent sinkholes were over 10 cm/yr (*Remote Sensing 8*, 2016). The subsidence is not strictly vertical inasmuch as there is a measureable horizontal component from the edges towards the areas of maximum elevation change.

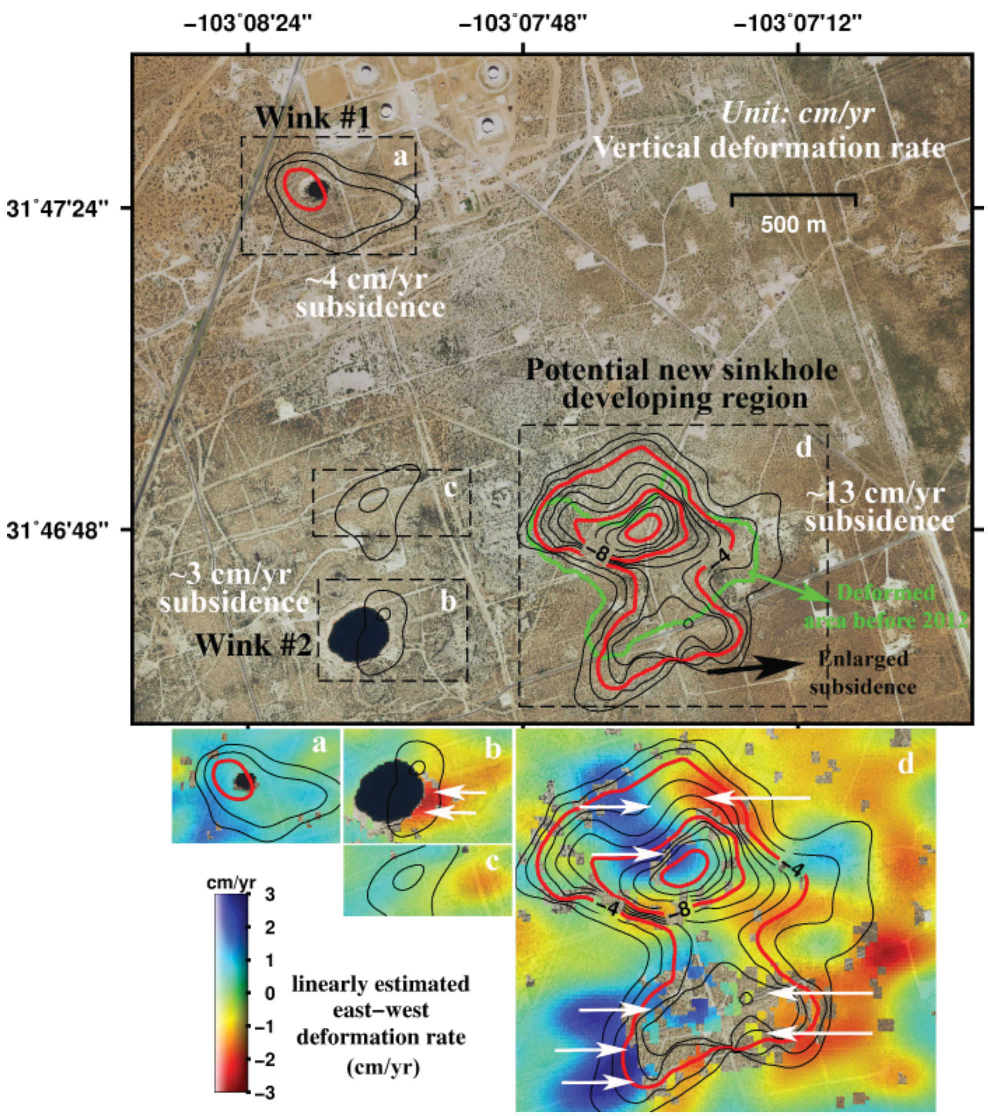
The Wink area only has about 1000 residents. Wink grew in response to the discovery of oil in the early 20th century; the peak period of production was between1920-1950. Sinkhole #1 developed in 1980 in the vicinity of an abandoned oil well whereas sinkhole #2 developed in 2002 within 1.5 km of an abandoned water supply well. Kim, Lu and DeGrandpre suggest that something more might be in play such as changes in groundwater levels. The Wink sinkholes appear to be associated with swarms of sinkholes cropping out along the 400 km trend of the Pecos River from Santa Rosa (Blue Hole Spring) in the north to Wink in the south--there are plenty of targets out there waiting for new images!

Zhong Lu serves on the NISAR-committee that oversees the design and launch of the first dedicated US civilian InSAR satellite, a joint mission between NASA(N) and India's space agency(I). In the absence of such a satellite, Zhong currently works through the European, German, Italian and Japanese Space Agencies.

The Shuler-Foscue Chair was donated by the late Robert C. Dunlap, Jr. (B.A. 1933) in honor of the two foundation professors.

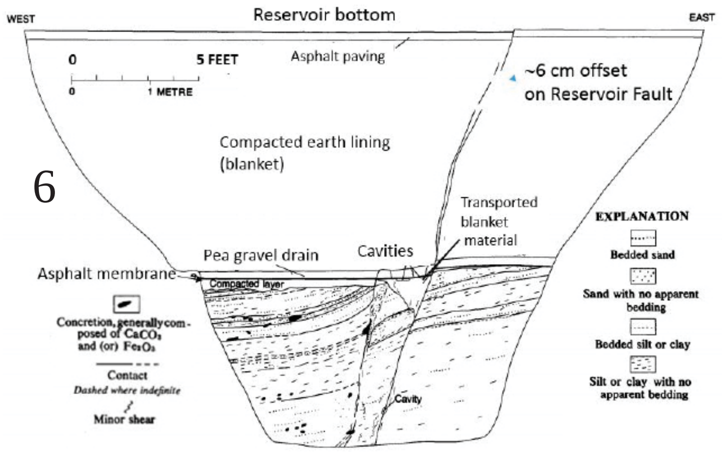
The cartoon on the right illustrates how the first pass of the satellite generates a radar image. The second pass generates the interfereogram. Each time a color fringe is repeated, there is one wavelength shift in elevation. By counting the color fringes and their spacing a sense of the spatial distribution of the deformation is readily apparent (Lu and Dzurisin, 2014).



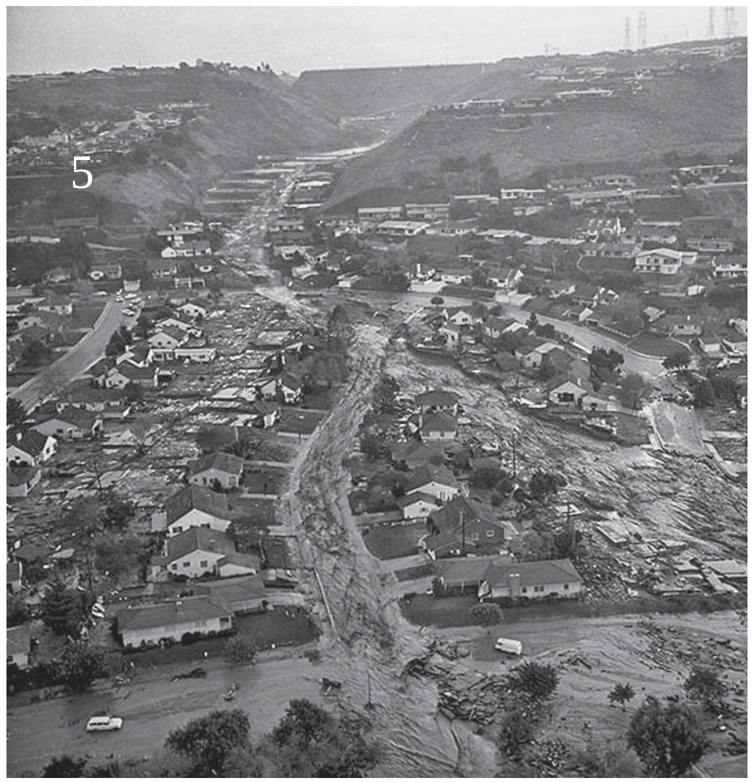


The vertical and horizontal components of relative displacement are shown for the Wink area, West Texas. Sinkhole #2 is approximately 3 km on a bearing of ~040 from the Wink City Hall. Wink sinkhole numbers 1 and 2 (insets a and b, respectively) are water filled and exhibit ~4 and ~3 cmy/yr of recent subsidence. Inset areas c and d also exhibit subsidence with d suffering some 13 cm/year of displacement. The green line outlines the area of subsidence prior to 2012. The red lines show the enlarged and deepening areas of subsidence in images after 2012. The color contoured insets, a-d show the linearly estimated east-west horizontal vectors. Areas in blue are moving eastward whereas warmer color indicate a westward horizontal component. The axis of opening is broadly north-south (after Kim et al. 2016).

Baldwin Hills Dam Disaster, 1963: Water Flooding for Enhanced Oil Recovery Increases Creep Rate in the Active Inglewood Newport Fault Zone



Cross section through the reservoir fault revealed by post-mortem trenching



The Baldwin Hills Reservoir failed catastrophically on Saturday, December 14th, 1963. It was built between 1947-1951 for the Metropolitan Water District of Southern California. The reservoir sat on the eastern edge of the Inglewood Oil Field which itself straddles the Inglewood-Newport Fault Zone, a right lateral strike slip fault system. The fault zone parallels the coast of California from San Diego County to the south and terminating in the LA Basin to the north where it truncates against transverse range structures.

Civil engineers had designed the reservoir with a novel asphalt membrane and monitoring system that was supposed to protect the dam in two ways. The membrane was meant to shield the hydraulic fill in the dam from the penetration of reservoir water (a piping hazard) and secondly, to seal the floor and walls of the dam against potential slip on the active faults in the area. The reservoir staff routinely monitored the creep on what became known as the Reservoir fault (top left and right). In 1963, coinciding with a water flooding program in the adjacent oil field, the creep rate increased (Hamilton and Meehan, 1971) eventually causing the membrane to fail along a ~6 cm offset.

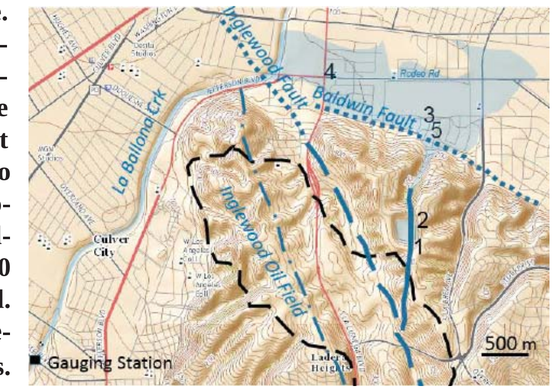
A reservoir caretaker heard the sound of running water in drain pipes below the asphalt membrane near the northeast corner of the reservoir. A crack opened up on the interior face of the 70.7 meter high dam allowing the main mass of water to flow into the hydraulic earth fill of the dam.

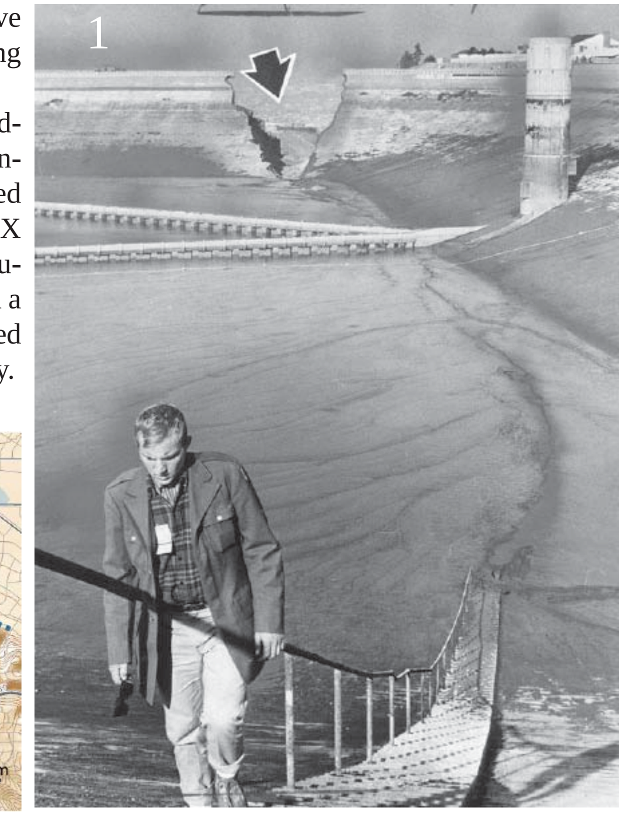
Clockwise from top right: 1) Breach in the wall of the Baldwin Hills Dam looking towards the north taken from the southwest corner of the dam showing the trace of the Reservoir Fault. 2) The crevasse in the northeast corner of the dam opened up along the Reservoir Fault. 3) The foundation of a 2-story Village Green apartment is all that is left of a building that took the brunt of the outflow at the base of the hill. 4) The corner of Rodeo Road and La Cienega Blvd., ~2 km downstream from the breach. 5) A view looking up Cloverdale Avenue to the south. 6) Profile through a trench transecting the reservoir fault.

A local television station KTLA-Channel 5 began to broadcast live video of the the whole affair. It is perhaps the first civil engineering disaster to be broadcast live with footage from helicopters.

Action by Los Angeles Police and Fire departments and broadcast media coverage allowed for residents to evacuate downstream from the dam. The three plus hours of effort limited loss of life to five in the subsequent flood that dumped close to 9.5 X 10^6 m^3 of water through the face of the dam in 77 minutes. Fortunately, a concrete lined channel to the west, La Ballona Creek, and a slightly elevated railroad right of way along Exposition Blvd. funneled the water down the creek directly into the ocean at Marina Del Ray.

The flood zone is in blue. The water crest was initially ~75 ft high declining to 25 ft depth at the base of the hill. Most of the water drained to the west. Peak hydrograph flux in La Ballona Creek was ~160 m^3/s (Gallegos et al. 2009). Numbers 1-5, refer to picture localities.

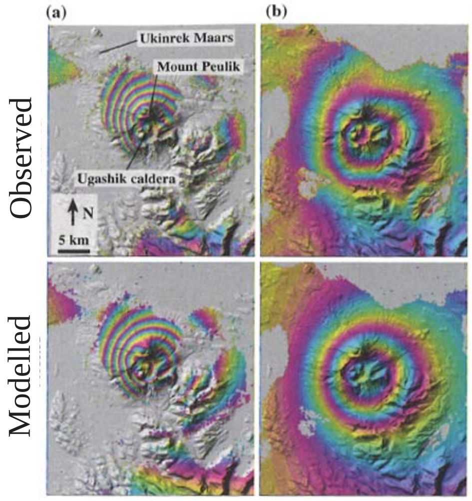




InSAR Imaging of a Volcanic Arc: Future Real-Time Monitoring of Ground Motion

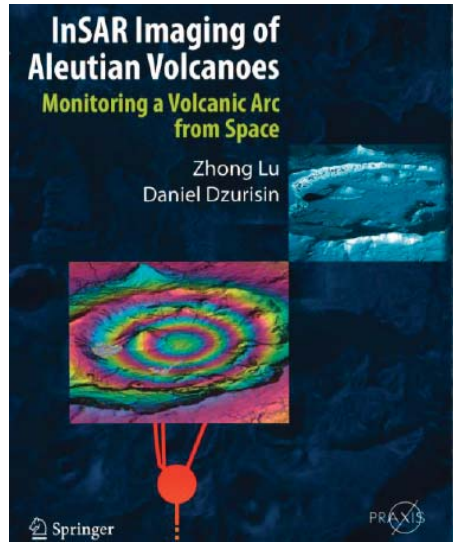
Professor **Zhong Lu** and USGS colleague **Daniel Dzurisin's** 2014 book on the Aleutian Arc shows that it is a dynamic place with well-behaved volcanoes erupting like expected, deformation (inflation) followed by eruption and those less well behaved, eruption without precursor deformation and volcanoes deforming without eruption. Each volcano has a unique sequence of events. Learning the styles of eruptive intervals will be key to making more informed decisions about volcanic hazards. Instead of being the "final word," they see their effort to document the activity of 38 volcanoes (dormant and active alike) using 25,000 radar images as just a beginning.

The prospect of many new satellites may enable the monitoring of magma movement at mid-crustal levels and its staging prior to major volcanic eruptions. InSAR images (top) and deformation models (bottom) for dormant volcano Mount Peulik showing the volcano for an interval before a



May, 1998, earthquake swarm (b: 1996-97) and two images taken over a four year interval that includes the swarm (a: 1995-1999). No eruption occurred, but these images clearly indicate deformation was occuring aseismically before the earthquake swarm. Each complete color band sequence corresponds to 2.8 cm of deformation along the line of sight of the satellite.

The lower frames show the effect of the addition of a spherical volume of magma intruded at 7 km depth on the surface topography. Even though there is a uniqueness problem with the modeling, the images and their modelled data demonstrate the potential of the technique which is currently limited by the number of radar images available.



The book is published by Springer-Verlag under the Springer Praxis Books:Geophysical Series. The ISBN number is 978-3-642-00347-9; it is also

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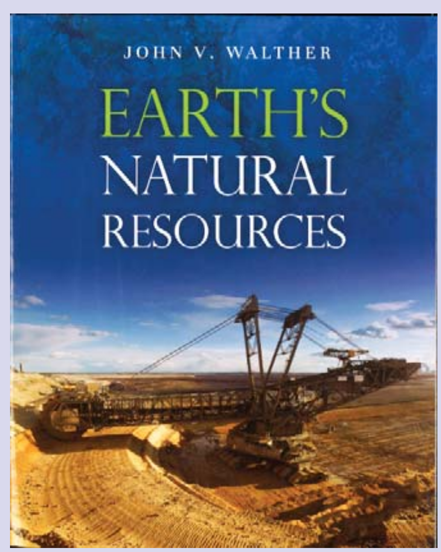
John Walther, Matthews Chair, Geochemistry, has written his second book based upon a course he teaches called *Resources and the Environment (*GEOL 3330). The book is published by Jones and Bartlett Learning. His first book *Essentials of Geochemistry* is now in its second edition.

This second book on earth resources benefits from an earth systems approach. It is pitched for geology majors and for environmental science students or the public comfortable with journals such as *Science News* or *Scientific American.* After a basic introduction to geology, the book is divided into sections on Energy resources; Metals (in several chapters); Life supporting resources (building materials; chemicals, e.g. nitrates for fertilizer; gases from the atmosphere or as byproducts of petroleum production); Water and soil as resources.

As John notes, "the energy available to humankind limits *what can* be done, and influences *what will* be done." As our civilization becomes more adept at harvesting resources more efficiently, the population has grown orders of magnitude beyond what ever could have been possible without technology and resources.

It is notable that there is much discussion of life sustaining resources such as industrial minerals, soil and water. Ultimately there is no civilization without water and soil. Complex civilization depends upon massive exchanges of energy and resources.

For a data-driven, balanced and dispassionate view of resources and the environment, John's book is a great place to start.



News of alumni, faculty, & friends

Maria Richards, Geothermal Laboratory, is President-elect of the Geothermal Resources Council Board of Directors. She will serve as President starting in January 2017 for a term of two years. The council is a non-profit organization formed in 1970 to encourage and promote the use of geothermal energy. With members from 47 different countries, it promotes public forums on geothermal energy as well as facilitates cooperation between industry, government and academia.

Benjamin Phrampus (Ph.D. 2015) defended his thesis entitled *Gas Hydrate as a Proxy for Contemporary Climate Change & Shallow Heat Flow on the US East Coast & North Slope of Alaska.* He is now a National Research Council Postdoctoral Fellow, a competitive fellowship program vetted by the National Academy of Science. Ben is continuing his submarine clathrate work at Oregon State University.

Rachel Campbell, B.S. 2014; M.S, 2016) defended her dissertation on *Stratigraphic Architecture and Reservoir Characteristic of Slumped Distributary Mouth Bar Deposits, Cretaceous Ferron Sandstone, Utah: An Analysis of Sedimentary Fabric and Facies Utilizing Outcrop and Core Data*. She took a job with Anadarko Petroleum located in The Woodlands, TX.

Katarina Marino (B.A. Geology and Journalism, 2013) reports that she is in the middle of her first year in a Science Communication master's program at the Otago University, Duneidin, New Zealand. She has a science website called, "the ROCK Record." The link is: https://therockrecord.wordpress.com/.

Pamela Kempton (M.S. 1980; Ph.D. 1984) returned to the United States from the United Kingdom Natural Environment Research Council (NERC) where she last served as Head of Research and Director of Science. NERC is similar to the U.S. National Science Foundation. Pam is entering her 4th year as Head of the Kansas State Department of Geology where she is involved in an initiative to build a $45 million, 78,000 square foot building for Geology.

Professor Matthew Hornbach and **Maria Richards** hosted the 8th Conference on *Power Plays: Geothermal Energy in Oil & Gas Fields*. The conference was held in SMU's Cox Collins Executive Education Center with >100 participants. See *www. smu.edu/geothermal* for the details.

Professor Brian Stump and **Craig Pearson (M.S. 1985; Ph.D. 1994)** are members of the *Governor's Technical Advisory Committee (TAC) to TexNet and the Bureau of Economic Geology***.** The mission of TAC is to fulfill the responsibilities outlined by House Bill 2 of the 84th Legislature in order to understand seismicity within the State of Texas. **Craig Pearson** is the seismologist for the Texas Railroad Commission.

Heather DeShon (B.S. 1999), Brian Stump, and Chris Hayward (Ph.D. 1999) are members of the *Dallas/Irving Earthquake Working Group* consisting of representatives from the cities of Irving and Dallas, the US Geological Survey and other state/federal agencies involved in emergency management. The group began meeting in response to the earthquakes straddling the boundary between Irving and Dallas.

Professor Maria Beatrice Magnani has been selected for the second consecutive year as an National Science Foundation Geodynamic Processes at Rifting and Subducting Margins (GeoPRISMS) Distinguished Lecturer. Two of her previous lectures are available online at http://geoprisms.org/education/distinguished-lectureship-program/current-speakers/.

The Huffington Department of Earth Sciences won 1st place for the best industry field trip for a site visit to the department. The regional "Award" of merit "In Maintaining Energy Excellence (AIMEE)" was given by the Association of Desk and Derrick Clubs. The field trip participants toured the Geothermal Laboratory, the Shuler Museum, and laboratories for Stable Isotopes, Remote Sensing and Seismology. In addition to the staff, graduate students, **Mason MacPhail, Xie Hu,** and **Casey Brokaw (B.S. 2014)** made presentations.

Lauren Michel (M.S., 2008)) has completed a post-doctoral fellowship jointly funded by professors **Neil Tabor** and **Bonnie Jacobs**. She has taken a faculty position at Tennessee Tech starting fall semester.

Jason Head (Ph.D., 2002), University of Cambridge, Zoology Department where he is University Lecturer and Curator of Vertebrate Paleontology, presented a seminar to the department on *Reconstructing paleoclimates from the vertebrate fossil record: ecometrics, giant snakes, and equatorial environments during the Paleogene greenhouse.*

Xie Hu and **Kimber DeGrandpre** are both recipients of NASA's graduate research fellowships that provide three years of funding for research towards a PhD. Xie's thesis proposal relates to monitoring landslide deformation using InSAR. Kimber's thesis project is centered on subduction zone volcanoes in the Aleutian Arc using InSAR, GPS, and seismicity.

Fold out credits: Photos http://framework.latimes.com/2013/12/13/the-1963-baldwin-hills-dam-collapse/#/0, or LA Public Library 00060032 trench profile modified from USGS PP-882, Castle and Yerkes (1976).

Please share any career news and interesting photos with us for use in our newsletter. Contact Stephanie Schwob or Lacey DeMara at 214-768-2750.

****All prior issues of* Geology at SMU *can be found online.***

http://www.smu.edu/earthsciences

Roy M. Huffington Department of Earth Sciences

David D. Blackwell, Professor *Emeritus,* , Ph.D., Harvard. Geothermal studies and their application to plate tectonics, energy resource estimates and geothermal exploration.

Heather DeShon, Associate Professor Ph.D., University of California, Santa Cruz. Earthquake seismology, tectonics of convergent margins, earthquake hazards, induced seismicity.

Rita C. Economos, Assistant Professor, Ph.D., University of Southern California. Igneous petrology, zircon geochemistry and geochronology, tectonics associated with magma emplacement

Robert T. Gregory, Professor, Chair, Ph.D., California Institute of Technology. Stable isotope geology and geochemistry, evolution of earth's fluid envelope and lithosphere.

Matthew Hornbach, Professor, Ph.D., University of Wyoming, Reflection seismology, heat flow, marine geophysics, natural hazards

Louis L. Jacobs, Professor, Ph.D., University of Arizona. Vertebrate paleontology, evolution.

Bonnie F. Jacobs, Professor, Ph.D., University of Arizona. Paleobotany & palynology of the Cenozoic.

Zhong Lu, Shuler-Foscue Chair, Ph.D. University of Alaska. Radar remote sensing, natural hazards, surface deformation

Maria Beatrice Magnani, Associate Professor, Ph.D.,University of Perugia, Italy, Active source seismology, crustal tectonics.

James E. Quick, Professor, Ph.D., California Institute of Technology. Igneous and metamorphic petrology, tectonics, volcanology.

Brian W. Stump, Albritton Professor, Ph.D., University of California, Berkeley. Seismology, seismic source theory, regional waves, seismic and infrasonic instrumentation.

Neil J. Tabor, Professor, Ph.D., University of California, Davis. Sedimentology, paleosols, stable isotopes and paleoclimate.

John V. Walther, Matthews Professor, Ph.D., University of California, Berkeley. Experimental and theoretical aqueous geochemistry.

Crayton J. Yapp, Professor, Ph.D., California Institute of Technology. Stable isotope geochemistry, environmental isotope studies

Selected Adjunct Faculty

Steve Bergman, Research Professor, Ph.D., Princeton University. Tectonics, petrology & geochronology.

Anthony Fiorillo, Research Professor, Ph.D., Pennsylvania. Museum of Nature & Science. Vertebrate paleontology.

Mihan H. McKenna, Research Associate Professor, Ph.D., Southern Methodist University. Seismology and Infrasound.

Peter Malin, Research Professor, Ph.D., Princeton University, seismic instrumentation and exploration.

Matthew Siegler, Research Assistant Professor, PhD. University of California, Los Angeles, Planetary Geophysics

Troy Stuckey, Adjunct Associate Professor, Ph.D., University of North Texas. EPA. Environmental Science and Policy.

John Wagner, Research Professor, Ph.D., University of Texas, Dallas. Chief Geologist, Venari Resources, USA.

Alisa J. Winkler, Research Professor, Ph.D., Southern Methodist University, Mammalian paleontology, anatomy.

Dale A.Winkler, Director, Shuler Museum of Paleontology, Ph.D., UT Austin. Paleontology, paleoecology, stratigraphy.

Pierre A. Zippi, Research Professor, Ph.D., University of Toronto. Biostratigraphy, palynology, and oil exploration.

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