GEOLOGY at SMU

An occasional newsletter for alumni and friends: April 2005.

John Walther finishes textbook

Geochemistry for a New Generation

Professor John Walther's textbook, *Essentials of Geochemistry,* is now available from Bartlett and Jones. It is one of this publisher's new offerings in the upper division/graduate level geology textbook field.

Walther did tours of duty at Berkeley, where he completed his Ph.D. under this year's Harold Urey medal winner Professor Harold Helgesen, Yale and Northwestern before he came to SMU as the 2nd Matthews Chair holder. The faculty at each of these institutions have produced some of the best known textbooks in geology, geochemistry, geophysics, and petrology. After his arrival at SMU, conversations with then chairman A. Lee McAlester convinced John to write a textbook in geochemistry. While at Yale, McAlester was the editor and a contributor to the very impressive Prentice Hall Foundations in Earth Science Series.

After more than six years of steady work later, the book is being used for the first time by this year's *Geochemistry* class. Students who confront this text will be exposed to a book with a very clear exposition, loaded with illustrative examples and numerous problem sets. This is a book aimed at those who want to apply thermodynamics to geochemistry and its application to the Earth and beyond.

Matthews Chair Holder John Walther Research Interests

- Mineral solubilities at elevated temperatures and pressures
- Rates of mineral dissolution
- Mechanisms of surface reaction
- Fluid rock interactions in the crust

The book covers the Earth starting with its aggregate chemical and physical state; this sets up an overview of thermodynamics. With this foundation in place, the chemistry of minerals and fluids sets the stage for geochemical analysis of important lithospheric processes. Beyond this, there are sections on the cosmic abundances of the elements, radioactivity and stable isotopes. The coverage also crosses over to a welcome discussion of organic geochemistry.

Available at the publisher's website is a downloadable copy of the computer program SUPCRIT92. Students test their new understanding of thermodynamics through computer calculations. The program enables the students to perform real world thermodynamic analysis of gases, fluids, solids, and aqueous species from approximately magmatic temperature to the freezing point of water and from 5,000 times atmospheric pressure to earth surface conditions.

Cover of John Walther's new 700 page textbook shows tufa deposits from Yellowstone National Park. Carbon dioxide outgassing of discharging fluids drives precipitation of calcium carbonate overcoming the retrograde solubility of calcite.

John can now devote more time to the laboratory where he measures rates of dissolution as a function of pH, temperature, pressure and composition. Surface charge distribution at the mineral-fluid interface helps explain changes in dissolution rates of aluminosilicates that occur as a function of pH. There is usually some pH where the rates pass through a minimum. For quartz and corundum, these minima occur at different pH; the trick is how to use the oxides to make predictions about the behavior of other more complex aluminosilicates. The goal: a better description of the Earth and the tools to understand other planetary objects where fluid- rock interaction is important.

Chairman's Report

Geochemistry + Plate tectonics = Geochemical dynamics

By Robert T. Gregory

Photo by Hillsman B. Jackson

We 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.

In 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_2 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_2 and H_2O (both greenhouse gases) plus plate tectonics provide a "thermostatic control" on the climate of the Earth.

This 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.

Figuring 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^{th} 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.

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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}O (Figure 2) whereas rocks from deeper parts of the oceanic crust were depleted in ^{18}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 $^{18}O/^{16}O$ ratio of the ocean must be near steady state. By his estimates, the oxygen isotopic composition of seawater achieves a steady state when its $^{18}O/^{16}O$ 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 $^{18}O/^{16}O$ 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 $^{18}O/^{16}O$ ratios referenced to standard modern seawater (the e 1. Bottom: a0 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 (a-FeOOH): 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 d 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 (Fe_2O_3) in vacuum yields water (and small mounts of CO_2).

$$2\ FeOOH = Fe_2O_3 + H_2O\ \ (+\ CO_2)$$

The CO_2 in goethite is present as a component in a kind of interterstitial solid solution. This CO_2 component can be represented as $Fe(CO_3)OH$. Thus,

$$FeOOH + CO_2 = Fe(CO_3)OH$$

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 ($d^{13}C$ values) are related to the concentration and the $d^{13}C$ value of 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

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^3 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.

Geolo

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, Assistant Professor and Chair of the Environmental Science Program, Ph.D., Arizona. Paleobotany & palynology of the Cenozoic. bjacobs@smu.edu.

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

Jason R. McKenna, Research 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, 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.

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