GEOLOGY at SMU

An occasional newsletter for alumni and friends: December 2006.

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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.atd

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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.

Chairman's Report

M e Le e C ad P a ea : Me e C a e a e G be

By Robert T. Gregory

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.

Photo by Hillsman B. Jackson

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 A , La a H (B.S. 1956), e Pe a e Ge e a Lea e a R c Le ac S & B e

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.

B & A b Se a Pa e e P c B de l ac P b ed 70 Yea A SMU Sc e ce J a F e d & Lab a

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

NASA Landsat 2000

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

T d ISEM S e E c : Ice a d V f E e Se f S f c e c W F F e

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.EA.S.; Jim Gibbs, Jack Hamilton, Bobby Lyle, and Leighton Steward, Starky Wilson, ISEM Board Members; Adam Dunsworth, Roy Huffington, and Ray Marr.

Maa N S C ca c

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.

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

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.

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