

# GEOLOGY *at SMU*

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An occasional newsletter for alumni and friends: April 2005.

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**Chairman's Report****Geochemistry + Plate tectonics =  
Geochemical dynamics**

By Robert T. Gregory

**W**e are pleased to announce in the cover story the publication of Matthews Chair John Walther's new geochemistry textbook. Geochemistry is an important area for our department as it heads into the 21st century. Over half of the current faculty and their students make use of our various analytical laboratories.

Much of the work in our laboratories is devoted to pursuits relevant to climate change. Crayton Yapp's ground breaking work on the mineral goethite is the subject of our central story. Crayton's discovery of a small amount of carbon dioxide housed within the goethite crystal structure allows him to use carbon isotopes in addition to the carbon concentration to calculate pressures of carbon dioxide in the ancient atmosphere from paleosols.

**I**n trying to explain differences between Earth and Venus, the late Harold Urey, credited with founding the field of stable isotope geochemistry, recognized the importance of water and carbon dioxide and their roles in chemical weathering and atmospheric composition. Carbon dioxide plus water provides acid for the dissolution of igneous or metamorphic minerals unstable under Earth surface conditions. He reasoned that the consumption of carbon dioxide by this process would prevent any planet with oceans from having a carbon dioxide-rich atmosphere. Urey reasoned that Venus must have lost an ocean of water early in its history resulting in an atmosphere with 90 bars CO<sub>2</sub> pressure.

On a planet with an ocean, the dissolved cations and the complementary bicarbonate anions are transported by rivers into the oceans where carbonate minerals and silica precipitate to deposit pelagic carbonate and siliceous oozes on the seafloor; this removes carbon dioxide from the atmosphere. Pelagic sediments riding on the top of the oceanic plates make their way to subduction zones where metamorphic decarbonation reactions release carbon dioxide that eventually makes its way back out to the atmosphere closing the cycle.

Dynamic systems with sources of a compound like carbon dioxide (outgassing and decarbonation reactions) and sinks (chemical weathering and sedimentation) tend toward

steady states. CO<sub>2</sub> and H<sub>2</sub>O (both greenhouse gases) plus plate tectonics provide a "thermostatic control" on the climate of the Earth.

**T**his modern view of the carbonate-silicate cycle pre-supposes the plate tectonic paradigm. Before plate tectonics, these

processes were viewed as part of a one way differentiation of the Earth. John Walther's dissolution experiments have consequences for the rates of chemical weathering. It has been known for over a hundred years that weathering affects the flux of chemicals delivered to the oceans by rivers.

One of the first quantitative estimates for the age of the Earth was derived by measuring the salt content of the oceans and dividing it by the flux rate inferred from measurements on rivers. The age estimates using elements like sodium were on the order of 100's of millions of years; in agreement with Lord Kelvin's calculations based upon the cooling of the Earth. Of course the discovery of radioactivity and its application to geochronology early last century shattered the 100 million year old Earth idea forever.

**F**iguring out why the salt content of the oceans grossly underestimated the age of the Earth had to wait for the discoveries from the last half of the 20<sup>th</sup> century brought on by the plate tectonic revolution. Dredging and drilling of the seafloor (e.g. the Deep Sea Drilling Project, DSDP) yielded up hydrothermally altered basaltic rocks similar to those found in rock associations recognized in the Alps called ophiolites (see the panoramic view of Mt Cervino on page 7). The metamorphosed greenstones (and brownstones) called spilites were loaded with albite (sodium end member of plagioclase) replacing calcic plagioclase (Figure 1). This albite provided the missing sink for sodium delivered to the oceans through chemical weathering by the river flux. The discovery of "black smoker" hot springs at midocean ridges indicated that altered

**Figure 1: Thin section of an Archean (>2.6 Gyr old) pillow lava from the Pilbara Block, Western Australia, exhibiting characteristic signs of seafloor hydrothermal alteration. The amygdule is lined with calcite (clear) and filled with chlorite (dark green). Albite replaces Ca-plagioclase laths. The hydrothermally altered greentone is a sink for seawater-derived Na, Mg, and carbonate.**

Photo by Hillsman B. Jackson

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samples were the result of normal processes occurring at seafloor spreading centers where mantle upwelling renews the crust.

Every element and isotope needed to be re-evaluated in the context of these newly discovered processes. In the 1970's, a graduate student at the University of Chicago, named Karlis Muehlenbachs, analyzed seafloor rocks for oxygen isotopes; he made a remarkable discovery. Rocks from the top part of the oceanic crust were enriched in  $^{18}\text{O}$  (Figure 2) whereas rocks from deeper parts of the oceanic crust were depleted in  $^{18}\text{O}$  relative to their original pristine mantle-derived magmatic isotope ratios.

The oceanic crust was both a source and a sink for heavy oxygen. Even though Muehlenbachs did not have a complete section of crust, he figured that the  $^{18}\text{O}/^{16}\text{O}$  ratio of the ocean must be near steady state. By his estimates, the oxygen isotopic composition of seawater achieves a steady state when its  $^{18}\text{O}/^{16}\text{O}$  ratio is about 6 per mil lower than the mantle. Plate tectonics holds the composition near steady state, a type of geochemical dynamics. In less than 5 years, studies of a complete section of ocean crust from the Samail ophiolite, Oman (Gregory & Taylor, 1981), provided confirmation of the Muehlenbachs hypothesis.

The geologic stability of the  $^{18}\text{O}/^{16}\text{O}$  ratio of seawater enables stable isotope geologists to take advantage of this property to measure paleotemperatures, one of Urey's first tasks >50 years ago. Measurements on "proxies" (carbonates to ice cores) have elucidated the climate history of the Earth as never before.

**Figure 2: Top--Pillow lavas from the Oman ophiolite exhibit the so-called "brown-to-green " facies seafloor hydrothermal metamorphism shown in Figure 1. Bottom: The deviation in the  $^{18}\text{O}/^{16}\text{O}$  ratios referenced to standard modern seawater (the e 1. Bottom: a 1t972102(102u)02(e)0( 849(e)00e)0(e)0( 640( 640ro)3(n)0(**

## SMU Alumnus Professor David Dunn retiring from public life

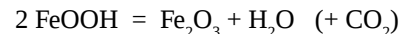
David Dunn, (B.S., 1957; M.S. 1959), *Emeritus* Professor of Geosciences and former Dean of the School of Natural Sciences and Mathematics at the University of Texas at Dallas is closing down his UTD office to move to Green Valley, Arizona, south of Tucson.

Dr. Dunn most recently was the Vice-Chair of the Earth Science Task Force (ESTF) for the Texas State Board of Education. In 2002, the board appointed the task force as a result of efforts by a broad group of earth science professionals (including SMU and ISEM representatives) to get the teaching of earth science on an equal footing with chemistry, physics, and biology in Texas secondary schools.

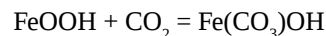
Since 1999, earth science offerings are not explicitly part of the TAKS testing program resulting in their

## Natural Rust ( $\alpha$ -FeOOH): $\text{CO}_2$

For Professor Crayton Yapp, the mineral goethite (iron hydroxide) represented the ideal candidate to measure the ancient meteoric water line (the linear relationship between the  $\delta$  values of hydrogen and oxygen in natural surface waters) because it contained both hydrogen and oxygen. During stepwise dehydration experiments, necessary to extract the hydrogen isotopes, Crayton discovered that measureable amounts of carbon dioxide were actually sequestered within the goethite mineral structure. The solid state transformation of goethite (FeOOH) to hematite ( $\text{Fe}_2\text{O}_3$ ) in vacuum yields water (and small amounts of  $\text{CO}_2$ ).



The  $\text{CO}_2$  in goethite is present as a component in a kind of interstitial solid solution. This  $\text{CO}_2$  component can be represented as  $\text{Fe}(\text{CO}_3)\text{OH}$ . Thus,



During heating, decarbonation was occurring along with dehydration. This carbon dioxide was only discovered because Crayton had the curiosity, and took the care, to analyze the contents of a second trap for reaction products other than water. A new paleoenvironmental probe was born.

Concentrations (mole fractions of carbon dioxide, X) and carbon isotope ratios ( $\delta^{13}\text{C}$  values) are related to the concentration and the  $\delta^{13}\text{C}$  value of  $\text{CO}_2$  in the local environment at the time of crystallization. As a result, goethites (photos on the left) from natural paleosols (ancient soils) can yield information on the carbon dioxide in the Earth's ancient atmosphere. Remember that goethite, once formed, is relatively inert so that it faithfully records the conditions of its formation.

Top right: Goethite from two ancient weathering profiles. The slopes



**Geological Sciences Hamilton Scholars**

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|------|------------------------|--------------------------|
| 1997 | Carl Romney            | SAIC                     |
| 1999 | Peter Marshall, O.B.E. | Blacknest, U.K.          |
| 1999 | James O'Brian          | Florida State University |
| 2000 | Chen Yun-tai           | Inst. Geophysics, China  |
| 2002 | Charles "Buck" Wilson  | University of Alaska     |
| 2004 | Robert R. Blanford     | AFTAC                    |
| 2005 | Robert B. Smith        | University of Utah       |

ogy of the Yellowstone area. While the public thinks of Yellowstone as a National Park with superb wildlife, geologists know it as a gigantic volcano. Calderas, large closed depressions representing the collapse of the surface as a result from the loss of magma from below, reach 70 km in diameter in the Yellowstone area.

At Yellowstone, there are 3 big calderas, two of which are relatively intact. The biggest eruption occurred about 2 million years ago and produced at least 2,500 km<sup>3</sup> of magma, much of which was dispersed by the jet stream leaving identifiable ash deposits covering an area larger than

The **3rd Golden Mustang Geologist Dinner** will be held at the SMU Faculty Club on May 12, 2005, celebrating the class of 1955. Each year, we invite all of the classes who took their degrees more than 48 years ago. Professor *Emeritus* Jim Brooks will once again be master of ceremonies.

The late **Claude Albritton, Jr. (B.S., 1933)**, was honored (in memoriam) as an “SMU Scholar of Science” in an exhibition opened March 2nd, through April 15th, by Central University Libraries on display on the first floor of the Central University Library. **Professors Jim Brooks and David Blackwell (B.S., 1963)** spoke at the opening of the exhibit that centered around Jim Brook’s tribute entitled, *Claude Albritton: Architect of the University*. John Finney, ISEM Librarian, organized Claude’s exhibit.

**LaCretia Dickerson (B.S., 2004)**, winner of last year’s undergraduate of the year award, has been working for Cirrus Associates. She splits her time between on-site work and her office in Richardson. She is doing site inspections and involved in environmental remediation projects.

