Geology at SMU

An occasional newsletter for alumni and friends: December 2006.

Ethiopian Plateau Studies

Fossil Plants Constrain Ancient Climate

Climate change is a topic of great current interest because of the potential impacts of global warming on the planet. We rely upon global circulation models to provide scenarios of future climate change. One of the few ways to test the efficacy of circulation models is to see how well they simulate known past conditions. Geological Sciences faculty member Bonnie Jacobs makes use of fossil plant assemblages to estimate past precipitation and collaborates with faculty colleague Neil Tabor who estimates past precipitation and temperature from fossils, soil minerals, and stable isotopes. Understanding past climate conditions at tropical latitudes has big implications for predicting future climate and its economic consequences.

Geologists have long been able to semi-quantitatively gauge climate changes by examining the distribution of climate sensitive sedimentary rocks (glacial till, carbonates coals, evaporites, eolian sandstones, and paleosols) and assemblages of fossils. Put plate tectonics into the mix and the distribution of these sedimentary rocks and fossils, in the context of continental drift, reveals some astounding things about ancient climate: greenhouses and icehouses and even a Late Proterozoic snowball earth with equatorial glaciers!

Associate Professor Bonnie F. Jacobs
Research Interests

- Palynology (study of ancient pollen)
- Paleobotany and paleoecology
- Climate change in tropical regions
- Paleoclimatology

During these major climatic excursions, it is clear that climate changes most dramatically at high latitudes (e.g. dinosaurs roaming the polar regions now under ice or tundra). While climate changes at the poles may seem extreme, their overall effect on weighted global means is not so great because the surface area at the poles is less than that at the equator.

What is less well known is how much climate changes at low latitudes during the Phanerozoic (post snowball Earth).

Fossil leaf from Chilga, in the tropical Ethiopian highlands. Leaf shape and size are sensitive to climate. Statistical analysis of the relative abundances of species with leaves with different morphologies can be used to estimate past climate. Chilga preserves a wealth of fossil plants, providing valuable climate and ecological information about the past.

Because of the equable conditions attributed to low latitude climate, it is a much more difficult problem to get at changes in the parameters that dominate the global mean values.

Bonnie Jacob's work is aimed at piecing together the Cenozoic vegetation and climate history of tropical Africa, focusing on plant fossils from the East African Rift (~13 to 6 Myr), a crater lake in Tanzania (46 Myr), and most recently Chilga, Ethiopia, which date to 28 Myr.The Tanzanian and Ethiopian studies provide the only quantitative estimates of paleoclimate for the Paleogene (65 to 24 Myr) of tropical Africa, and are almost equally as rare for the Paleogene in providing vegetation reconstructions based upon plant macrofossils. Sections in Ethiopia such as those on the Margargaria River (page 7) have yielded abundant plant fossils and paleosols. The results so far indicate a much warmer and more equable climate for the Chilga region of Ethiopia, a big change for the tropics.

Bonnie Jacobs, Chair of the Environmental Science program, officially joined the faculty of Geological Sciences this summer as a full-fledged member, ending years of adjunct status.

Published by Department of Geological Sciences, Dedman College, Southern Methodist University

Chairman's Report

More Lessons from the Colorado Plateau: Meteor Crater after Gilbert

By Robert T. Gregory

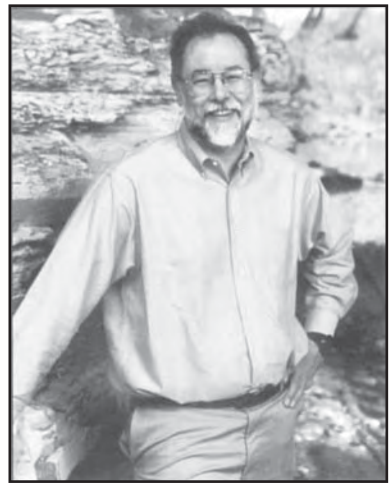

Photo by Hillsman B. Jackson

The origin of Meteor Crater is one of those scientific controversies with a rich history. In a series of papers, beginning in 1936, SMU faculty members John D. Boon and Claude C. Albritton, Jr. (*Field and Laboratory*, 1936, 1938a &1938b) weighed in on the controversy concerning the origin of craters as either being of impact (meteoritic) or cryptovolcanic in origin. A similar controversy exists today concerning the causes of mass extinction as being either external to the earth (large impact driven) or internal to the earth (volcanic superplume driven).

In a previous *Geology at SMU (Fall 2003)*, the exploits of G.K. Gilbert in his quest to prove the existence of impact craters concluded exactly the opposite by rigorously adhering to the scientific method. Gilbert concluded erroneously that the crater was caused by a cryptovolcanic explosion attributed to the interaction of magma with groundwater. These types of explosions leave behind volcanic craters called maars (page 6). Meteor Crater sits on the Colorado plateau in a region with numerous volcanoes and examples of volcanic maars.

Gilbert, on the basis of topographic and magnetic surveys, concluded that the crater contained no buried iron meteorite, i.e. the debris around the crater was sufficient to restore the original topography. He had assumed that the meteorite would survive the impact and would still be buried somewhere beneath the crater. His failure to find evidence for the existence of the buried meteorite was sufficient for him to reject his hypothesis. The association of iron meteorites with the crater was deemed fortuitous.

Mining engineer Daniel Barringer rejected Gilbert's analysis because meteoritic material was thoroughly admixed with ejected material. He took out mining claims to exploit what he thought were considerable reserves of meteoritic iron. An extensive field program, backed up by core drilling, mapped out the distribution of rocks of the crater. The drill bit penetrated through the Coconino Sandstone into the red beds of the underlying Hermit Shale and Supai Group. Barringer noted that the underlying sediments were essentially undisturbed so that he was convinced that the crater was not the result of volcanic or hydrothermal activity.

For the Coconino Sandstone, it was a different story. The rocks were pulverized into rock powder whose origin was inferred to be the result of the impact. Barringer reported in his 1909 monograph that the Coconino Sandstone underlying the crater locally exhibited what he called slaty cleavage (see photograph on page 5) resulting from the intense compression induced by the impact of the iron meteorite. The metamorphism was from the top downward.

Judging by the papers that were published at the time of the exploration program, Barringer clearly encouraged other geologists to visit the crater and study the samples recovered during the exploration program. U.S. Geological Survey geologist George T. Merrill (1908) examined a suite of samples that were donated to what is now the Smithsonian Institution.

Petrographic examination documented the shocked and strained quartz. Thin sections revealed the existence of peculiarly twinned silica and regions of amorphous silica. Merrill compared the apearance of the pumaceous glass to that of fulgurite (glass produced by lightning strikes). The glass was inferred to be of shock origin. The discovery of the as yet unknown high pressure polymorphs of SiO_2, coestite and stishovite, was left to Eugene Shoemaker and coworkers some fifty years later. The photomicrographs in the 1908 publication appear to show the textural types where the discovery was eventually made (see page 3, dark areas between grains, 2nd and 3rd photomicrographs).

G.K. Gilbert's analysis miconstrued the velocity of incoming meteorites. He assumed that the meteorite would remain largely intact. Barringer's colleague Tilghman apparently was well aware of the craters produced by military ordinance and mining explosives.

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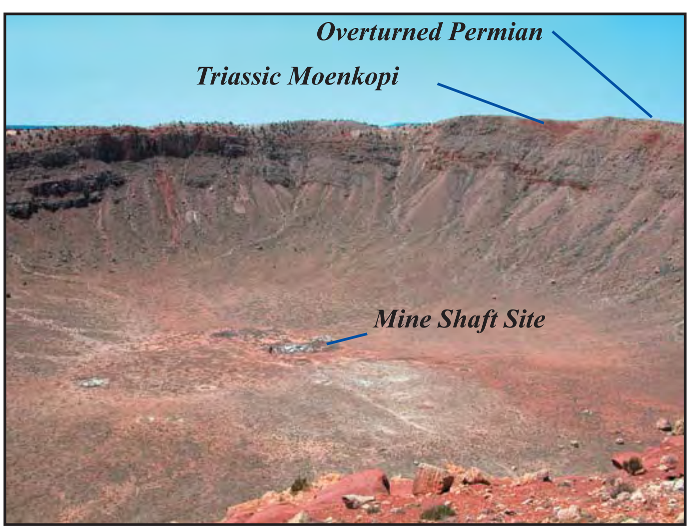


Looking into Meteor Crater from the north wall. The crater is approximately 170 meters deep. An excellent topographic map is reproduced in Merrill's 1908 publication. On the crater floor, the remains of the exploration shaft are still visible. See the photograph on page 3 for a close up. In the foreground are outcrops of Triassic Moenkopi Formation. It is overlain by debris of the underlying Permian formations. Eugene Shoemaker used the overturned beds as evidence for the impact origin.

Continued from Page 2

Within a decade of Gilbert's analysis, estimates for impact velocities ranged up to 70 km/sec based upon measurements on shooting stars. There was talk of the meteorite vaporizing on impact. All of the ingredients for a consensus were already present by 1908. Most likely the conflict of personalities (deference of the community on one hand for Gilbert and entrepreneurial aggressiveness on the part of Barringer) robbed Barringer of the satisfaction of convincing the geologic community.

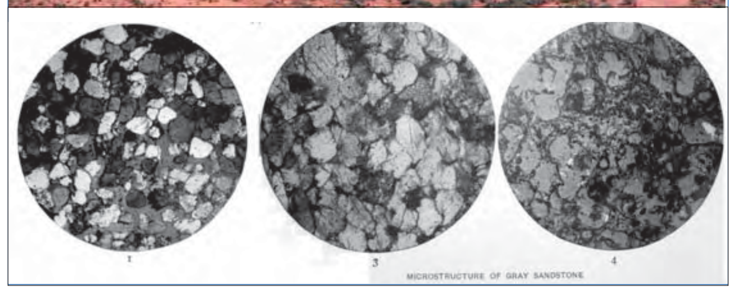
The velocity of an incoming meteorite is readily calculated using conservation of energy (kinetic and potential). Because mass of the meteorite (m) is present in every term and we multiply by 2 to clear the fraction of 1/2 for the kinetic energy terms, the potential energy term algebraically becomes the escape velocity. If the approach velocity was zero, the meteorite would still come in at some 11 km/sec, the escape velocity; this is a minimum estimate for a large body. The impact velocity is the square root of the sum of the squares of escape velocity plus the approach velocity. The latter are likely to be of the magnitude of planetary orbital velocities; for the Earth this is close to 30 km/sec.

Impact Velocity from Energy Conservation

$$\frac{1}{2}mv^2_{approach} - \frac{GM_{earth}m}{\infty} = \frac{1}{2}mv^2_{impact} - \frac{GM_{earth}m}{R_{earth}}$$

$$v_{impact} = \sqrt{v^2_{approach} + v^2_{escape}}$$

Boon and Albritton's analysis (pages 4-5) foreshadowed future thinking about even bigger impact basins with central uplifts and ring zones. The energetics of these impacts could have planet altering consequences. They realized that these structures would be more numerous in the past and their existence would be recorded by the underlying structures long after the surface features were eroded away.



The fenced-in area marks the site of the mine shaft and some of the drilling operations mounted by mining engineer, Daniel Barringer, from 1903-1929. The white area is some of the crushed Coconino Sandstone brought up in the digging. A model of an astronaut to scale next to an American flag is just visible at the northwest corner of the fence. Compare against the same area in the photo on page 2. The rusted remains of a boiler and a winch are visible on the left side of the photograph. Three thin sections of Coconino Sandstone (x-polarized light) from Merrill (1908) showing the transformation to shock melt going from left to right. The 2nd and 3rd frames show the textural types where high pressure polymorphs of SiO_2, coesite and stishovite, were discovered by Eugene Shoemaker and colleagues.

Elected to 8 Different Halls of Fame For His Achievements

SMU Alumnus, Lamar Hunt (B.S. 1956), the Penultimate Gentleman Leaves a Rich Legacy in Sports & Business

Lamar Hunt (B.S., 1956), took his degree in geology and entered the oil business where he remained active until the bust of late 1980's. However, within a few years of earning his geology degree, Lamar followed his passion. He will be remembered for his considerable contributions to the "entertainment business and professional sports management." This was how he modestly described his career activities in his handwritten response to our alumni survey of 2001.

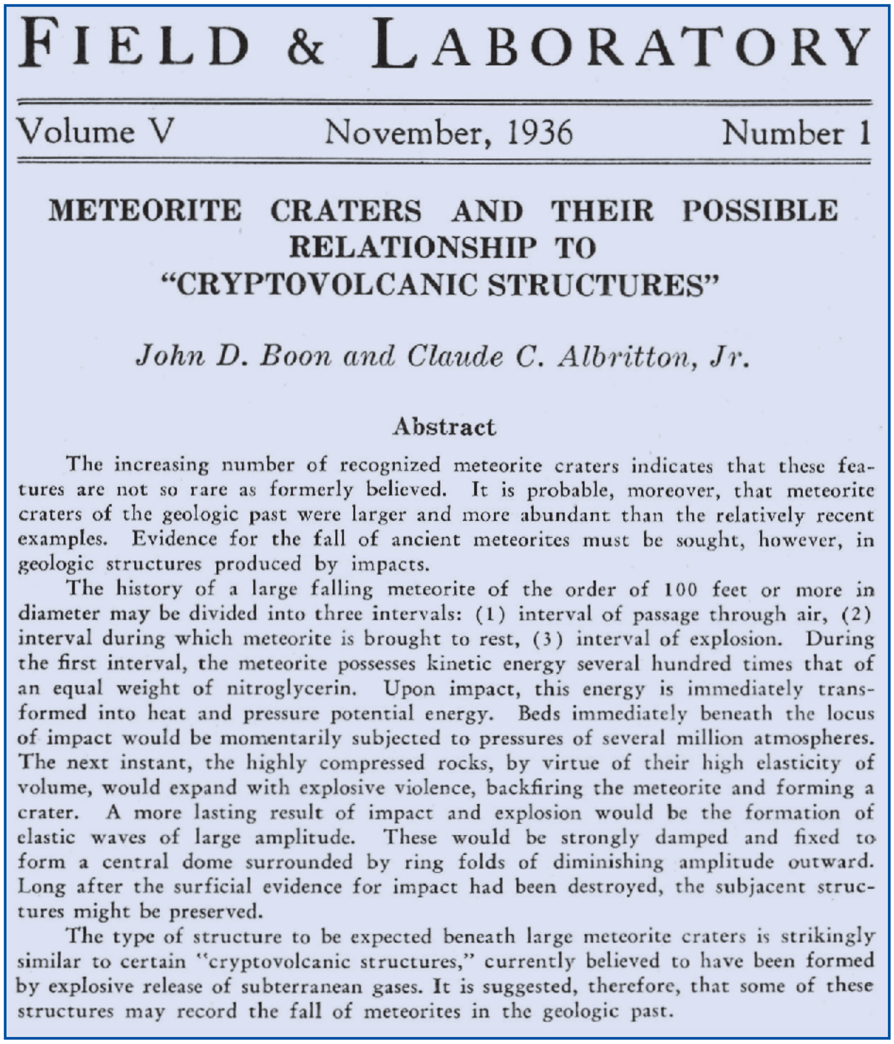
At the time of the survey, Lamar was certainly not a missing alumnus! He was chairing the SMU Board of Trustees Subcommitee on Intercollegiate Athletics. Lamar became more active in SMU Athletics after the "death penalty," lending his considerable stature towards restoring the credibility and integrity of the program.

Lamar was instrumental in bringing football back to campus. While Lamar's name is not on the stadium, he was a driving force behind the project; he attended virtually every meeting of the oversight committee that helped bring the stadium to life.

When asked to list one professional accomplishment, Lamar wrote, "A bit of a tongue and cheek accomplishment is that because of geology training, I identified a number of boulders at a stadium project as being glacial in origin causing our organization ("Columbus Crew") to use many large boulders in the decoration of the stadium in Columbus, Ohio."

At his memorial service at Moody Coliseum, December 16, 2006, one of the best comments described the origins of life's opportunities as being by birth, circumstance, or by creation (invention). It was further noted that it is rare to see all three types of opportunities embodied in the life of a single person. Lamar certainly was that person.

Boon & Albritton Seminal Paper on the Physics of Bolide Impacts Published 70 Years Ago in SMU's Science Journal "Field & Laboratory"



FIELD & LABORATORY

Volume V November, 1936 Number 1

METEORITE CRATERS AND THEIR POSSIBLE RELATIONSHIP TO "CRYPTOVOLCANIC STRUCTURES"

John D. Boon and Claude C. Albritton, Jr.

Abstract

The increasing number of recognized meteorite craters indicates that these features are not so rare as formerly believed. It is probable, moreover, that meteorite craters of the geologic past were larger and more abundant than the relatively recent examples. Evidence for the fall of ancient meteorites must be sought, however, in geologic structures produced by impacts.

The history of a large falling meteorite of the order of 100 feet or more in diameter may be divided into three intervals: (1) interval of passage through air, (2) interval during which meteorite is brought to rest, (3) interval of explosion. During the first interval, the meteorite possesses kinetic energy several hundred times that of an equal weight of nitroglycerin. Upon impact, this energy is immediately transformed into heat and pressure potential energy. Beds immediately beneath the locus of impact would be momentarily subjected to pressures of several million atmospheres. The next instant, the highly compressed rocks, by virtue of their high elasticity of volume, would expand with explosive violence, backfiring the meteorite and forming a crater. A more lasting result of impact and explosion would be the formation of elastic waves of large amplitude. These would be strongly damped and fixed to form a central dome surrounded by ring folds of diminishing amplitude outward. Long after the surficial evidence for impact had been destroyed, the subjacent structures might be preserved.

The type of structure to be expected beneath large meteorite craters is strikingly similar to certain "cryptovolcanic structures," currently believed to have been formed by explosive release of subterranean gases. It is suggested, therefore, that some of these structures may record the fall of meteorites in the geologic past.

Field and Laboratory **was published as an outlet for the scholarly activities of the science departments at SMU from 1932 to 1964.**

Meteor Crater (bottom image) compared with a volcanic maar, Pinacate volcanic field, Mexico, at the same scale with the similarity of the morphologies clearly evident. Eruptions that produce volcanic maars generally give some evidence of their volcanic origin (e.g. tuffaceous material in the pyroclastic deposits rimming the crater). The only products of melting at Meteor Crater have whole rock chemistries dominated by a single component, SiO_2, from the *in-situ* shock induced melting of Coconino Sandstone.

Mechanics of a Meteorite Impact

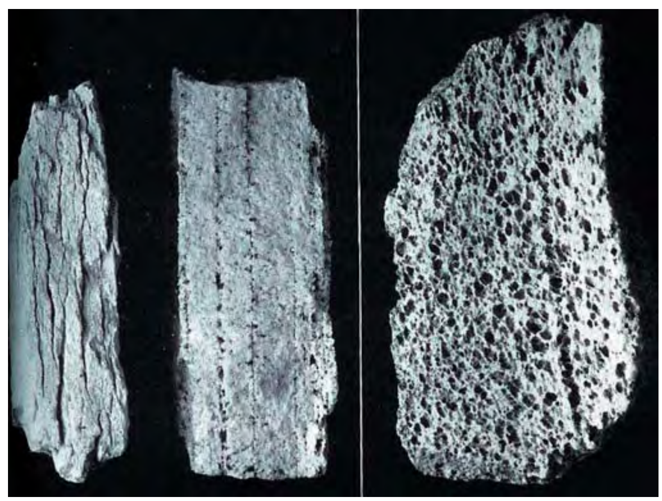
The last seconds of a meteorite's 4.5 billion year journey.

1) ***Interval of passage through the air****:* The meteorite comes in with tremendous kinetic energy; its velocity has a value between 1.4 times the Earth's orbital velocity around the Sun and the escape velocity for leaving the Earth (~11 km/sec). Boon & Albritton surmised a velocity of 25 km/sec.

2) ***Interval during which the meteorite is brought to rest:*** A hot gaseous layer surrounds the bottom of the meteorite just before the impact. The shock of the impact compresses the target rocks and meteorite to momentary pressures estimated to be greater than those present in the core of the Earth, 14 million atmospheres in Boon and Albritton's calculation.

3) ***Interval of explosion:*** The meteorite comes to rest, the highly compressed materials expand with explosive consequences excavating the crater and obliterating most of the meteorite.

The conundrum of the missing meteorite, the target of Daniel Barringer's decades long search, was obviously on the minds of Boon & Albritton, probably unaware of astronomer F.R. Moulton's unpublished analysis for Barringer's investors. It was commissioned just before the Great Depression and Barringer's death in 1929. Moulton concluded that the impactor would probably not survive its collision with the Earth.



Figures clockwise from top right: Photograph of the Meteor Crater taken from the northern approach to the crater. The crater is approximately 1.2 km in diameter and rises about 75 meters above the plain of Moenkopi Formation in the foreground. The Holsinger iron meteorite, largest recovered fragment associated with the impact, is now on display in the museum at the crater. Samples of shocked Coconino Sandstone from Merrill (1908) showing the slaty cleavage developed perpendicular to bedding (left sample) and two examples of fused silica including a sample identified as silica pumice on the right. Over a half a century later, Eugene Shoemaker and colleagues discovered coesite and stishovitie, high pressure polymorphs of SiO_2, not known at the time. Panorama of Meteor Crater taken from the north rim during the 2006 Geology Field Studies excursion.

Additional References: Barringer, 1909, National Academy of Sciences Philadephia, 52 pp; Gilbert, 1896, Science 3, 1-13; Merrill, 1908, Smithsonian Miscellaneous Collections 50, 461-498; Shoemaker & Kieffer, 1974, ASU Center for Meteorite Studies 17, 66 pp.

Third ISEM Summer Excursion: Iceland's Vision for Energy Self Sufficiency Without Fossil Fuel

By Louis L. Jacobs, President of I.S.E.M.

Iceland is the only country that sits on top of both a mantle plume and a midocean ridge. On the south side of the island, the mid-Atlantic Ridge comes ashore where exposures of uplifted pillow lavas form sea cliffs (left). The volcanic activity of the plume under Iceland generates a constructional pile of volcanic rocks that provides the topographic relief necessary for hydroelectricity generation.

As a result, Iceland will probably be the first country in the world to transition to a fossil fuel free, low CO_2 emissions economy when it comes to energy generation and transportation. Iceland already taps its extensive geothermal energy (a working geothermal plant on the left) and hydroelectric reserves for power generation. Icelanders use geothermal fluids for direct heating of their towns.

The next step is to convert to hydrogen fuel cell powered transportation. The availability of cheap power enables the electrolytic generation of hydrogen. The compressed hydrogen is now becoming available in Iceland at local gasoline stations.

The 2006 Institute for the Study of Earth & Man excursion participants: Professors David Blackwell, James Brooks, Bonnie Jacobs, & Louis Jacobs, Geological Sciences; Professors Bijan Mohraz, Civil & Environmental Engineering, David Johnson, Mechanical Engineering, and James Dunham, Associate Dean, S.E.A.S.; Jim Gibbs, Jack Hamilton, Bobby Lyle, and Leighton Steward, Starky Wilson, ISEM Board Members; Adam Dunsworth, Roy Huffington, and Ray Marr.

Maars Not So Cryptovolcanic

Oblique aerial photograph of Al Wahbah, a Cenozoic maar found at the western edge of the Harrat Kish'b volcanic field associated with the opening of the Red Sea, Saudi Arabia. Al Wahbah is approximately 2 km across and is about 200 meters deep. The explosion removed half of the pyroclastic cone shown in the lower left corner of the photograph. Lava flows from the younger shield volcanoes on the skyline flowed around Al Wahbah. The brownish material ringing the crater is palagonite tuff. The dark colored rocks in the crater's steep walls are Precambrian basement rocks.

News of alumni, faculty, & friends

Graduate student Juan Garcia Massini took this panoramic view of outcrops of terrestrial sediments showing some cut and fill channels as well as deposits that contain fossil plants along the Margargaria River, Chilga, Ethiopia. This field work is part of a collaborative project funded by the National Science Foundation to study low-latitude Cenozoic tropical climate. Professor Bonnie Jacobs and students, Garcia-Massini and Aaron Pan, are using paleobotanical assemblages to constrain the climate at this time, one of the only ways to test the predictions of atmospheric circulation models. Professor Neil Tabor is also a colloborator on the project; he is using the numerous paleosols, their clay mineralogy and their stable isotope ratios to make quantitative estimates of the paleotemperatures during the Cenozoic.

Roy M. Huffington (B.S., 1938) attended the SMU Board of Trustees December meeting where he announced his establishment of two Ben Franklin-style trusts valued at $5 million each, one to benefit the faculty of SMU and the other to benefit its students. Roy is the major benefactor of Geological Sciences having previously funded the Albritton Chair and the Huffington Graduate Fellowships.

Barb Dutrow (M.S. 1980; Ph.D., 1985), a faculty member at Louisiana State University, is the 2007 President of the Mineralogical Society of America. The society is responsible for the venerable journal, *American Mineralogist* and the short course series, *Reviews in Mineralogy.*

Tae-Sung Kim (Ph.D., 2006) completed his thesis on various aspects of seismo-acoustics on the Korean Peninsula including the discovery of a natural infrasound waveguide. He is continuing on as a post-doctoral fellow with faculty member Brian Stump.

John Robbins (M.S., 2006) defended his thesis on stable isotopes applied to archaeological sites in the Channel Islands, California. Torbin Rick, Anthropology, co-supervises the work on one of earliest sites of human habitation in North America.

Ileana Tibuleac (Ph.D., 1999) is now a Research Faculty member at University of Nevada, Reno, after a several year stint at Westin Geophysics.

Rebecca Ghent (Ph.D., 2001) is now an Assistant Professor at University of Toronto, Ottawa, where she continues her work in planetary geophysics.

Graduate students **Aileen Fisher (B.S., 2004)** and **Mahesh Thakur** attended the SAGE field geophysics camp.

Joseph Grinnell (B.S., 2006) and Patrick Stepp (B.S., 2005) shared the Goodell-Richards undergraduate of the year award. Ph.D. student **Meredith Faber** received the Goodell-Richards teaching assistant award. **H.Grant Goodell (B.S., 1955)** established the awards to honor the late Art Richards.

Please share any career news and interesting photos with us for use in our newsletter. Contact Jenny Rosendahl.
**All prior issues of Geology at SMU can be found online at*
http://www.smu.edu/geology

Dr. William Heroy, Jr. (1915-2006), former Geological Sciences faculty member, passed away on September 25, 2006. Bill majored in geology, earning a B.A. from Dartmouth College in 1937 and a Ph.D. from Princeton University in 1941. After WWII, he joined The Geotechnical Corporation in Dallas, where he worked from 1945-1965, advancing to President of the company. When Geotech was purchased by Teledyne, Dr. Heroy took the post of Group Executive Assistant to the President, until he moved to Southern Methodist University. For seven years, Bill served as Vice-President Treasurer of SMU; then he presided over the Institute for the Study of Earth and Man until his retirement in 1981.

For his illustrious public service, Dr. Heroy was awarded the G.S.A. Distinguished Service Award and the A.G.I. Campbell Medal. A.G.I now presents the Heroy Award for distinguished service in his honor.

Jack Hamilton has established the Heroy Geoscience Student Support Fund in honor of his former Geotech colleague to be held in the Institute for the Study of Earth and Man. "This gift is intended to recognize Bill's lifelong commitment to geosciences and his understanding of the importance of financial support in preparing geoscientists of the future!" For more on this, contact ISEM or Professor Louis Jacobs. ---James Brooks, Professor Emeritus, Geological Sciences.

Geological Sciences Faculty, Southern Methodist University

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

James E. Brooks, Professor *Emeritus,* Ph.D., University of Washington. Stratigraphy and Sedimentology

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

Eugene T. Herrin, Shuler-Foscue Professor, Ph.D., Harvard. Theoretical and applied seismology, solid earth properties, computer analysis of geophysical data.

Louis L. Jacobs, Professor, Ph.D., University of Arizona. President of the Institute for the Study of Earth and Man. Vertebrate paleontology, evolution.

Bonnie F. Jacobs, Associate Professor and Chair of the Environmental Science Program, Ph.D., University of Arizona. Paleobotany & palynology of the Cenozoic.

A. Lee McAlester, Professor, Ph.D.,Yale University. Marine ecology-paleoecology, evolutionary theory, Paleozoic geology, petroleum geology.

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

Neil J. Tabor, Assistant 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, fluid-mineral interactions in the crust.

Crayton J. Yapp, Professor, Ph.D., California Institute of Technology. Stable isotope geochemistry applied to the study of paleoclimates, paleoatmospheres, and the hydrologic cycle.

Adjunct Faculty

Steve Bergman, Adjunct Assistant Professor, Ph.D., Princeton University. Tectonics, Petrology & geochronology.

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

Jason R. McKenna, Research Assistant Professor, Ph.D., Southern Methodist University. Applied Geophysics.

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

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

John Wagner, Adjunct Assistant Professor, Ph.D., University of Texas, Dallas. Chief Geologist, Nexen Petroleum, USA.

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

Dale A. Winkler, Adjunct Associate Professor and Director, Shuler Museum of Paleontology, Ph.D., University of Texas at Austin. Paleontology, paleoecology, stratigraphy.

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