GEOLOGY at SMU

An occasional newsletter for alumni and friends. December 2002

Crayton Yapp studies climate changes

Dallas metropolitan area CO_2 factory

Two global carbon cycles are at work on our planet. The first is a short-term cycle, which operates on time scales of a few years to decades and transfers carbon between biological, atmospheric, and oceanic reservoirs. Photosynthesis and respiration are key processes in this short-term cycle. The second global carbon cycle is long-term (thousands to millions of years) and carbon is transferred between buried organic matter, the atmosphere, rocks such as carbonates, and the oceans. Atmospheric CO_2 is an essential "middle man" in both cycles, and the atmosphere acts as a clearinghouse for transfer of carbon from one reservoir to another. Therefore, the rates of the transfer processes control the concentration of CO_2 in the atmosphere.

Not only is the remarkable CO_2 molecule a crucial part of the carbon cycles, but it is also (after H_2O vapor) the second most important greenhouse gas in the Earth's atmosphere. Consequently, variations in the amount of atmospheric CO_2 can affect global climate. Over the past 450,000 years (until about the 1870's A.D.), concentrations of atmospheric CO_2 had not exceeded 300 parts per million (ppm); see page 7. However, beginning in the 19th century, atmospheric CO_2 concentrations rose at increasingly rapid rates to a current (and rising) global value of about 370 ppm. The principal reason for this accelerating rise seems to be the rapid increase in combustion of fossil fuels associated with industrialization and population growth. This increased use has effectively short-circuited the long-term carbon cycle and speeded the return of buried organic carbon to the atmosphere as CO_2.

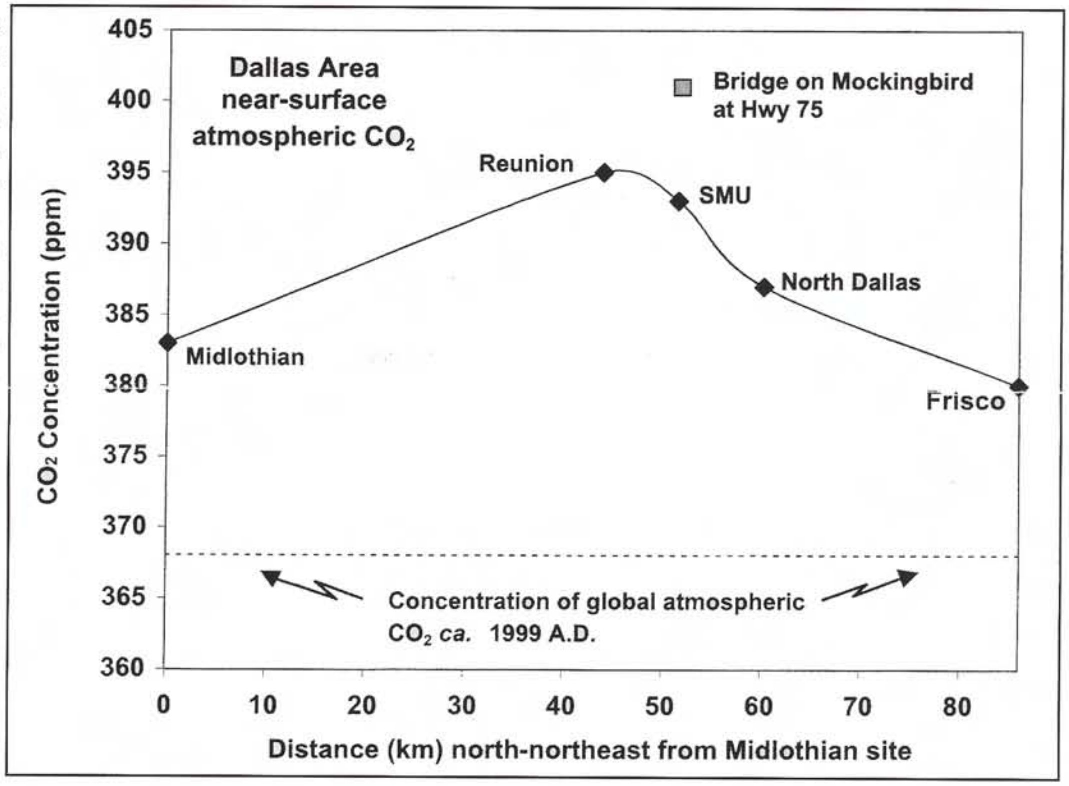

Figure 1: Average atmospheric CO_2 concentrations measured at six sites in the Dallas area. The site on the bridge at Mockingbird is distinguished from the others because of its immediate proximity to the heavily traveled street.

Carbon contains two naturally occurring non-radioactive isotopes with atomic mass numbers of 12 (^{12}C) and 13 (^{13}C). Small variations in $^{13}C/^{12}C$ ratios occur in natural materials as a consequence of a variety of processes (for example, photosynthesis). These variations are manifested in fossil fuels and atmospheric CO_2. Natural gas, which is predominantly methane, typically has a lower $^{13}C/^{12}C$ ratio than coal or petroleum products such gasoline. The $^{13}C/^{12}C$ ratios of all of these fossil fuels are, in turn, lower than that of "background" atmospheric CO_2. Thus, addition of large amounts of CO_2 to the atmosphere as a result of combustion of fossil fuel tends to raise the concentration and lower the $^{13}C/^{12}C$ ratio of the resultant atmospheric CO_2 mixture.

Continued on Page 7

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Chairman's Report

Monitoring a planet's vital signs

By Robert Gregory

Global warming is an issue that is constantly in the news. Every time we have a heat wave or unseasonably warm temperatures, it gets attributed to global warming. The source of global warming, we are told, is us. This carbon dioxide buildup appears to be related to the combustion of fossil fuel and to the deforestation brought on by human population growth.

In this issue, Professor Crayton Yapp reports on one aspect of his research with Shannon Clark Thorne (our guest contributor on page 3) into the carbon cycle, that is soon to be published in *Applied Geochemistry*. We highlighted Crayton's groundbreaking work on ancient carbon dioxide in the *Dedman College Newsletter,* Winter 2002.

We also report on new Ph.D. Meena Balakrishnan and her work on the stable isotope ratios of land snails of the Great Plains and their significance for 10,000 year scale climate change. Meena's work, also supervised by Crayton, was done in collaboration with Anthropology's Professor David Meltzer.

The common threads in all of this work are the stable isotopes of hydrogen, carbon, nitrogen, oxygen and sulfur, all of which are elements present in common compounds that occur as solids, liquids, and gases.

These elements are ideal tracers of processes that occur in the atmosphere, biosphere, hydrosphere, and lithosphere. In no small way, measuring the stable isotope ratios of common compounds is analogous to taking the vital signs of the planet.

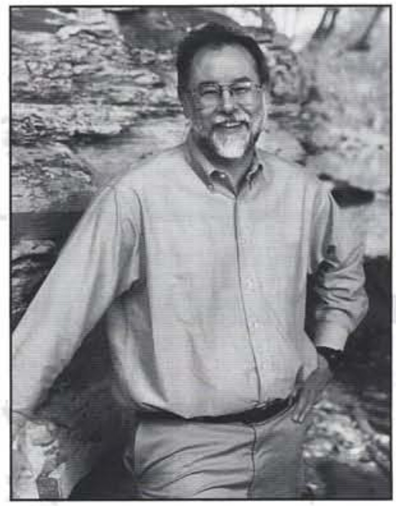
At SMU, we specialize in the isotopes of hydrogen, carbon, and oxygen; paleoclimate from the Archean to last week's rainstorm is the subject of much of the activity of the lab.

So what do stable isotopes tell us about climate? We have learned that the current Earth waxes and wanes between larger continental ice sheets and its present state. For a good portion of the Tertiary, the Earth has been in a state of ice age. These continental ice sheets apparently grow slowly and collapse quickly; the evidence comes from oxygen and hydrogen isotopes.

There are longer periods, 100 million year scale, where the Earth is in a warmer "greenhouse state." The difference in global mean temperature between the long-term greenhouse state and the long-term icehouse state is not that great, maybe as little as 5 °C.

Work done at the SMU Stable Isotope Laboratory shows that even during a global greenhouse period, there is probably enough ice around to generate small changes in sea level. These are required to explain cyclicity in platform sediments of the type reported to us this Fall by AAPG Distinguished Lecture Professor Michael Grammer (M.S.'83).

On still longer scales, there is an inferred long term general warming of the Earth resulting from the increasing luminosity of the Sun with time. Crayton Yapp's Ordovician goethite samples record 15x present-day atmospheric CO_2 while at the same time indicating tropical surface temperatures similar to those of today. Proterozoic glaciations may be the biggest yet inferred from the rock record.

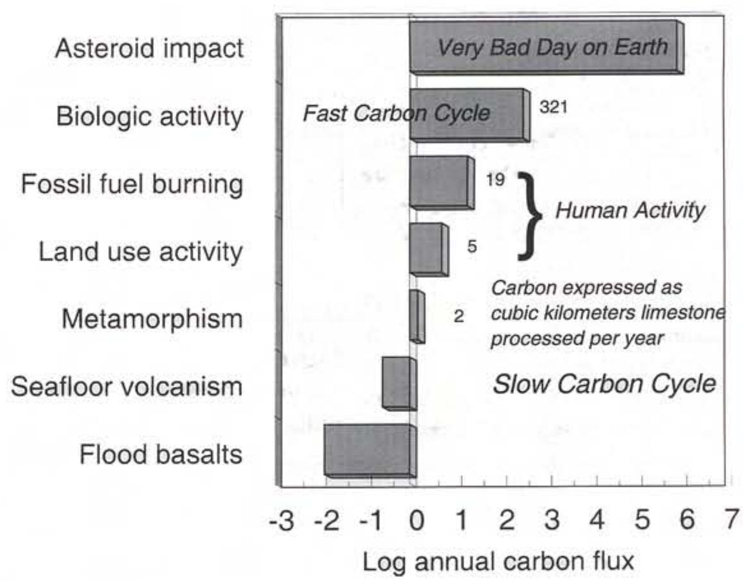


Should we be worried about global warming? The figure below and the graph of modern CO_2 growth compared against the last 160,000 years suggests that there is cause for concern.

Even the levels of atmospheric CO_2 targeted by the Kyoto protocol will allow CO_2 concentrations to grow to levels (≈550 ppmV) last seen many millions years ago when sea level was much higher than it is today.

For the last 450,000 years, the levels have oscillated between 175 and 300 ppmV (one major cycle is shown on the graph on page 7). The fast cycle fluxes, while enormous, are throttled by the oxygen content of the atmosphere: respiration and photosynthesis must stay in rough balance.

The rates at which we are burning carbon are geologically anomalous when cast in rates tied to the rock cycle. If we want to slow the growth of Crayton's "Dallas' CO_2 factory," we must follow Bonnie Jacobs' lead (page 6) and make some informed choices. It may be easier and more economical to work the problem at the source than to engineer a gigantic atmospheric cleanup in the future.



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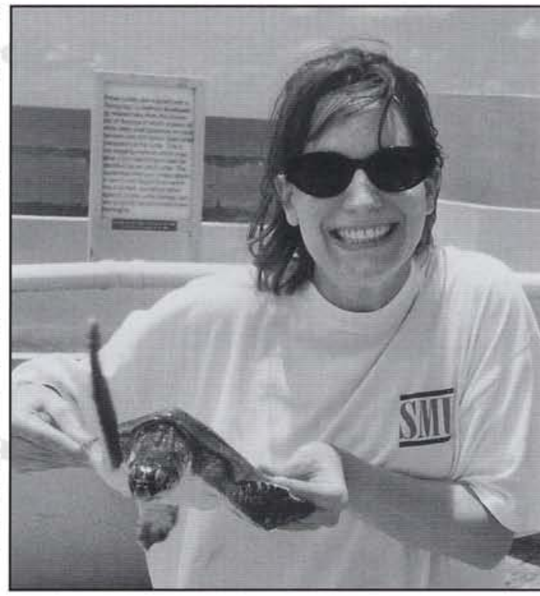
Shannon Clark Thorne

SMU geology grad takes skills to UT law school

(Note: We asked 2000 graduate Shannon Clark Thorne to give us a bird's-eye perspective of life in law school following her academic work here in Geology. She will graduate from the University of Texas School of Law in May 2003. Prior to law school, Shannon earned a BS and MS in Geology from SMU. Her thesis focused on variations in concentrations and carbon stable isotope values of atmospheric carbon dioxide in the Dallas metropolitan area. She is married to Brian Thorne, SMU class of '99 and '00, and resides in Austin, Texas. Her report follows.)



Shannon Clark Thorne

Last semester, I was one of thirty law students to be selected as a Teaching Quizmaster (TQ) for the class of 2005. *(A teaching quizmaster (TQ) is a mentor/teaching assistant for the first year law students. TQs conduct sessions for the first years to help them navigate their way through the law school and help teach the Legal Research and Writing course. TQs are selected based on the basis of demonstrated ability in the fields of legal research, writing, and teaching as well as their ability to serve as mentors.)*

At the first orientation for the TQs, a professor passed around a list of 30 unique characteristics, one belonging to each TQ. Our job was to match the person to the characteristic. I quickly scanned the list to find what characteristic identified me — it read "has a masters in Geology from SMU." That was how I stood out from my fellow TQs; it *is* how I stand out from my peers at the University of Texas School of Law.

To those that inquire about my background, the answer comes as a surprise. For many, the study of science and the practice of law are not compatible bedfellows. Science, a discipline of observations and hypotheses, is at odds with the legal system, a system that devises quick-fix solutions to whatever problems politicians deem important. However, despite such apparent differences, the studies of science and the law are actually quite similar.

With science, you gather the data, and with law you gather the facts of the case. Just as scientific data can dictate a research path so too can the facts of a case dictate an avenue of further investigation. In the disciplines of science and law, data and the facts of a case are compared with other data and other cases, distinctions are made, the data and cases are synthesized to develop a theory or rule that describes a particular area of scientific interest or an area of law.

Yet, with both science and law, the rule will not explain every situation and in these circumstances with both disciplines, it is important to know the limitations of the rule — what it tells you but also what it does not tell you. Science and law, both grounded in detailed analysis and careful application, are not so unlike as they may first appear — in my opinion, they make the perfect partnership.

Balakrishnan studies old and new snails

(Meena Balakrishnan came to the United States in 1996 to pursue a Ph.D. here at SMU. She is a native of Irinjalakuda, Kerala State, India. Meena chose SMU to follow her interest in environmental science. Her plans for the immediate future include writing and publishing. Married to fellow SMU geology alumnus Ken Wisian, they live in Weatherford.)

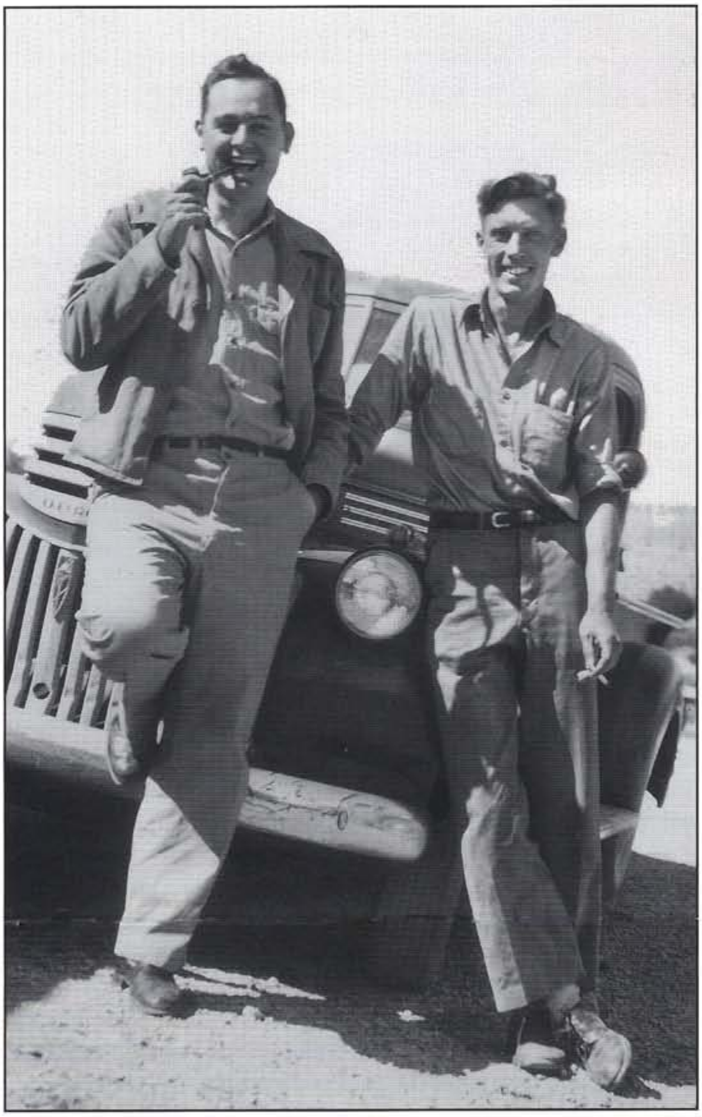
Meena came to SMU with a background in zoology. While at SMU, she developed an interest in stable isotope geochemistry, and decided to combine isotopic methods with her previous training to study environmental questions. Meena is particularly interested in climate changes in the past and in the kinds of insights that knowledge of such changes can provide into modern concerns about global warming in the face of population growth and increasing demands on resources.

The study of ancient climates depends upon the existence of "proxy" indicators of climatic variables such as temperature. Meena's training led her to focus on a proxy that most people regard as a nuisance—land snails. It happens that land snails are extremely sensitive indicators of their environments, most notably the climatic conditions. Land snails contain a record of these climatic conditions preserved in natural variations of the isotopic ratios of carbon and oxygen in the aragonite shell of the snail. Meena refined a mathematical model that explains precisely how the water, temperature, relative humidity and food sources in a snail's habitat might be related to the isotopic composition of the shell. She then successfully tested this model with isotopic data from modern snail populations.

With the conceptual framework provided by the model as a starting point, Meena analyzed and interpreted isotopic data from snail shells collected at the Folsom archaeological site in northeastern New Mexico. She found that there was an abrupt change in the climate of the Folsom site about the time of human occupation approximately 12,000 years ago.

According to Meena's thesis advisor, Crayton Yapp, the full significance of this climatic event for the story of human activities at Folsom during that time has yet to be established, but it is evident from Meena's results that "something was in the wind."

All of this work culminated in Meena's successful defense of her Ph.D. dissertation this fall.



In 1943 young Claude Albritton, left, and Art Richards were in Goodsprings, Nevada, working for the USGS and looking for strategic minerals for the war effort. In 1981, Roy Huffington and Phyllis Gough Huffington established the Claude C. Albritton, Jr., Chair in honor of their lifelong friend.

Roy M. Huffington's disting

By James Brooks
Professor Emeritus Geological Sciences

Roy M. Huffington, who graduated from SMU in 1938 with a baccalaureate degree in geology, has had a long, varied and very distinguished career – in geology, in the U. S. Navy, in petroleum exploration, in international business and in diplomacy.

After completing his SMU degree Huffington was accepted in the graduate program in geology at Harvard where he earned both the M.A. and the Ph.D. degree, finishing the latter in early 1942. Shortly thereafter Roy volunteered for the Navy where, over the next three and a half years he rose from the rank of Ensign to Lt. Commander.

During the latter part of this time he served on the staff of Admiral Spruance who had his flag in the *USS Hornet* – a famous battle carrier. Huffington received recognition for bravery in action – the Bronze Star, the Presidential Unit Citation, the Philippine Presidential Unit Citation and the Asiatic-Pacific Campaign Medal (with 7 battle stars).

Near the end of his service the *Hornet* and its battle group along with significant components of the Pacific fleet drove, under Admiral Halsey's orders, through the middle of a major typhoon – one that cost the Navy a number of smaller vessels and which damaged almost all of the vessels that experienced it.

After the war, Huffington joined the Humble Oil and Refining Company, now a part of Exxon Mobil. He worked largely in the Southwest as Field Geologist, Senior Geologist and Division Exploration Geologist. But when Esso, the parent Company of Humble, wanted him to move to Europe to organize a new subsidiary there Roy resigned and organized his own exploration company – Roy M. Huffington, Inc.

After about ten years of successful exploration in the Gulf Coast of Texas and Louisiana Huffington recognized that significant opportunities in exploration lay overseas.

He took note of the significant potential markets for clean burning gas that lay in Japan, Korea and Taiwan. After protracted

Bob Trace, class of 1940: A life of rocks and maps

Bob Trace earned his bachelor of science degree in 1940, being in the first full graduating class taught by the late Claude Albritton upon his return from Harvard in 1936.

At that time, the department had a small faculty built by its founding professor Ellis Shuler. Shuler hired people that he knew personally, and he relied on early SMU graduates, first Edwin Foscue and later the young Claude Albritton and a University of Chicago trained geographer named Virginia Bradley.

Bob recalls the contrast in styles between the older head of department and newly-appointed young assistant professors. Bob says, "Hiring Claude Jr. was the best thing Shuler could have done for SMU." It was a small but dedicated group operating out of the 2nd floor of Hyer Hall; most students got jobs as lab assistants.

After leaving SMU, Bob made an early attempt at continuing with graduate research, having developed a taste for it as an undergraduate research assistant. However, he was short of money so that he passed a "Junior Geologist" exam at the U.S. Geological Survey and was hired in at what is now a GS-5 level for the sum of $2,000 per year.

His first job, which was later to develop into a lifelong project, was to explore for fluorite in western Kentucky as part of minerals program from 1942 to 1945. While at the survey, he was introduced to one of Albritton's close friends, James Gilluly.

Just after the war, Gilluly moved to UCLA to become head of that department. Bob followed him to UCLA and planned to write up a Ph.D. based upon his fluorite work. He passed his orals and took a master's degree and left for summer field work with Gilluly on the Colorado Plateau.

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shed career benefits city, country and his alma mater

negotiations with the Indonesian government Huffington's group received concessions on the island of Borneo where they discovered major gas reserves.

This led to the development of a Liquefied Natural Gas plant that enabled the shipping of the gas north from Indonesia to the rapidly growing population centers and economies of eastern Asia which had major need of a large supply of relatively clean fuel. This paved the way for other successful international exploration activities.

During these years of extensive and successful international activity Roy had developed a well deserved and growing recognition for his ability to deal with foreign governments and industries and this led, in the first Bush administration, to his appointment as U.S. Ambassador to Austria. This was a singularly important post when he occupied it.

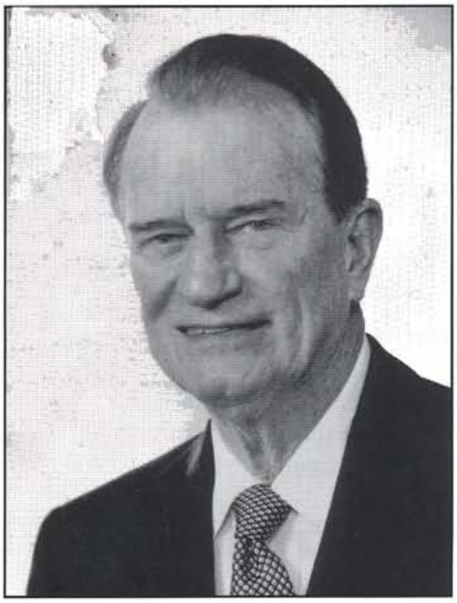
The Iron Curtain was in the process of falling and the economies of eastern Europe were growingly open to approaches from the West and the United States in particular to begin to develop their economies as free markets.

Moreover, Vienna was the seat of OPEC and the then Secretary General of OPEC was Dr. Subroto (of Indonesia), with whom Roy had developed a strong and cordial relationship when he was opening the LNG industry in Indonesia. For these and other reasons Huffington's three years in Vienna were particularly significant for the U.S. internationally.

At eighty five Roy continues to be very active and productive in a large variety of professional, civic and cultural activities – in Houston, in the nation and internationally.

Clearly, his SMU geological education coupled with his positive approach to opportunities and problems have enabled him to have a truly distinguished career that has benefited his city, his country, the international community and his alma mater.

In addition to the very generous Albritton Chair, the Huffingtons support graduate student research through their endowed fellowship program. They have also set up a Franklin Trust for the University.



Roy Huffington, above, earned his baccalaureate degree from SMU in Geology in 1938. At right, he appears in the 1938 Rotunda. He has had a distinguished career which covered the globe. On a more personal note, Mrs. Claude Albritton remembers that during World War II Huffintgon's ship would stop in Hawaii (where she was living) and he would bring her fresh fruit, a great commodity for the day.

Phyllis Gough Huffington, a Rotunda Beauty, was featured in the 1943 SMU yearbook.

USGS provides interesting livelihood for many geologists

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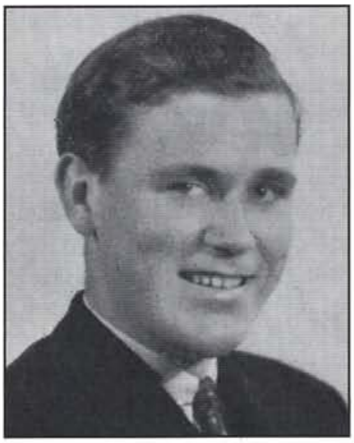
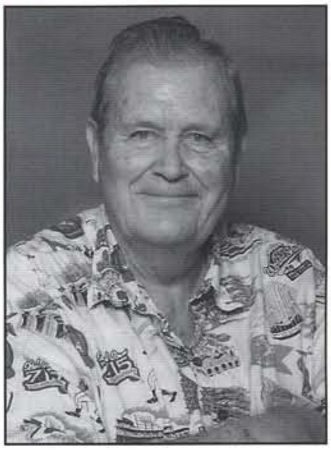
Once again the country's need for strategic minerals intervened, this time uranium for the growing nuclear program. In 1947, Bob rejoined the US Geological Survey to explore for uranium ore (carnotite) on the Colorado Plateau. The project was funded on a contract with the Atomic Energy Commission.

Bob never left the USGS, and he returned to the fluorite work in Kentucky after 1955. In his time at the survey, he completed seven 7.5 minute quadrangle maps and compiled 13 quadrangles into a map of the western Kentucky fluorospar district published as U.S. Geological Survey Professional Paper 1151-D.

In retirement, he continued to work part-time with the Kentucky Geological Survey. He now divides his time between Missouri and the Texas Rio Grande Valley.



Trace, in the 1937 Rotunda



Robert Trace, today

Herrick appointed principal investigator

(Note: Robert (Robbie) Herrick earned a Ph.D. in Geology in 1993 and now lives in Houston. Recently Herrick was featured in the Lunar & Planetary Information Bulletin, Summer 2002/ Number 93 - Lunar and Planetary Institute - Universities Space Research Association. We've reprinted that item below.)

Dr. Robert Herrick has been appointed principal investigator for the Lunar and Planetary Institute's Broker/Facilitator contract. The Broker/Facilitator program, administered by NASA's Office of Space Science Education and Public Outreach, is facilitated by the LPI for the mid- and southwestern region of the United States. The program aims to connect scientists with educators and educational programs. Dr. Herrick, whose primary research interests are impact cratering and large-scale tectonic and volcanic history of the terrestrial planets, has been with the Institute since 1993.

"I personally find educational and public outreach to be a challenging and rewarding task," Herrick said. "I strongly feel that every scientist should spend some effort communicating their work to the general public and working to improve general science literacy. After all, the citizenry does pay our salaries. Over the years I have been very involved in the planning and development of LPI's outreach program, and I now look forward to managing our Broker/Facilitator effort to broaden the participation of space scientists in educational outreach."

Severe Weather Awareness Series
January 17, 2003
1:00 - 2:00 p.m. -- SMU Campus, Heroy Hall, #153
2003 Severe Weather Preparedness Program
General Audience
Call or email Roy Beavers at rbeavers@mail.smu.edu -- 214.768.2756
Presented by SMU Department of Geological Sciences

Environmentally friendly isn't necessarily painful

By Bonnie Jacobs
Chair of the Environmental Science Program

Discussions about the environment can be downright depressing. Conversations always seem to evoke lamentations about the current state of our air quality (much less than satisfactory in Dallas), our voracious and ever-growing appetite for energy to fuel everything from our clock-radio alarm in the morning to the light we turn off at night, and chemicals that make their way into (even treated) waste water from herbicides to pesticides to hormones and hormone-mimics. That such conversations often end with the urge to run to the latest escape movie is no surprise, but I'm here to tell you that all is not lost - quite yet. We can and should be economic activists - and it does NOT require self-flagellation and long-suffering sacrifice. Here's how and why.

Let's start with air pollution and energy use. Depending on who's calculating the statistics, our poor air quality originates primarily with too many vehicles on the road or with power plants that burn coal to produce the electricity we depend on. Certainly, both are to blame. But, before you run to the theater, let's just see if we can tackle the vehicle issue and save the coal plants for next time. Between 1985 and 1999 the average fuel efficiency of new vehicles in the U.S. fell from 25.9 mpg to 23.8 mpg because of the popularity of larger and less fuel-efficient vehicles - OK, that's depressing. But here's the optimistic part. I purchased a hybrid vehicle two (2!) years ago from my local Toyota dealership. My Prius gets about 48 mpg in the city has not given me any mechanical problems, does not need to be plugged in, is peppy enough to merge onto Central Expressway without praying for mercy from other motorists, and seats five people or two people and two large dogs. This vehicle has two engines, one gas and one electric. The electric engine works at times when the car needs little energy (decelerating or at slow speeds or traffic lights) and the gas engine kicks in at other times. The gasoline engine runs so cleanly that this car is called a "super ultra low emission vehicle." My first inspection in October. was a breeze, and we've been so happy with this car my husband purchased one last year. And, the cost of these cars is $20,000 - downright cheap in comparison to the latest Navigator.

Every day, I meet people who are not aware that hybrid vehicles are readily available or that they drive essentially like any other car. It would be an interesting sociological study (perhaps depressing in its own right) to understand why some ridiculous internet urban legends take on a life of their own, ricocheting from one desk-top to the next at tremendous speed, while a simple but important truth such as the current availability of fuel-efficient and nearly emission-free vehicles stays rooted to the ground and invisible. Perhaps fuel-efficiency just isn't juicy enough but, if you've read this far, now you are in the know.

If even one eighth of all car-owning Dallasites were to switch to hybrid vehicles it would have a tremendous impact on our collective fuel consumption and air quality. But, think of the economic impact. If consumers were really after fuel-efficient, super ultra low emission vehicles, car-makers and congressional representatives alike would be scrambling to supply them.

Congress comes in here because they recently voted down a bill to increase the corporate average fuel efficiency (CAFE) standards (a minimum fuel efficiency with which carmakers must comply) for cars. True, they increased efficiency standards for light trucks and SUV's, but by a paltry 1.5 miles/gallons by 2005.

A more effective approach is for each of us to make a wise choice the next time we're in the market for a car. This is the way to be an economic activist - and it's also the way to save yourself some money. Be a smart and concerned consumer at the same time - and you'll be sitting righteously and optimistically - in a vehicle of change for the better.

Bonnie Jacobs is the chair of the Environmental Science Program and has taught at SMU for 15 years. A native of New York City, she lives in Dallas with her husband, SMU Professor Louis L. Jacobs, their two teenagers, and two large dogs. Bonnie parks her stylish and fuel efficient vehicle in parking lot E on the SMU campus.

SMU faculty members Louis L. Jacobs and Bob Gregory teamed up with Dallas area high school and junior high school science teachers to collect fossils in an area that was covered by an ocean 95 million years ago. This activity was part of an all-day workshop held on Saturday, November 23. The teachers looked for fossils during the morning session and heard a lecture on geologic time in the afternoon. This is the second in an ongoing series of *Science Teachers on Campus* offered by the department to foster relationships between science teachers and SMU and to promote earth science education in high schools.

Short and long-term carbon cycles are at work

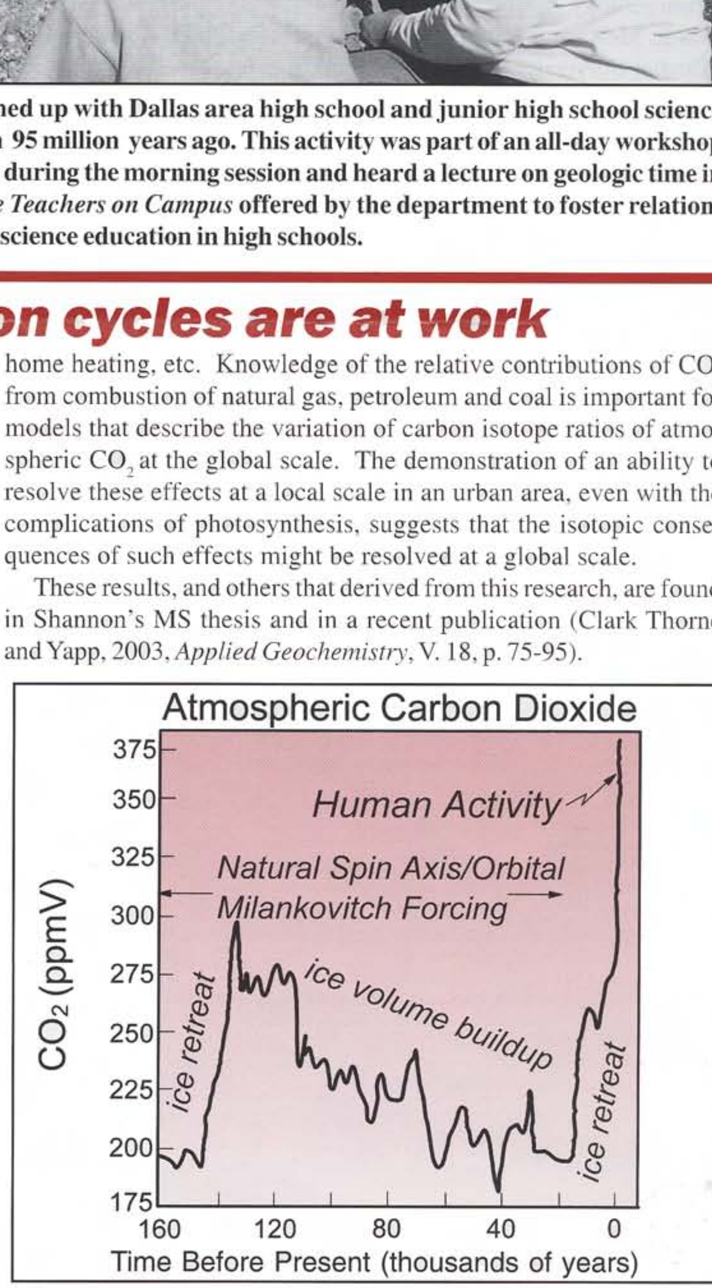
Continued from Page 1

Urban areas are concentrated sources of fossil fuel combustion and thus act as CO_2 "factories." Curiosity about the patterns of CO_2 distribution in an urban setting led geology faculty member, Crayton Yapp, and his former graduate student, Shannon Clark Thorne (MS, 2000) see page 3, to undertake an exploratory study of the variations in the concentration and stable carbon isotope ratios of atmospheric CO_2 in the Dallas metropolitan area. Over a period of about one and a half years, Shannon collected 157 samples of air and measured the concentration and carbon isotope ratio of the CO_2 in each. Moreover, she measured the carbon isotope ratios of local sources of CO_2 to the atmosphere including exhaust from automobiles, combusted natural gas and organic matter in the soils.

The average concentrations of CO_2 at six sites are shown in Figure 1 and ranged from 380 to 401 ppm. As seen in the figure, even at the margins of the Dallas metropolitan area (Frisco and Midlothian sites) near-surface atmospheric CO_2 concentrations were well above the global background value at that time. Although representing a limited number of sites, the spatial pattern of CO_2 concentrations in Figure 1 suggests the presence of a "CO_2 bubble" in the Dallas area atmosphere.

The corresponding carbon isotope data indicate that the increased CO_2 concentrations are primarily a result of combustion of fossil fuels. This study also demonstrated that seasonally changing patterns of fossil fuel use could be detected in the carbon isotope ratios of Dallas area atmospheric CO_2. Increased contributions of CO_2 from combustion of natural gas were clearly evident during the colder months when furnaces were turned on for home heating, etc. Knowledge of the relative contributions of CO_2 from combustion of natural gas, petroleum and coal is important for models that describe the variation of carbon isotope ratios of atmospheric CO_2 at the global scale. The demonstration of an ability to resolve these effects at a local scale in an urban area, even with the complications of photosynthesis, suggests that the isotopic consequences of such effects might be resolved at a global scale.

These results, and others that derived from this research, are found in Shannon's MS thesis and in a recent publication (Clark Thorne and Yapp, 2003, *Applied Geochemistry*, V. 18, p. 75-95).



Geological Sciences Faculty, Southern Methodist University

David D. Blackwell, Hamilton Professor, Ph.D., Harvard. Geothermal studies and their application to plate tectonics, especially of the western United States; energy resource estimates and geothermal exploration.

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.

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

Jason R. McKenna, Visiting Assistant Professor, Ph.D., Southern Methodist University. Thermal mechanical evolution of subduction zones.

Brian W. Stump, Albritton Professor, Ph.D., University of California, Berkeley. Seismology, earthquake and explosion source theory, regional wave propagation, seismic and infrasonic instrumentation and data acquisition, and mine-related seismicity.

John V. Walther, Matthews Professor, Ph.D., University of California, Berkeley. Experimental and theoretical aqueous geochemistry, fluid-mineral surface interactions, kinetics of dissolution, and mineral solubilities as a function of temperature, pressure and solution composition.

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 of sedimentary basins, surface processes, volcanology, geochronology and hard rock petrology.

Anthony Fiorillo, Research Associate Professor, Ph.D., Pennsylvania. Curator of Paleontology, Dallas Museum of Natural History.

Bonnie F. Jacobs, Adjunct Assistant Professor and Chairman of the Environmental Science Program, Dedman College. Ph.D.,University of Arizona. Paleobotany of Tertiary deposits of Africa, application of pollen analysis to Cenozoic geological and environmental Problems.

Douglas H. Oliver, Research Assistant Professor, Ph.D., Southern Methodist University. Structural geology, tectonics, and economic geology.

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.

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