GEOLOGY at SMU

An occasional newsletter for alumni and friends: March 2008.

A.V.P. for Research & Dean of Graduate Studies

Quick Studies Subvolcanic Plumbing

Every commerical airliner that flies over Alaska must avoid volcanic ash plumes that are serious hazards for jet engines. Pilots get their information on volcanic hazards from the U.S. Geological Survey. New hire James E. Quick, previously, was the director for the survey'sVolcanic Hazards Program. This program is responsible for volcanic hazard assessment and the monitoring of volcanoes wherever U.S. national interest dictates.

When a volcano erupts at the surface, the style of the eruption is a function of all of the things that happened to the magma from its generation in the source region, its transport to the surface, its interactions with its surroundings, and its composition and physical state at the time of the eruption. Even though Quick's most recent appointment concerned the monitoring of active volcanic hazards, most of his career has been spent examining magmatic processes that occur deep in the crust or in the uppermost mantle.

Professor James E. Quick
Ph.D. Caltech, 1981
Research Interests: Architecture of magmatic systems

Quick's seminal work on the Trinity peridotite from the Klamath Mountains in Northern California documented in a most spectacular way the interaction between ascending basaltic melts and wall-rock peridotites. These upper mantle rocks formed beneath an oceanic spreading center now exposed in mountain belts as ophiolites (transported rock sequences of oceanic crust and uppermost mantle). The amount of olivine plated out on conduit walls meant that midocean ridge basalts had all fractionated olivine and hence were not primary melts of the mantle.

Turning his attention to layered gabbros, common in oceanic layer 3 (about two thirds of the thickness of oceanic crust), Quick documented how dynamic processes driven by gravity modified crystal mushes resulted in the large scale layering of gabbro bodies.He coined the term "gabbro glacier" to describe the process; his gabbro glacier model is very influential in marine geology circles.

Cross cutting clinopyroxenite dike symmetrically flanked by dunite (buckskin brown, smooth surface) harzburgite and lherzolite (salt and pepper surface on the left) showing the effect of the passage of magma (dunite and clinopyroxenite) on the successive depletion of wall rock peridotite in melt components going from dunite, to harzburgite to least depleted lherzolite.

In the Ivrea zone of the Italian Alps, Quick and coworkers mapped a lower-crustal layered gabbro body that intruded metasedimentary, lower crustal rocks. Chemical and isotopic variations in the layered gabbro demonstrate its transformation from a primary melt of the mantle to crustally contaminated magma. This interaction was a two-way process so that heat from the gabbro partially melted the host rocks to produce high silica magmas.

Quick thinks that they may have mapped the subvolcanic plumbing zone that would have fed a supervolcano (e.g., a Yellowstone) at the surface. He and his colleagues are currently making the field connections between the lower crustal rocks and the rocks that may be remnants of a contemporaneous caldera at the surface. If successful, they will have discovered the first vertical profile of an entire supervolcano from the surface to its lower crustal roots.

James E. Quick officially joined SMU during the summer, 2007, as the new Associate Vice President for Research and Dean of Graduate Studies. His home base is Earth Sciences.

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

Chairman's Report

Magma Production Rates: Mantle Melting and the Thickness of the Crust

By Robert T. Gregory

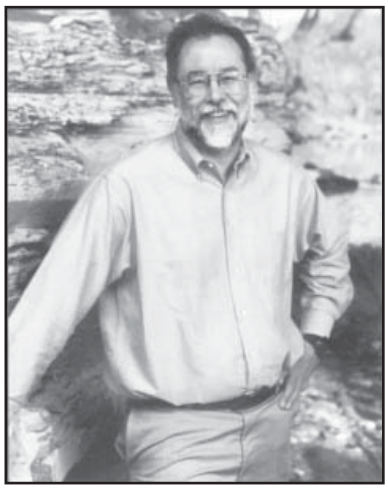

Photo by Hillsman B. Jackson

Our understanding of the origin of oceanic crust received a big boost during the plate tectonic revolution. The study of ophiolites, sequences of rocks presumed to be slices of ancient oceanic lithosphere, provided land-based geologists the opportunity to map oceanic rocks that could not be readily sampled by the dredge or the drill. One of the most interesting results of seismic surveys of oceanic crust is that the thickness of crust seems to be remarkably uniform independent of spreading rate. This result dates back to the pioneering refraction work done out of Scripps Institution of Oceanography by Russ Raitt and George Shor.

Spreading rates vary by about a factor of 10 in the modern ocean basins, so that it is interesting to speculate about what oceanic crust may have looked like in the Archean (>2.6 billion years ago). The mechanism for generating oceanic crust is important for the heat budget of the Earth; today it accounts for a significant fraction, almost 10%, of the geothermal output (e.g., *Geology at SMU,* December 2006). What happens to the amount of magma produced and to the thickness of the crust back in time when there was more heat production from radioactive elements such as during the Archean?

This is a problem where the type of mantle petrology practiced by new faculty member James E. Quick becomes important. Most petrologists now agree that the upper mantle of the Earth is dominated by peridotite, a peridot-rich rock. Peridot is the gemologists name for olivine. Upper mantle peridotite usually contains, in addition to olivine, two pyroxenes (orthyroxene or enstatite and clinopyroxene or diopside). Depending upon the pressure, there may also be accessory spinel or garnet.

The mantle source regions for basalt are dominated volumetrically by olivine and pyroxene with minor amounts of aluminous phases. Yet, partial melts of the mantle yield basalt and gabbro the dominant rock types of the oceanic crust. Gabbro is the slowly cooled plutonic equivalent of basalt. Gabbroic rocks, that faithfully reflect basaltic liquid compositions, are typically dominated by the mineral plagioclase (>50 volume %). Plagioclase, a member of the feldspar group, is a solid solution of $CaAl_2Si_2O_8$ and $NaAlSi_3O_8$. Our concepts of crust *versus* mantle are defined on the basis of feldspar occurence. In seismology, the special term describing the transitions from a feldspar-dominated lithology to olivine-dominated mantle lithology is called the Moho.

The Earth manages to partially melt an olivine($(Mg, Fe)_2SiO_4$)-rich rock and produce a magma dominated by plagioclase components that eventually makes its way to the surface. If it crystallizes deep enough in the mantle, it makes an eclogite (a mixture of pyroxene and garnet). The keys to understanding magma production rates are the melting relationships of mantle pyroxenes. Under mantle conditions, because of solid solution, pyroxene is the home of aluminum, calcium and sodium, the major constituents of plagioclase in addition to silicon and oxygen. The change in coordination from 4 nearest neighbors for Al in plagioclase to 6 nearest neighbors in pyroxene is a response to pressure. Of the two pyroxenes, clinopyroxene is the more important carrier because it naturally accommodates calcium.

Quick's original work on the Trinity Peridotite is important because it demonstrates the sequence of mineralogic depletion in a fertile (capable of generating basaltic liquid) peridotite (see photo on page 1). Aluminous peridotite called lherzolite loses its calcium-rich clinopyroxene first to become harzburgite, mixtures of olivine and orthopyroxene. Upon further melting or reaction with melts, the rocks transform by magmathermal interactions to become dunite (an olivine-dominated rock). The inferred sequence of melting is olivine plus two pyroxenes, olivine plus orthopyrxoene, and finally olivine by itself. The components necessary to make basalt are dominantly extracted as lherzolite transforms to harzburgite. This is

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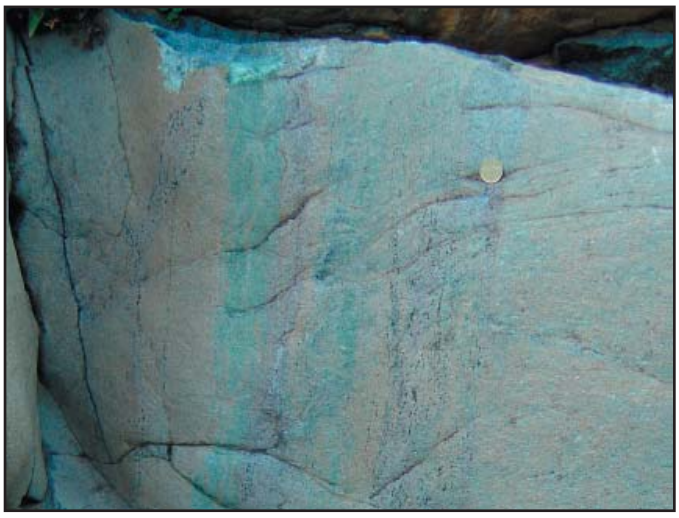


An example of a fertile mantle peridotite from the Ivrea Zone of the Alps. A near vertical foliation is present with bands of Cr-rich green diopside (clinopyroxenite) parallel to the foliation. The darker minerals are spinels rich in chromium. The more massive pale rock is lherzolite (olivine + Ca-Mg pyroxene + enstatite, Mg-rich pyroxene). The elements that melt out of the rock to produce feldspar in basalt largely come out of the pyroxene.

Continued from Page 2

why harzburgite is the most common rock sampled beneath the crust/mantle boundary recorded by ophiolites. So what happens when the temperature of the mantle melting is increased? Clearly, the amount of plagioclase and eventually crust produced is limited by the volume of aluminous pyroxene. More heat leaves more dunite residuum but does not result in more gabbroic liquid. The resulting liquids that become more Mg-rich have names like picrite and komatiite. The later, named after a place in South Africa, is considered on the basis of melting experiments to be a very high temperature melt of the mantle, ~1500 ºC.

Magmas that are very rich in magnesium tend to be highly fluid. Experimental petrologists estimate that they form some 60 km below the surface. Because fluid magmas typically travel as veins and dikes, they quickly lose heat to their surroundings and as a result drop crystals. For Mg-rich magmas (ultramafic), the mineral most commonly precipitated is olivine in the form of cross-cutting dunite. Peridotites from ophiolites or the so-called Alpine peridotites are full of cross-cutting dunite bodies left behind by ascending magmas.

The answer to the question about why the thickness of oceanic crust is so insensitive to spreading rates is now for two reasons: firstly, the amount of feldspar extracted from the mantle is largely limited by pyroxene content and secondly, increased degrees of melting yield more olivine-rich rocks in the upper mantle because of the efficient separation of olivine from ascending melts. Increased degrees of partial melting of the mantle do not yield more oceanic crust; the thickness of the crust is robust against changes in spreading rates.

The boundary between the crust and mantle is exposed in the Oman Mountains, Sultanate of Oman. Rocks to the right are peridotite (olivine-rich rocks) consisting of the subtypes dunite, the buckskin brown color, and harzburgite (olivine + orthopyroxene), the darker rocks. Plagioclase feldspar-rich rocks on the left are separated from the mantle by a thin dark layer of wehrlite, a magmatic accumulation of olivine and pyroxene. Seismically, the crust-mantle boundary is marked by the predominance of Al-rich feldspar of the crust.

Jane Christman Albritton Life-Long Partner to Professor Claude Albritton, Jr., & Grand Matriarch of SMU Geology

Jane Christman Albritton died on Saturday, September 22, 2007, after a stay of a few days in Baylor Hospital. Jane had suffered many years from a lung problem resulting from an encounter with bird flu in Ethiopia. Pneumonia was the ultimate cause of her death. Jane was married to Claude Albritton for 5 decades until his death in 1988.

The Albrittons were very effective partners, not because they were alike but because in many ways they were opposites who shared the same goals. Together, they made a dynamic pair who contributed much to their family, to the university, to the city, to the geological community and to the world. Jane was very much her own person with her own distinctive approach to almost everything.

One of those distinctions is that, as a young woman, Jane was hired as a park ranger at the Volcano House on the big island of Hawaii. She kept the job until the National Park Service discovered that she was a woman; there were no female park rangers at the time. In a compromise to keep the job, she was reclassified as a switchboard operator. Jane met Claude in Hawaii, most likely as a result of her position near the volcano, and relocated to Dallas to join Claude who was a young professor in the SMU Geology Department. Jane never forgot her ties to Hawaii.

Jane had a deep respect and affection for the things that Claude did and, in her own way, was totally and effectively supportive of them. This included joining him in the deserts of Nevada while walking barefoot in grand Hawaiian style.

As Claude's memory faded within the SMU community, Jane was a very effective advocate for Claude's important legacy to SMU. Jane was a frequent participant at our Golden Mustang Geologist Dinners held each spring. She contributed the idea for the article on the balloon bombs of World War II and elucidated Claude's role in locating their source (*Geology at SMU*, 2003).

At the University of Hawaii, a scholarship supports elementary education in memory of Jane's contributions to early childhood education. The SMU Albritton Chair and a Geological Society of America scholarship honor Claude.

J.E. Brooks, D.B. Blackwell, & E.T. Herrin, contributors.

Geological Sciences to Earth Sciences: A name change for the "Anthropogene"

SMU Board Approval at Dec. Meeting

Earth Sciences is the new name for the Geological Sciences Department. It is time for an update to better reflect the type of science "Geology" has become. While geology is truly the study of the Earth, the perception of geology in the public eye is too narrow to reflect the richness of the modern discipline. With the Apollo 8 mission in 1968, the astronauts were the first humans to see the Earth in its entirety. This view was particularly stunning when the Earth was first seen to rise over the Moon. The science of comparative planetology was about to take off.

A Punctuated History of Modern Geology

Post World War II: Marine geology and geophysics expands and isotope geology is born because of the nuclear age.

1950s: Cold war generates new interest in science education: earth science becomes early secondary school subject.

1960s: Nuclear atmospheric test ban treaty generates big investment in modernizing seismology to detect underground tests. SMU's Gene Herrin plays a key role.

•Plate tectonic revolution grows out of marine geophysics.

•Space race and Apollo program provides second big boost to geochemistry and petrology.

•Foundations of Earth Science series edited by A. Lee McAlester expands the palette of introductory geology offerings.

1970s: "Earth" in book titles begins to dominate over "Physical Geology."

•A.Lee McAlester publishes a book called *the Earth* using an "earth systems" approach; SMU President, James Zumberge, retains the title, "Physical Geology," for his textbook.

1980s: The *Cosmos* era: integrated science approach reflecting new discoveries in cosmology, planetary science and astronomy initiated by the late Carl Sagan.

•Impact of geochemist C.D. Keeling's carbon dioxide measurments becomes tied to concerns about climate change.

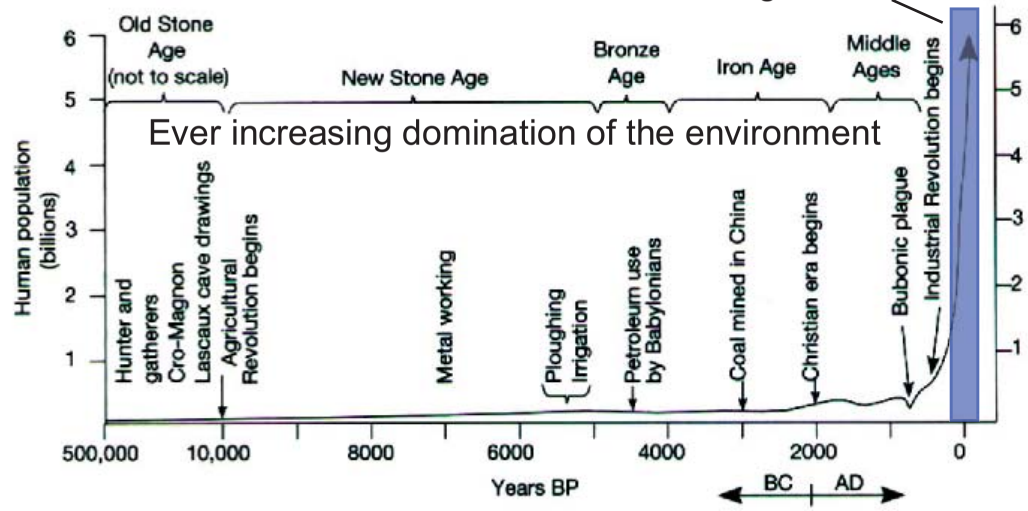
Clockwise from top right: The Earth rises over the Moon in this shot from NASA's Apollo 11 mission. Graph midpage: Human population growth shown against the backdrop of technological advances which have accelerated exponentially with the population. Unprecedented growth of human population, near "zero" on the x-axis, corresponds to the "Age of Oil" which will be less than a quarter of a millenium (modified after Mckenzie, 1998). Bottom: NASA's composite of the Earth at night showing the impact of electric lighting made possible by power generation that largely relies on fossil fuel located by geologists; this is a stunning example of one of the effects of the Anthropogene.

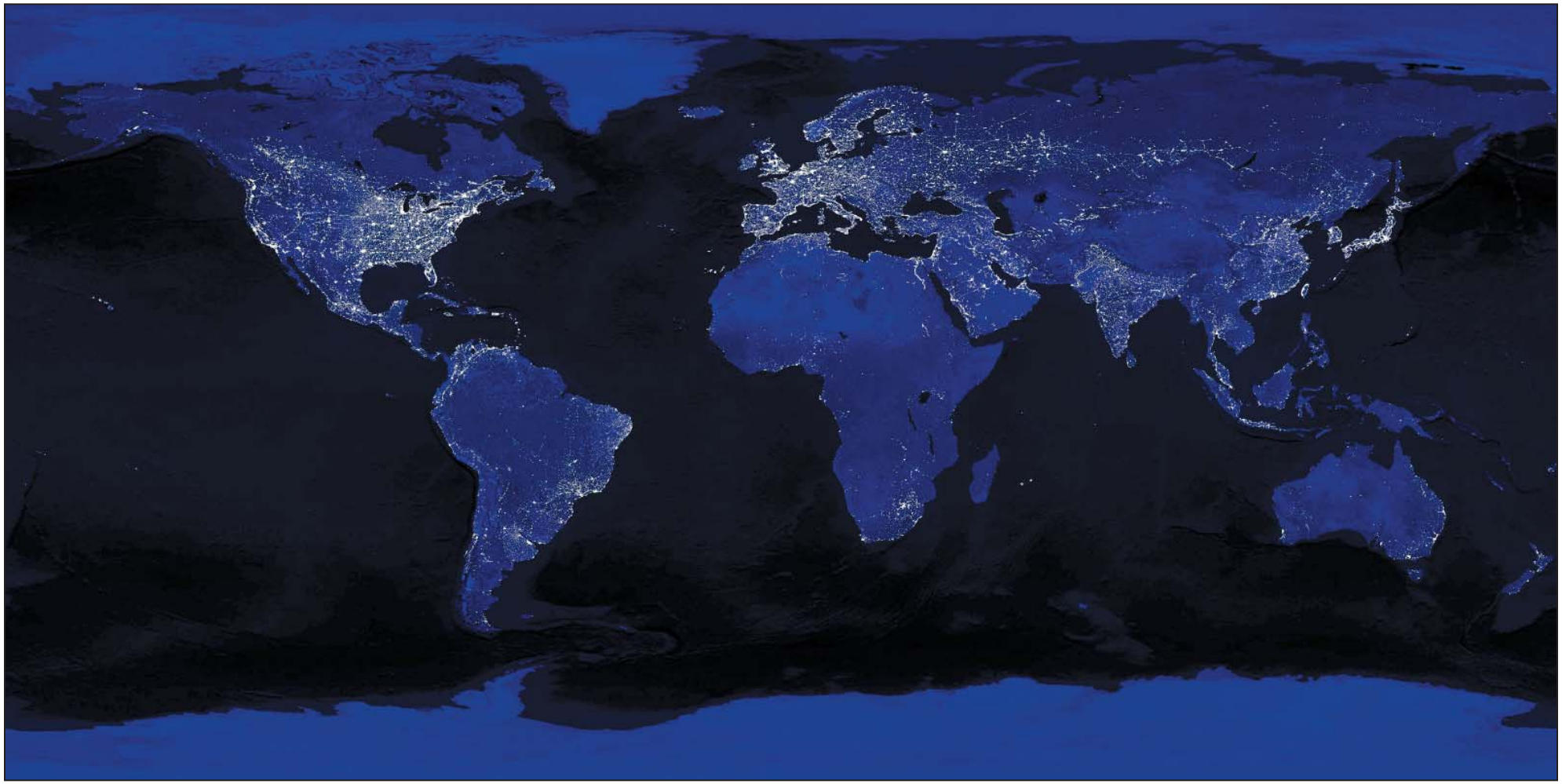
The challenge of the 21st Century will be whether our species has the ability to adapt to the new storylines brought on by our own success at using the environment for our purposes. The composite of the Earth at night clearly shows one spectacular effect of the "Anthropogene" resulting from the exploitation of energy. The understanding of modern earth science is central to our continued and future prosperity.

The Age of Oil

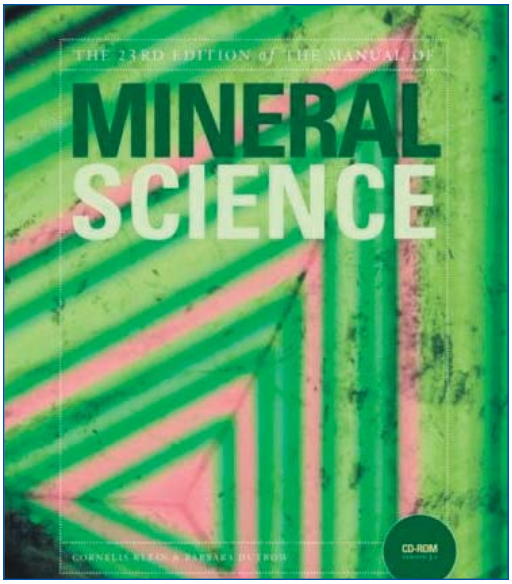
1990s: "Earth Systems" approach becomes dominant.

Modern geology is more properly called "earth science" as it addresses not only the study of rocks and minerals, oil and gas or fossils, but the Earth as an interacting whole: the interplay between the atmosphere, hydrosphere, lithosphere and even the deep interior of the Earth including its core. We have a unifying theory called plate tectonics that describes surface motions of the crust and uppermost mantle. It is the existence of these dynamic plates and water near its triple point combined with the distance from the Sun that makes the Earth habitable. Comparison of the Earth against the other planets and their satellites clearly shows how special we are: the Earth is the only place in the Solar System with the inherent stability of environment to allow us to flourish.





Alumna Barb Dutrow joins the Dana's Mineralogy franchise as coauthor of Mineral Science 23rd ed.



A picture of a thick section of a large tourmaline crystal (several cm scale) cut to show 3-fold symmetry and the delicate chemical zonation is the 23rd edition's cover photo.

Barb Dutrow (M.S. 1980; Ph.D., 1985), a faculty member at Louisiana State University, is now co-author of *the Manual of Mineral Science, 23rd edition*, based upon *Dana's Mineralogy* originally published in 1848. She joins, as co-author, Cornelius Klein, University of New Mexico, who joined Harvard's Cornelius Hurlbut as coauthor for the 19th edition published in 1977.

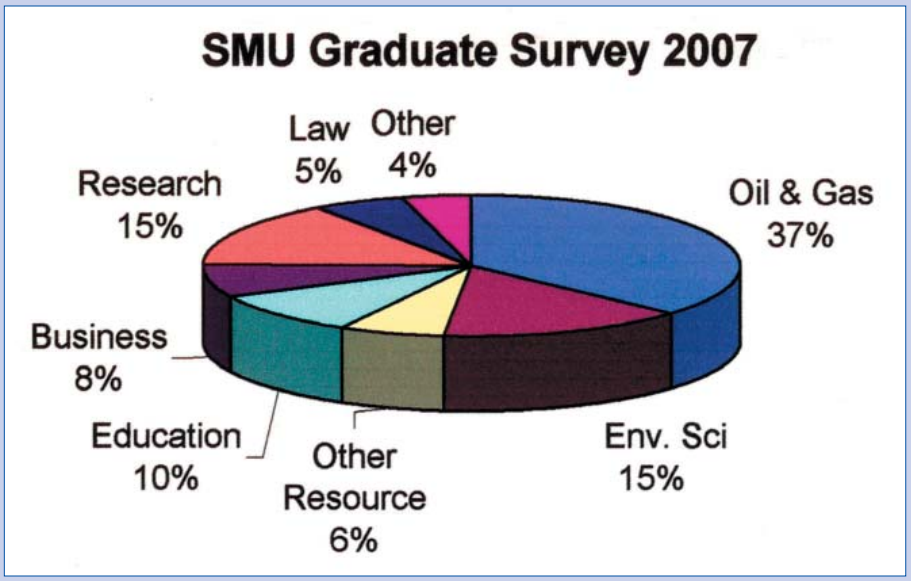
The 23rd edition represents an extensive rewrite (now some 10% more pages) while remaining faithful to the spirit of the previous editions that cover crystal chemistry, crystallography and comparative mineralogy. The new edition is more student friendly. Former chapters are now multiple, smaller coherent units; each chapter starts with a statement of a key concept.

Mineralogy is a core subject in our department, part of our Earth Materials sequence. Mineral science is a field that is cross fertilized by chemical and solid state physics with applications to materials science. With its roots in atomic theory and symmetry, mineralogy bridges 20 orders of magnitude from the volume of a unit cell, a mineral's basic building block, to a thumbnail mineral specimen.

Experiencing the difference between pyroxene and amphibole cleavage has its roots in the *t-o-t* beam structures now observable by electron microscopy at the nanometer scale. Aesthetics aside, the applications of the mineral sciences support our way of life.

Alumni Career Choices Stable

During the Fall Semester 2007, we repeated our survey of the alumni using the same format that was used in 2002. We only contacted alumni who did not respond to the previous survey. The results of this survey were consistent with the results of the previous one (see *Geology at SMU*, October, 2002). As we said before, "Geology is always a good bet." Careers in oil and gas still dominate the responses with recent graduates getting snapped up due to the shortage of geologists and the pressures on companies with aging work forces. A large number of our bachelor degree holders go on to higher degrees.



Opposite page top: **Geothermal springs at Yellowstone National Park** exhibiting different colors related to a multiplicity of environments around the hot spring from silica oversaturated blue waters to yellow to brownish-red colors of bacterial colonies that exploit the extreme chemical and physical environment for their metabolism. Extremophiles are critical for understanding how early life may have evolved on the Earth. The **2007 Institute for the Study of Earth & Man excursion** participants: Professors David Blackwell, James Brooks, Robert Gregory, Bonnie Jacobs, Louis Jacobs, Roy Mink (new research professor) and James Quick (US Geological Survey, see our cover story), Earth Sciences; Professor, David Johnson, Mechanical Engineering, S.EA.S.; James Gibbs, Jack Hamilton, Ray Marr and Leighton Steward, ISEM Board Members; Adam Dunsworth, vidographer; Diana Vineyard and Kent Newman, logistical support, and guest excursion leader: former Hamilton Visiting Professor, Robert Smith, University of Utah.

More news of alumni, faculty, & friends

Professor Emeritus James E. Brooks contributed to Archaeologist Fred Wendorf's *History of Fort Burgwin* published in 2007. Wendorf, through his friendship with the major benefactor, William Clements, and Brooks, through his administrative leadership, were instrumental in the establishment of the Fort Burgwin site as the SMU at Taos facility.

Barb Dutrow (M.S. 1980; Ph.D.,1985), LSU's Adolphe G. Gueymard Professor, presented her Presidential Address for the Mineralogical Society of America at the national GSA meeting in Denver.

Kamil Erkan (Ph.D., 2007) completed his thesis on relating heat flow to tectonics. He is a post-doctoral fellow at Ohio State University.

Paul Golden (M.S., 1986) defended his Ph.D. thesis on design and applications of infrasound arrays for the monitoring of nuclear tests. Paul is director of operations for the Lajitas (TXAR) and Mina (NVAR) arrays.

Heather Deshon (B.S., 1999) is a Research Faculty member at University of Memphis in their center for earthquake research. She presented a departmental seminar last year on the seismicity of subduction zones.

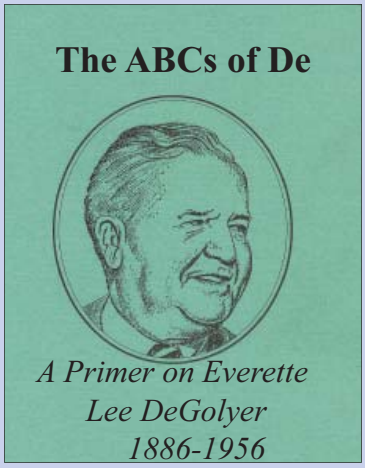
Jason Head (Ph.D., 2001) is now an Assistant Professor in the University of Toronto system where he continues his work on vertebrate paleontology.

Undergraduate **Rachel Barber (B.S., 2007),** now at University of Oklahoma, attended the SAGE field geophysics camp. Undergraduate **Katherine Becker, (B.S. Geology & Chemistry, 2008**) attended a field camp in Turkey this summer.

Candice Adkins (B.S., 2007) received the Goodell-Richards award. She is now a graduate student in hydrology at the University of Arizona. Ph.D. students, **Scott Myers** and **John Robbins (M.S. 2007)** received the Goodell-Richards teaching assistant award.

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/earthsciences

Herbert Robertson (B.A., 1951; M.S., 1959) finished his book entitled, *The ABC's of De: A Primer on Everette Lee DeGolyer, 1886-1956*, published by the DeGolyer Library. The book was unveiled at the DeGolyer library on October 9th on the anniversary of DeGolyer's birthday in 1886. The book is organized by key words that are listed in alphabetical order and documents the life of the visionary oilman. DeGolyer was a lifelong friend of the late Claude Albritton, Jr., and through this relationship, DeGolyer made major contributions to the libraries at SMU.



Many SMU geology students were interns at DeGolyer-McNaughton with Herb Robertson being one of them. After a career in exploration geophysics, Herbert developed an interest in the life of DeGolyer and began research towards a definitive biography emphasizing his contributions to science. The current primer is gleaned from the more than 2000 page manuscript generated by years of research.

The book is available through the SMU DeGolyer Library. Contact DeGolyer Librarian Russell Martin for further information.

Earth 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. Paleoecology, evolutionary theory, petroleum geology.

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

Anthony Fiorillo, Research 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.

L. L. "Roy" Mink, Research Professor, Ph.D., University of Idaho. Geothermal energy and hydrology.

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, Nexen Petroleum, 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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