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Greenhouse gas sequestration in abandoned oil reservoirs: The International Energy Agency Weyburn pilot project

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Cover: Deployment of the permanent passive recording seismic array at the Weyburn site. Shown is the field unit used to deploy coil tubing (from the large truck-mounted spool) and the wooden spool housing the seismic cable and geophone array. For permanent deployment, the seismic cable is lashed to the coil tubing (acting as a strength-member) and deployed to 1400 m depth through the wellhead (right side of image). The cable is then cemented in place. See "Greenhouse gas sequestration in abandoned oil reservoirs: The International Energy Agency Weyburn pilot project," by D.J. White et al., p. 4–10.

SCIENCE ARTICLE

CORRECTION

The biota used in the cover art from the March issue of *GSA Today* was based largely on the following articles: Tarduno, J.A., Brinkman, D.B., Renne, P.R., Cottrell, R.D., Scher, H., and Castillo, P., 1998, Evidence for extreme climatic warmth from Late Cretaceous Arctic vertebrates: Science, v. 282, p. 2241–2244; and Herman, A.B., and Spicer, R.A., 1997, New quantitative palaeoclimate data for the Late Cretaceous Arctic: Evidence for a warm polar ocean: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 128, p. 227–251. These references inadvertently were not included in the caption.

Greenhouse gas sequestration in abandoned oil reservoirs: The International Energy Agency Weyburn pilot project

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ABSTRACT

Carbon dioxide sequestration in geological reservoirs is being evaluated internationally as a viable means of long-term CO_2 storage. The International Energy Agency Weyburn CO_2 Monitoring and Storage Project is designed to investigate the technical and economic feasibility of CO_2 storage in a partially depleted oil reservoir in conjunction with enhanced oil recovery operations. Two key elements of the project are (1) the establishment of a regional geoscience framework as a means for prediction of the long-term fate of injected CO_2, and (2) development and application of geophysical/geochemical monitoring and verification methods to track the spread of CO_2 within the reservoir. To date, 1.90 billion m^3 of CO_2 have been injected into the reservoir, the effects of which are imaged by the various monitoring methods.

INTRODUCTION

Carbon dioxide is the primary anthropogenic greenhouse gas in the modern-day atmosphere and is a critical component in models of global climate change (IPCC, 2001). It is estimated that ~6 gigatons of carbon enters the environment annually as a result of global energy-related CO_2 emission, with North America being responsible for ~20%–25% of this total (International Energy Agency [IEA], 2000). Recognition of the importance of CO_2 emissions has stimulated research toward mitigation of CO_2 effects as mandated under the Kyoto Protocol of the United Nations Framework Convention on Climate Change.

CO_2 sequestration in geological reservoirs is being evaluated internationally as a viable means of long-term CO_2 storage and climate change mitigation (EAGE, 2000). In 2000, the IEA Weyburn CO_2 Monitoring and Storage Project was initiated to investigate the technical and economic feasibility of CO_2 storage in a partially depleted oil reservoir (Government of Canada, 2000). The IEA Weyburn project is exploiting EnCana Corporation's $1.5 billion, 30-year commercial CO_2 enhanced oil recovery operation, which is designed to recover an incremental 130 million barrels of oil from the Weyburn field through the injection of gaseous CO_2 under pressure. Specifically, the IEA Weyburn Project aims to comprehensively monitor and verify the progress of the CO_2 flood and establish the likelihood of safely storing the CO_2 in the reservoir for the long term. Toward this end, a multidisciplinary, integrated program has been formulated to address critical issues central to safe and cost-effective, long-term storage of CO_2. In this article, we focus on the regional geoscience framework and the monitoring and verification components of the project.

GEOLOGICAL SETTING AND HISTORY OF THE WEYBURN FIELD

The Weyburn oil field is located southeast of Weyburn, Saskatchewan, within the north-central Williston Basin, which contains shallow marine sediments of Cambrian to Tertiary age (Fig. 1). The Weyburn field, which covers ~180 km^2, was discovered in 1954 and hosted an estimated 1.4 billion barrels of oil. Primary production within the field continued until 1964, when the initiation of waterflood resulted in oil production peaking at 46,000 barrels/day in 1965. Waterflood has continued since then, with horizontal infill drilling commencing in 1991. Approximately 24% of the original oil in place had been recovered by 2000 when CO_2 injection began.

Weyburn oil reserves reside within a thin zone (maximum thickness of 30 m) of fractured carbonates in the Midale beds (Fig. 2) of the Mississippian Charles Formation, which were deposited in a shallow carbonate shelf environment. The reservoir comprises two intervals, an upper Marly dolostone (0–10 m thick) and lower Vuggy limestone (0–20 m thick) that are sealed by anhydritic dolostones and anhydrites of the Midale Evaporite. The Midale Marly unit ranges from chalky dolomudstone

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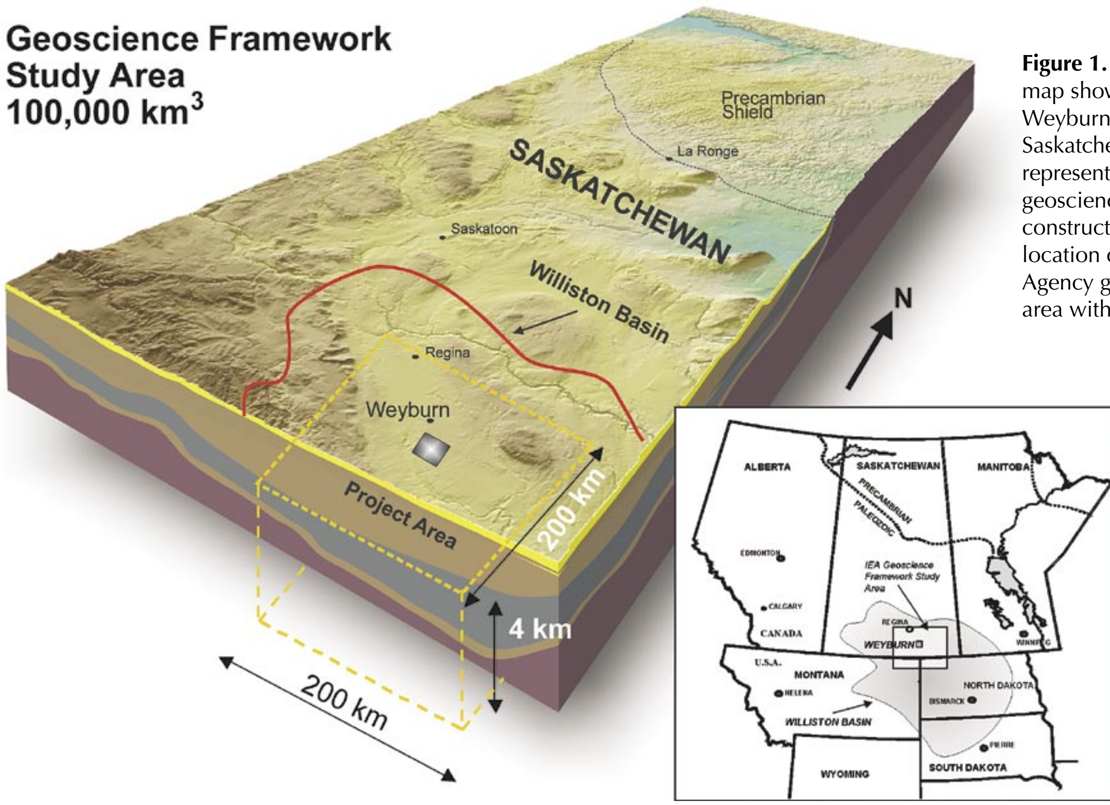


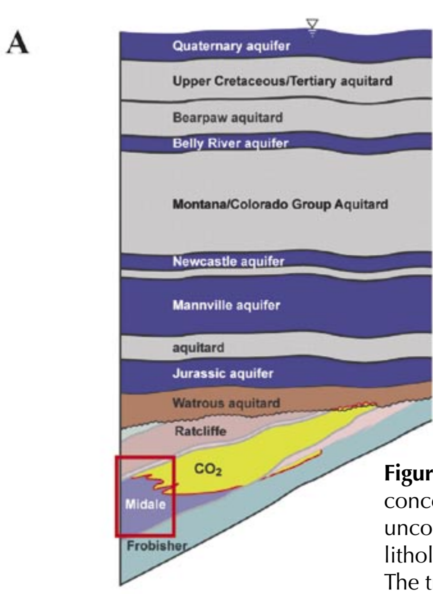
Figure 1. Three-dimensional map showing the location of the Weyburn study area in southeastern Saskatchewan. The dashed cube represents the area where the geoscience framework is being constructed. Lower inset shows the location of the International Energy Agency geoscience framework study area within the Williston Basin.

to calcitic biofragmental dolostone with intervening thin beds of biofragmental limestone. The fractured, Vuggy unit includes a lower, peritidal "shoal" sequence with common secondary (vuggy) porosity, and an upper shallow marine "intershoal" sequence dominated by fine-grained carbonate sands. The Midale Marly has relatively high porosity (16%–38%) and low permeability (1 to >50 millidarcy), whereas the Midale Vuggy has relatively lower porosity (8%–20%) and higher permeability (10 to >300 millidarcy). The higher permeability within the Vuggy unit resulted in preferential recovery of oil from this unit during the waterflood stage of production.

The dominant fracture set within the reservoir strikes NE-SW as determined from core and imaging logs (Bunge, 2000). This orientation is sub-parallel to the regional trajectories of maximum horizontal stress (Bell and Babcock, 1986) and is parallel to the horizontal well direction. The vertical stress at the reservoir level due to the lithostatic load is ~34 MPa as estimated from a density log, and the minimum horizontal stress is ~18–22 MPa in this region (McLellan et al., 1992).

THE CO_2 FLOOD

The CO_2-based enhanced oil recovery (EOR) scheme was initiated in



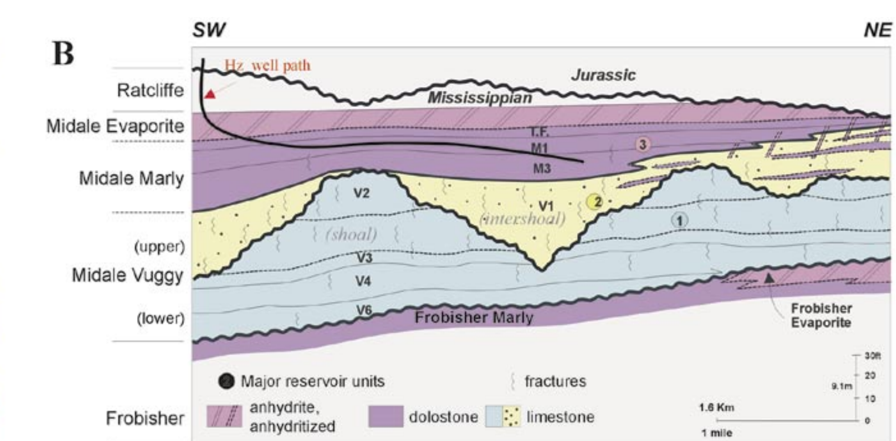


Figure 2. A: Simplified regional hydrostratigraphy above the Frobisher sequence. The CO_2 is conceptually shown migrating up-dip within the Midale beds, which subcrop at the Mississippian unconformity and the overlying Watrous aquitard. **B:** Representative schematic distribution of major lithologies within the Midale reservoir with approximate location indicated by the red rectangle in A. The trajectory of a horizontal (Hz) injection well is shown within the Midale Marly unit.

September of 2000 in 19 patterns[1] of the EnCana Weyburn unit at an initial injection rate of 2.69 million m^3/day (or 5000 tonnes/day). The present rate of CO_2 injection is 3.39 million m^3/day of which 0.71 million m^3/day is CO_2 recycled from oil production. The CO_2 EOR is contributing over 5000 barrels/day to the total daily production of 20,560 barrels/day for the entire Weyburn unit. As of May 30, 2003, cumulative CO_2 injected was 1.90 billion m^3. The CO_2 flood will be expanded gradually over the next five years into a total of 75 patterns with ~10.8 billion m^3 (or ~20 million tonnes) of injected CO_2 anticipated over the lifetime of the project. The source of CO_2 is the Dakota Gasification Company's synthetic fuel plant located in Beulah, North Dakota. The CO_2 is transported 320 km via pipeline to the Weyburn field.

The reservoir is at ~1450 m depth in the EOR area and has a mean temperature of 63 °C. Estimated pore pressures of ~14 MPa existed when the field was originally discovered, and during waterflood they ranged from 8 to 19 MPa. Recently measured pore pressures range from 12.5 MPa to 18 MPa with an average of ~15 MPa. These conditions exceed the critical point pressure and temperature (7.4 MPa and 31 °C) of CO_2, and thus the injected CO_2 initially exists as a supercritical fluid in the reservoir. It is anticipated that the injected CO_2 will cause minor dissolution of carbonate minerals, as CO_2 will dissolve to some extent in water present in the reservoir, forming bicarbonate until equilibrium is reached. This is ionic trapping of CO_2. The presence of minor amounts of silicate minerals within the reservoir may also enhance the capacity of the reservoir to sequester CO_2 through mineral trapping as reactions between the silicates and CO_2 may lead to the precipitation of carbonate minerals.

THE REGIONAL FRAMEWORK

The motivation for developing the regional geological framework is to establish a means for predicting whether injected CO_2 may migrate beyond the immediate injection site over the long term. To address this requirement, key elements of the regional framework that must be identified include potential fluid pathways, including faults, fracture zones and controlling depositional features, such as zones of salt dissolution. CO_2 traps and trapping mechanisms (e.g., seals and aquitards) within the stratigraphic column must be identified as well, and the transport properties of deep aquifers (e.g., porosity, permeability, fracture distribution, formation-water flow rates and directions) need to be established.

The conceptual model of CO_2 storage is shown in Figure 2. CO_2 is injected into the Midale reservoir beds where the overlying Midale evaporite forms the primary physical barrier to CO_2 migration. However, the Midale reservoir beds are truncated to the northeast (as mapped in Fig. 3) where they subcrop beneath redbeds (dolomitic to anhydritic siltstones and mudstones) of the Watrous Formation. This forms a secondary seal. Above the Watrous aquitard, there are several regional aquifers sandwiched between thick shaley aquitards, which constitute the major flow units and flow barriers of the hydrostratigraphic framework.

To develop a detailed understanding of the geology and hydrology from the Precambrian basement to the surface, a regional three-dimensional geological framework (shown conceptually in Fig. 1) is being constructed within an ~100 km radius about the Weyburn field. The framework is based on geological and geophysical compilations from the existing catalog of logged core from boreholes across the area, as well as reprocessing of 1600 km of seismic reflection profiles across the area with stratigraphic control provided by the correlation of seismic sections with geophysical logs. For example, the subcrop and reservoir interval and upper seal isopach are

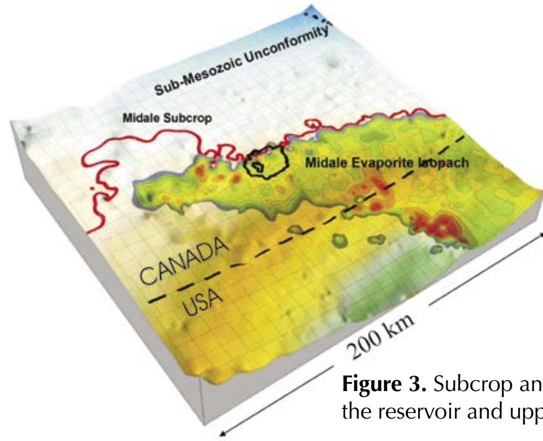


Figure 3. Subcrop and isopach of the reservoir and upper seal.

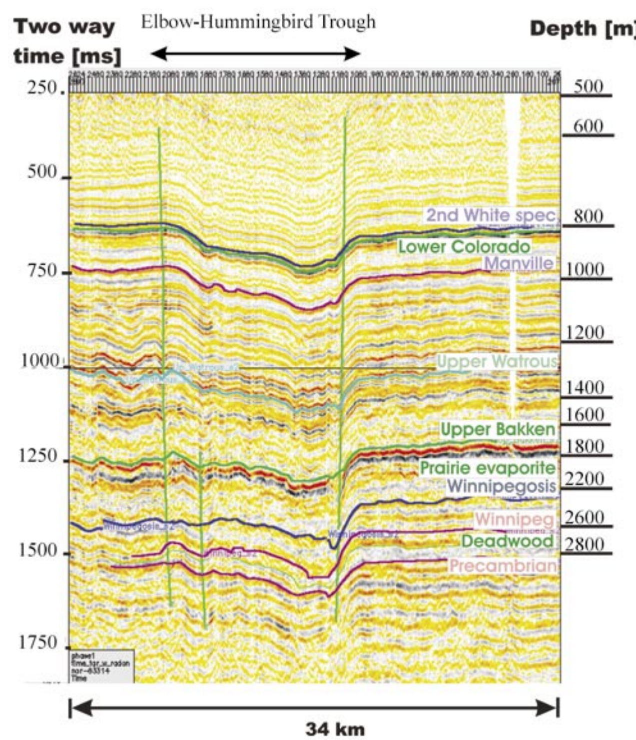


Figure 4. A representative two-dimensional seismic profile from the 1600 km of profiles that are being used with geophysical and core logs to construct the regional geological framework. Horizons that are picked regionally include the Precambrian unconformity, Deadwood, Winnipeg, Winnipegosis, Prairie Evaporite, Upper Backen, Upper Watrous, Manville, Lower Colorado, and 2nd White spec. The subvertical green lines represent interpreted lateral discontinuities in the picked horizons that could be faults or fracture systems that may potentially act as fluid pathways.

[1]Pattern refers to a group of injection and production wells that occupy an area of approximately 1 km^2.

depicted in Figure 3. Similar maps are being constructed for other key stratigraphic units. Figure 4 portrays an example of the regional seismic reflection data with horizons that are being picked as well as interpreted "faults." The latter may act as potential pathways for fluid migration, but the actual hydraulic characteristics of these zones (porosity, permeability) are unknown.

Regional fluid flow-direction, flow-rates, and water chemistries of the 20 major aquifers between the Precambrian basement and the land surface are being mapped in the Weyburn Project area. In addition, permeability and porosity data from core analyses and drill-stem tests are being processed using geostatistical tools to obtain hydraulic parameters for each aquifer.

RESERVOIR CHARACTERIZATION AND CO_2 FLOOD MONITORING

As CO_2 is injected into the reservoir, its spread will be influenced by heterogeneous, anisotropic permeability, and it will displace and mix with existing reservoir fluids (oil, water, and gas) resulting in pore pressure and fluid composition changes within the reservoir. Furthermore, the matrix rock of the reservoir will respond dynamically to this process, potentially with associated microseismicity signaling local deformation (e.g., fracturing or pressurization of existing fractures). Typical magnitudes of injection-related microseisms range from –4 to 0 (Maxwell et al., 2003). The preferred fluid pathways may in fact be altered by the injection process as pressure changes within the reservoir may open or close fracture systems.

Monitoring of the CO_2 flood at the Weyburn field includes seismic and geochemical methods, which are intended to document as much of this dynamic process as possible. Baseline static characterization of the reservoir (e.g., porosity, permeability, fracture systems, fluid distribution) prior to injection is important in planning the flood and anticipating how it will proceed. Following flood initiation, the goal is to track the saturation and distribution of CO_2 within the reservoir, assess the interaction of the CO_2 with the other reservoir fluids, determine pressure variations, and identify off-trend flow so that the injection process can be adjusted accordingly. Finally, monitoring provides a means of verifying the volume of CO_2 that resides within the reservoir. Efficient and complete access to the reservoir volume and avoidance of premature flow-through of CO_2 to producing wells is important whether enhanced oil recovery or CO_2 storage is the ultimate goal.

Geochemical Monitoring

Chemical and/or isotopic compositions of aqueous fluids and gases are being monitored and compared to

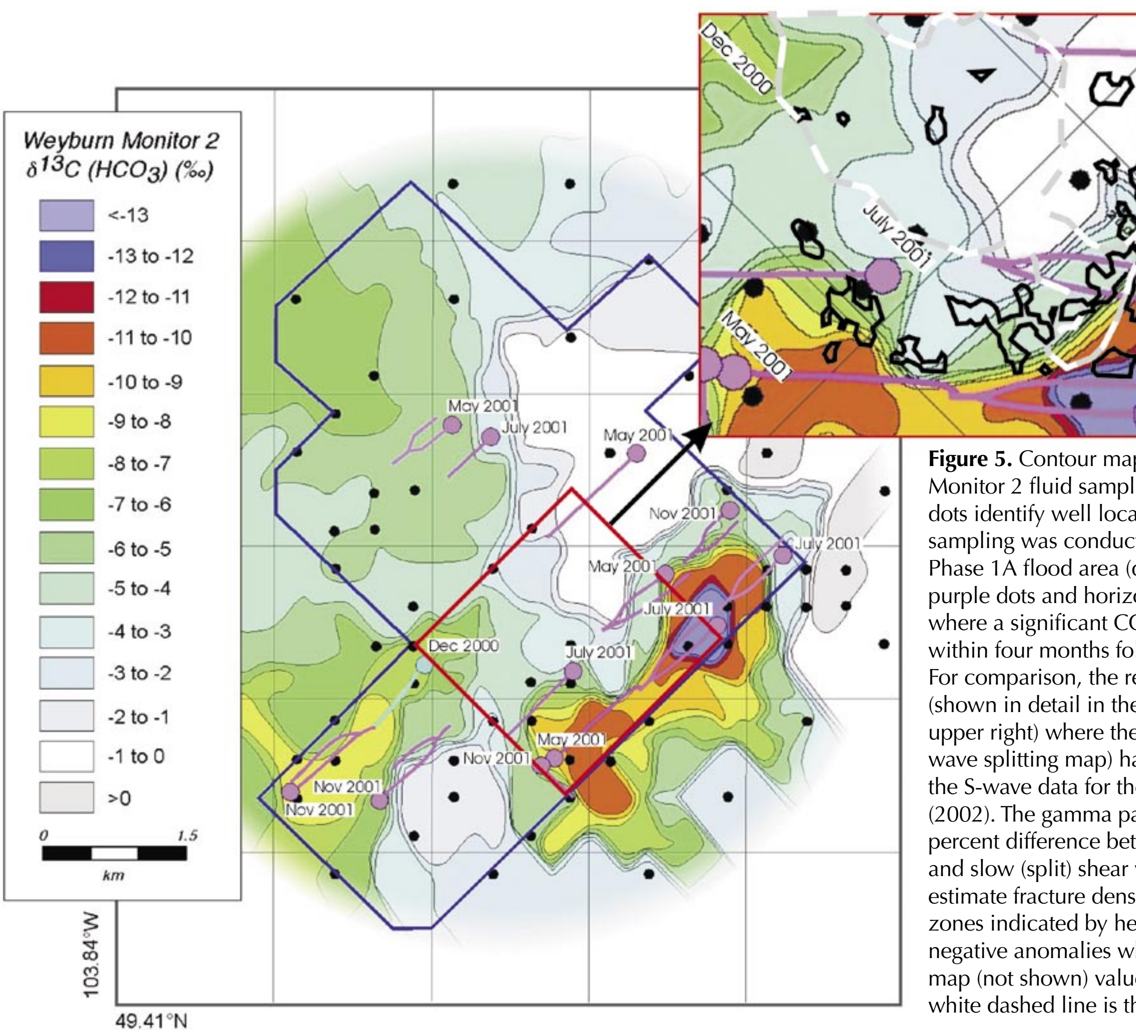


Figure 5. Contour map of the $\delta^{13}C$ values from the Monitor 2 fluid sampling survey (July 2001). Black dots identify well locations where fluid and/or gas sampling was conducted within the nine-pattern Phase 1A flood area (dark outline). The larger, purple dots and horizontal well legs identify wells where a significant CO_2 response was observed within four months following the sampling survey. For comparison, the red square identifies an area (shown in detail in the expanded inset panel, upper right) where the gamma parameter (or shear-wave splitting map) has been determined from the S-wave data for the Monitor 2 seismic survey (2002). The gamma parameter is a measure of the percent difference between the velocities of the fast and slow (split) shear waves and can be used to estimate fracture density and direction. In the inset, zones indicated by heavy black outlines identify negative anomalies where the gamma parameter map (not shown) values are <–10%. The heavy white dashed line is the salt dissolution edge.

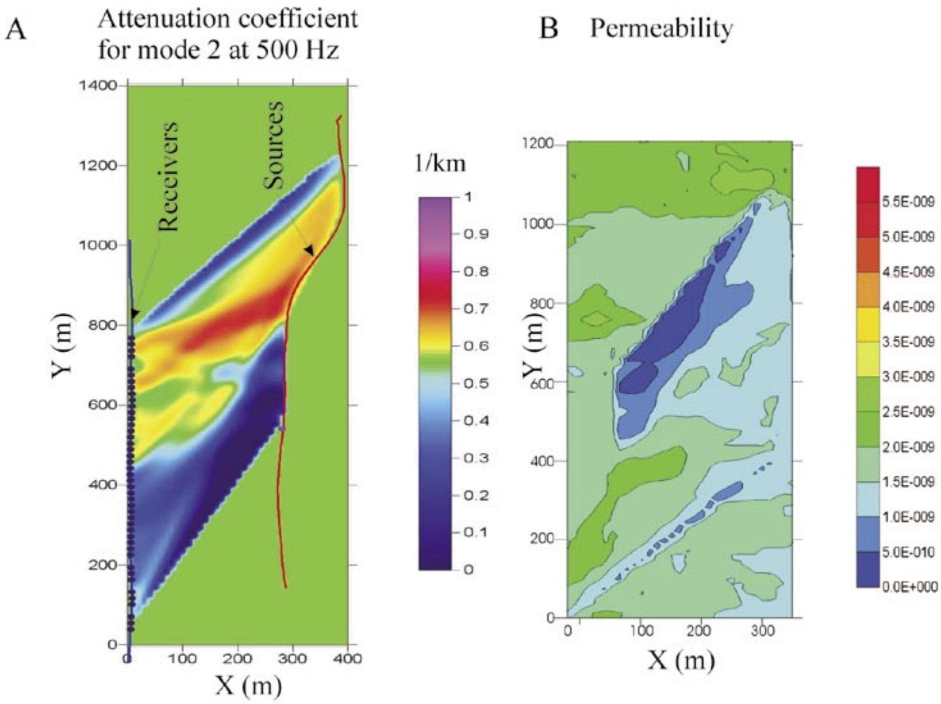


Figure 6. A: Horizontal crosswell attenuation tomogram for a sub-horizontal slice through the Marly unit (see Fig. 7 for orientation). The tomogram is determined for energy with a center frequency of 500 Hz. **B:** Permeability calculated using the attenuation values from A, based on the Biot relationship and using parameters (porosity and fluid viscosity) from the existing reservoir model. Units are in cm^2 (1 darcy = 0.987×10^{-8} cm^2).

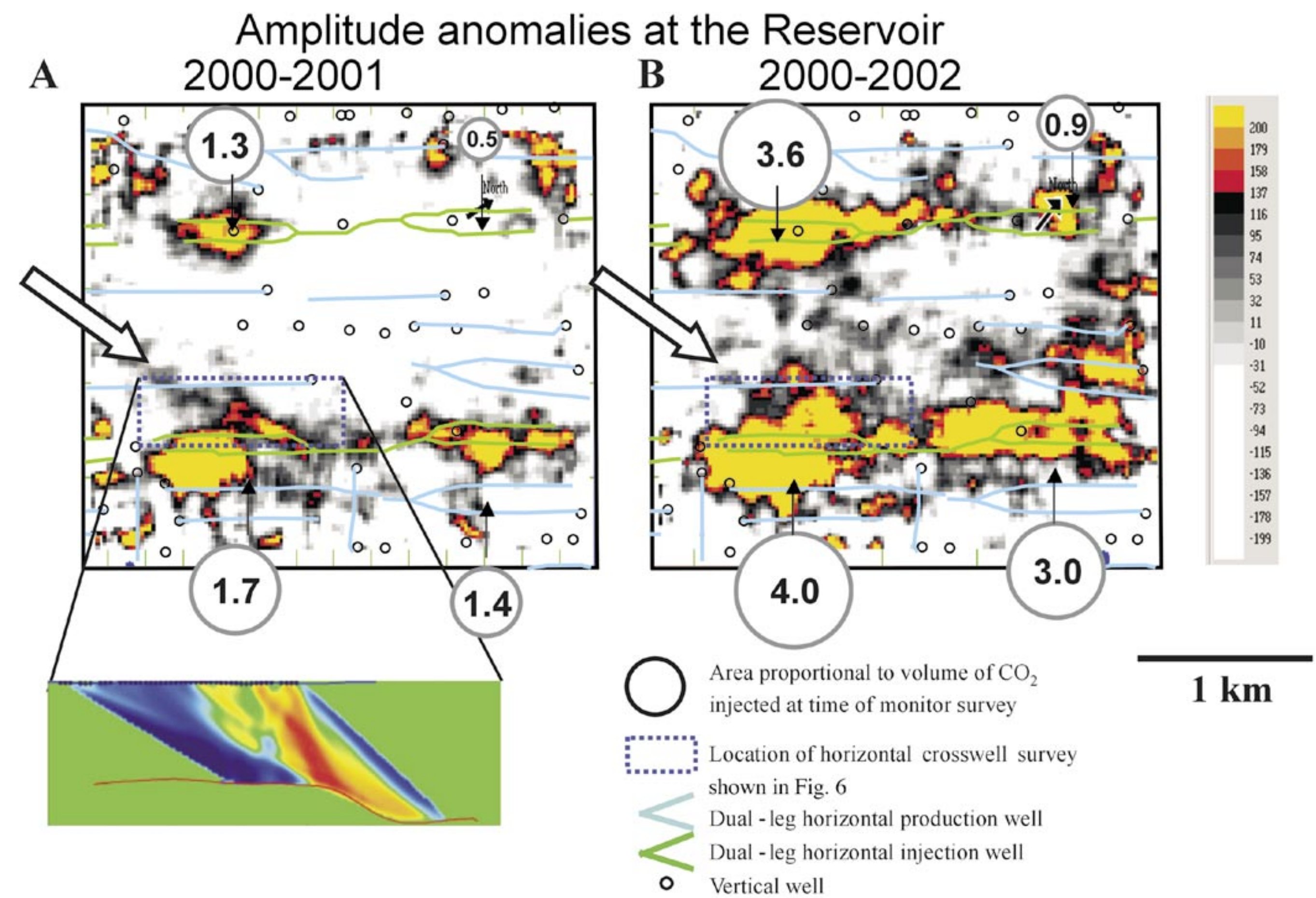


Figure 7. P-wave amplitude difference maps for baseline minus 2001 survey (A) and baseline minus 2002 survey (B), determined from the three-dimensional P-wave surface seismic data. The amplitudes were determined as the arithmetic mean over a 5 ms window centered on the reservoir horizon. The large circles represent the cumulative volume of CO_2 (at reservoir conditions in units of 10^6 m^3) that had been injected at the time of the monitor survey for each of the four dual-leg horizontal injectors. The large arrows indicate interpreted zones of off-trend CO_2 spread. In A, the attenuation tomogram from Figure 6 is shown in an expanded panel emanating from its position on the amplitude map.

pre-injection baseline measurements to trace and predict the movement of CO_2 and other fluids within the reservoir. In particular, carbon isotopes ($\delta^{13}C$) are being used to track the spread of trace amounts of injected CO_2 as a precursor of the advancing CO_2 "front." This is possible due to the distinct isotopic signature of CO_2 ($\delta^{13}C$ value of –35 per mil) delivered from the synthetic fuels plant. Changes in fluid and gas compositions over time indicate that interaction is taking place between reservoir fluids, injected CO_2, and reservoir rocks. For example, following the start of injection, the $\delta^{13}C$ (HCO_3) values of reservoir fluids have decreased dramatically from original values ranging from –1 to –7 per mil to values of –4 to –11 per mil (Fig. 5). The decrease in $\delta^{13}C$ (HCO_3) values is most easily attributable to the dissolution of injected CO_2. For geochemical monitoring surveys conducted at times greater than eight months following the onset of injection, a very good correlation has been observed between CO_2 distribution (as estimated from $\delta^{13}C$) and wells where CO_2 has been detected in significant quantity within a period of four months following the survey (see Fig. 5).

Pre-Injection High-Resolution Seismic Crosswell Imaging

Seismic crosswell data are intended to image variations in reservoir properties occurring on the scale of meters. Combined with borehole sonic logs (centimeter scale), vertical seismic profile data, and surface seismic data (10s of meters scale), these data will provide proper scaling relationships for understanding reservoir properties and processes at the reservoir dimensions.

A horizontal crosswell survey was acquired in two parallel horizontal wells (Fig. 6) in August 2000, prior to the start of CO_2 injection (Majer et al., 2001; Washbourne et al., 2001; Li et al., 2001). A piezoelectric source was deployed in one well and a 48-level hydrophone string in the opposite well. The frequency band of the source was 200–2000 Hz, an order of magnitude higher than the surface seismic source. To our knowledge, this was the first-ever deployment of a large-scale crosswell survey between horizontal wells.

The horizontal crosswells were located within the Marly unit (see Fig. 2B) of the reservoir. This layer has a much lower velocity (3.5 km/s) than the bordering layers (~5.5–6.0 km/s) and thus acts as a waveguide for seismic energy propagating across the layer. A tomographic imaging approach was developed to use this guided or trapped wave energy. An attenuation tomogram for 500 Hz energy is shown in Fig. 6A, with a first attempt at integrating this result with the existing reservoir model shown in Fig. 6B. The tomogram has been converted from an attenuation image to permeability within the depth slice by using porosity and fluid viscosity from the reservoir model, and using Biot relationships to calculate the permeability. The resulting permeability values clearly depend on the parameters from the reservoir model and the assumed attenuation mechanisms, but the observed trends should be robust. The permeability values obtained range from 50 to 150 millidarcy which is comparable to the range of permeabilities measured within this unit (10 to 500 millidarcy). Of note, the spatial trends in the calculated permeability are at an angle to the horizontal injection wells (oriented along-trend) and are also oblique to the local seismic impedance and porosity trends (cf. Li et al., 2001), suggesting the presence of off-trend zones of enhanced permeability. It should be noted, however, that due to the acquisition geometry, the tomographic image cannot resolve permeable zones that are oriented parallel to the horizontal wells.

Time-Lapse Multicomponent Three-Dimensional Surface Seismic Monitoring

Time-lapse seismic methods provide a powerful means of monitoring the progress of the CO_2 flood over time. The use of multicomponent imaging techniques provides a means of isolating the various reservoir characteristics that are affected by the flood (fluid distribution and saturation, pore pressure, fracture permeability). For example, in a fractured porous medium that is isotropic (or for some classes of anisotropic media), the P-wave amplitude response is sensitive to both pore fluid saturation and pressure effects, whereas the S-wave amplitude response is generally less sensitive to the composition of the pore fluid (e.g., Wang et al., 1998; Brown, 2002; Cardona, 2002). Thus, P- and S-wave amplitudes provide a potential means of discriminating pore pressure vs. pore fluid saturation effects, except in regions of the reservoir where fracture-related anisotropy has lower symmetry (Cardona, 2002). Furthermore, it is reasonable to assume that the injected CO_2 will exist primarily as a supercritical fluid or in an oil-CO_2 solution, because of the relatively low solubility (~2 mol% at reservoir conditions) of CO_2 in water and the relatively high reservoir pressures. This simplifies the interpretation of the seismic response in terms of pore fluid composition. Rock property measurements indicate that the effect on seismic amplitude of CO_2 dissolved in oil is small until saturation levels reach 50% (Brown, 2002). Maximum CO_2-induced P-wave velocity decreases of 4%–6% are expected with associated reflection amplitude decreases of 15%–20% (Davis et al., 2003).

Birefringence (i.e., splitting) of shear waves provides another independent means of characterizing an anisotropic medium. In the case of the reservoir, shear-wave anisotropy has been used to estimate fracture density, fracture direction, and location. It can also be used to monitor changes in the fractured medium over time due to dynamic changes in the reservoir processes. Davis et al. (2003) provide further details.

Time-lapse P-wave (2001 and 2002) amplitude difference maps for the first two monitor surveys relative to the pre-injection baseline survey (2000) are shown in Figure 7. P-wave amplitude anomalies are observed in the immediate vicinity of the horizontal injection wells. Generally, the areal extent of the anomalies surrounding any of the four dual-leg horizontal injection wells is proportional to the cumulative amount of CO_2 injected, whether the comparison is made for different injectors in the same monitor survey or for the same injector in subsequent monitor surveys. Preliminary volumetric calculations and sensitivity modeling suggest that the P-wave amplitude anomaly maps are primarily mapping the CO_2 saturation (pure phase and dissolved in oil) within the reservoir, with pressure effects having a secondary influence. The limited extent of the amplitude anomalies within the S-wave map (Fig. 2 of Davis et al., 2003) also supports this conclusion, as the S-wave anomalies should be more sensitive to pressure effects over most of this area. Detailed reservoir modeling and flow simulation is being conducted to calibrate the seismic results.

In addition to the main amplitude anomalies, there are also smaller off-trend anomalies that suggest that channeling of the CO_2 is occurring in some areas. One example of this is highlighted in Figure 7 (see arrow), where an E-W spur is observed emanating from the main anomaly. A similar trend is observed on the spatially coincident attenuation (or calculated permeability) image from Figure 6 (inset in Fig. 7) and to a lesser extent on the S-wave amplitude difference map (Fig. 2 of Davis et al., 2003). These observations imply the presence of enhanced permeability, which may be part of a larger pattern as described below.

A curvilinear pattern of S-wave identified anisotropy occurs along the bottom fringe of the sub-area (red rectangle) displayed in the inset of Figure 5, which correlates spatially with a similar pattern on the $\delta^{13}C$ map. This pattern generally follows the salt dissolution edge (white dashed line in inset of Fig. 5) of the underlying Prairie evaporite, suggesting that a network of fractures may exist within the reservoir in association with salt dissolution. Alternatively, the observed anisotropic zone may be associated with depositional facies-controlled fractures as it approximately corresponds to the transition from intershoal to shoal depositional facies in the Vuggy unit. In any case, both the seismic and geochemical results strongly suggest that the CO_2 flood is advancing preferentially along this zone of enhanced permeability.

Passive Monitoring

Long-term monitoring of microseismicity is intended to help assess the dynamic response of the reservoir to CO_2 injection and may prove useful as an alternate and/or complementary method of flood monitoring. Microseismicity will be analyzed to constrain the location, magnitude, source mechanism, and likely geologic source and frequency of occurrence of the characteristic seismicity and will be compared in detail with the CO_2 injection schedule and production rate variability. Local seismicity might be anticipated, for example, in association with CO_2-induced rock deformation (e.g., opening of existing fractures), rock failure due to salt dissolution in the underlying Prairie evaporite, or background seismicity associated with the regional stress regime.

Short-term monitoring to date has been unsuccessful in detecting significant microseismicity at the Weyburn field, in contrast to the experience in injection projects elsewhere (e.g., Maxwell et al., 2003). Short-term monitoring was conducted in 2001 for a period of several nights using the 48-channel hydrophone array deployed within the reservoir for the horizontal crosswell survey (see earlier section). Other attempts were made over a four-day cumulative period in 2000 and 2001 using the 12-level three-component downhole array deployed for vertical seismic profiling within a 200 m interval directly above the reservoir. To fully and finally assess microseismic levels at Weyburn, an eight-level array of three-component geophones has been cemented in place ~200 m above the reservoir. Data acquisition was initiated in August of 2003 and is intended to continue for at least six months.

CONCLUSIONS

The results obtained to date within the various elements of the Weyburn project are encouraging. The geoscience framework is at an advanced stage of construction and will form the basis for numerical modeling of the long-term fate of injected CO_2. The monitoring methods (seismic and geochemical) demonstrate that the response of the reservoir to CO_2 injection can be assessed and will be useful for the purposes of verifying the volume of injected CO_2. Ultimately, we anticipate that the results from the Weyburn project will contribute to rigorous assessment of the feasibility of using oil reservoirs for the sequestration of greenhouse gases.

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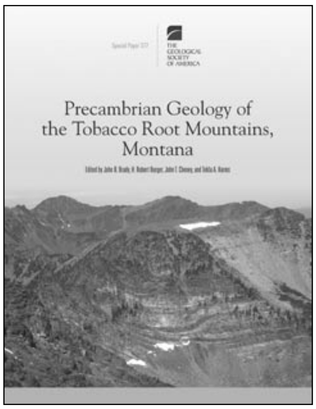
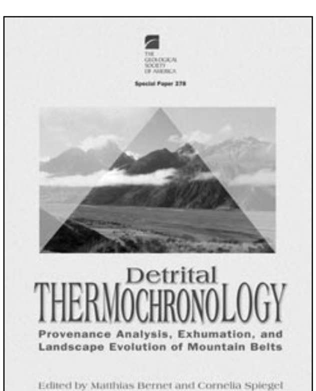


Precambrian geology of the Tobacco Root Mountains, Montana
edited by John B. Brady, H. Robert Burger, John T. Cheney, and Tekla A. Harms
SPE377, 256 p., plate
ISBN 0-8137-2377-9
$100.00, **member price $80.00**

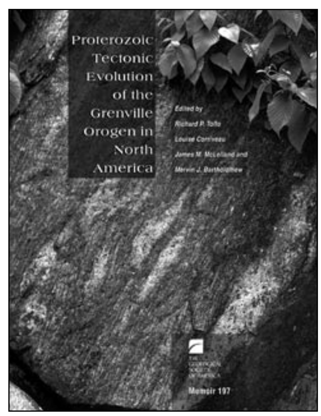
The Precambrian rocks of the Tobacco Root Mountains were subjected to an intense tectonothermal event (Big Sky Orogeny) during the collision of the Wyoming and Hearne provinces in the Early Proterozoic. This event overprinted earlier periods of deformation and metamorphism, but the unique lithologic packages present in the mountains aid in unraveling early from later events and in detailing many results stemming from this collision. Several papers review the geochemistry and petrology of the four major Precambrian rock sequences present in the Tobacco Root Mountains, providing the foundation for understanding the extensive information that follows. Another paper considers the meta-ultramafic rocks dispersed throughout all Precambrian exposures in the mountains. Petrologic observations from all four rock suites are interpreted in terms of a metamorphic history and a pressure-temperature path for the mountains during the Proterozoic event. Numerous radiometric age determinations from the suites are also presented. Together, the papers provide a solid base for understanding the timing of the tectonothermal events that affected these rock suites and for separating the effects of the last major event in the Early Proterozoic. Finally, two papers synthesize observed field relations, structures, and fabrics with age determinations and metamorphic history into a sequence of events by which the rocks of the Tobacco Root Mountains evolved, placing Tobacco Root geology into the context of the northern Wyoming province.



Detrital thermochronology—Provenance analysis, exhumation, and landscape evolution of mountain belts
edited by Matthias Bernet and Cornelia Spiegel
SPE378, 126 p., ISBN 0-8137-2378-7
$55.00, **member price $44.00**

Detrital thermochronology is one of the fastest-growing disciplines in geosciences today because it provides valuable insights into the long-term evolution of mountain belts and the interplay of tectonics and climate in orogenic systems. The ability to determine cooling or crystallization ages of detrital apatite, zircon, or white mica from synorogenic sediments using a variety of techniques such as fission-track, Ar-Ar, or U-Pb dating enables us to determine potential sediment source areas, reconstruct the thermal history of an orogen, calculate exhumation rates, and detect changes in topography and drainage divides. The different dating techniques can easily be combined on the same samples or with other analytical methods to obtain the maximum amount of information. This book discusses some of the fundamental aspects of detrital thermochronology and presents applications in different orogenic settings that highlight the value of this current development.

Memoir



Proterozoic tectonic evolution of the Grenville orogen in North America
edited by Richard P. Tollo, Louise Corriveau, James McLelland, and Mervin J. Bartholomew
MWR197, 798 p. plus index,
ISBN 0-8137-1197-5
$195.00, **member price $156.00**

The geological evolution of the Grenville orogenic belt represents one of the most widespread episodes of crustal modification in Earth's history. The 39 papers in this volume offer a system-wide perspective on rocks and processes of the Mesoproterozoic Grenville orogen and Appalachian inliers and include many multidisciplinary studies presenting results from integrated petrologic, geochemical, and geochronologic investigations. The volume includes contributions concerning the Grenvillian geology of Canada, the United States, and Mexico, focusing on both the tectonic evolution of the orogen and on innovative approaches to deciphering the igneous, metamorphic, structural, and metallogenic history of Mesoproterozoic assembly and Neoproterozoic rifting. The timing and regional correlation of events and processes is emphasized in order to bridge knowledge gaps within the orogen and to better understand the geodynamic framework.

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GSA Names 2004 Medal and Award Recipients

Medals and awards for 2004 will be presented at the Annual Meeting in Denver during the Presidential Address and Awards Ceremony, Saturday, November 6, at the Hyatt Regency Grand Ballroom.

Penrose Medal
W. Gary Ernst
Stanford University

Arthur L. Day Medal
Edward M. Stolper
California Institute of Technology

Young Scientist (Donath) Medal
Brian K. Horton
University of California at Los Angeles

GSA Distinguished Service Award
Peter W. Lipman
U.S. Geological Survey, Menlo Park

Donna L. Russell
GSA Foundation

GSA Public Service Award
Robert D. Ballard
Mystic Aquarium and Institute for Exploration

Honorary Fellows
Juan Luis Benedetto
Universidad Nacional de Cordoba, Argentina

Nicolas J. Beukes
Rand Afrikaans University, South Africa

Cornelius (Nok) Frick
President, International Union of Geological Sciences (South Africa)

Subaru Outstanding Woman in Science Award (Sponsored by Subaru of America, Inc.)
Constanza Bonadonna
University of Hawaii

AGI Medal in Memory of Ian Campbell
Ernest A. Mancini
University of Alabama

John C. Frye Environmental Geology Award
Raymond C. Harris and Philip A. Pearthree, for their 2002 book, *A Home Buyer's guide to Geologic Hazards in Arizona* (Arizona Geological Survey, Down-to-Earth 13)

Rip Rapp Archaeological Geology Award
Michael R. Waters
Texas A&M University

Gilbert Cady Award (Coal Geology Division)
Robert B. Finkelman
U.S. Geological Survey, Reston

E.B. Burwell, Jr., Award (Engineering Geology Division)
John W. Bell, Falk Amelung, Alan R. Ramelli, and Geoff Blewitt for their 2002 paper "Land Subsidence in Las Vegas, Nevada, 1935–2000: New Geodetic Data Show Evolution, Revised Spatial Patterns, and Reduced Rates" (Environmental & Engineering Geoscience, v. 8, no. 3, p. 155–174)

George P. Woollard Award (Geophysics Division)
David T. Sandwell
Scripps Institution of Oceanography

History of Geology Award
Stephen G. Brush
University of Maryland

O.E. Meinzer Award (Hydrogeology Division)
Ghislain de Marsily
Université Pierre et Marie Curie, Paris VI

G.K. Gilbert Award (Planetary Geology Division)
William K. Hartmann
Planetary Science Institute, Tucson

Kirk Bryan Award (Quaternary Geology and Geomorphology Division)
Stephen C. Porter
University of Washington

Laurence L. Sloss Award (Sedimentary Geology Division)
James Lee Wilson
Consultant, Texas

Career Contribution Award (Structural Geology and Tectonics Division)
Kevin C. Burke
University of Houston

Distinguished Career Award (International Division)
None awarded for 2004.

New day, time, and location:

GSA Presidential Address & Awards Ceremony

Sat., Nov. 6, 7–9 p.m.
Hyatt Regency,
Grand Ballroom

Join us Saturday to honor your fellow geoscientists—the award recipients, newly elected GSA Fellows, and Honorary Fellows—at the Presidential Address and Awards Ceremony, which will be followed by a cash bar reception.

We hope to see you there!

GSA Fellows Elected by Council on April 25, 2004

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Jeffrey C. Alt

Senior Research Scientist, University of Michigan

Jeffrey Alt was elected for his exceptional contributions to understanding the formation of new ocean crust, hydrothermal water-rock interactions, and sulfur isotope geochemistry.

Kevin M. Bohacs

Research Associate, ExxonMobil

Kevin Bohacs is an outstanding sedimentologist with ExxonMobil Upstream Research Company. He is well known for his comprehensive sequence-stratigraphic models in lacustrine and marginal marine basins. He interacts extensively with the academic community and has provided superb guidance and opportunities for geology graduate students interested in petroleum geology.

Scott R. Burns

Professor, Portland State University

Scott Burns is an enthusiastic and energetic person who has developed an excellent reputation as a geologist, teacher, and researcher. He is well known and respected for his work on landslides and related slope failures. In addition to his contributions to the profession, he has demonstrated his enthusiasm and knowledge in bringing geologic concepts to the public through frequent talks to local groups and by television appearances. His enthusiasm is contagious.

Michael D. Campbell

Principal, M.D. Campbell and Associates

Michael D. Campbell, P.G., P.H., the principal, M.D. Campbell and Associates, Houston, Texas, has 40 years of experience in hydrology, mining, and associated environmental and geotechnical fields as a consultant, lecturer, and senior manager. Additionally, he has provided litigation support and expert testimony services to industry and the legal community.

William Cavazza

Professor, University of Bologna

William Cavazza is a leader in the application of structural geology, sedimentology, stratigraphy, sedimentary petrography, and low-temperature geochemistry to the analysis of ancient and modern sedimentary basins. Other research interests include strontium-isotope stratigraphy, fission-track analysis, and the paleogeographic-paleotectonic evolution of the Mediterranean region. He has published on the geology of the Eastern Alps (Italy and Austria), the Rio Grande rift, the Rocky Mountains (Montana, Wyoming, and Utah), the Mojave Desert, the northern Apennines, southern Italy, and Corsica.

Carol A. Finn

Geophysicist, U.S. Geological Survey, Denver Federal Center

Carol Finn investigates important problems with multidisciplinary data, particularly from potential-field geophysics. Mapping sub-ice geology in Antarctica and basin geometry in Arizona and characterizing Precambrian terrains geophysically as guides for plate reconstructions are examples. She has published many refereed papers and is active in outreach and professional organizations.

Elizabeth H. Gierlowski-Kordesch

Associate Professor, Ohio University

Elizabeth Gierlowski-Kordesch has been a driving force in advancing the studies of modern and ancient lake systems through publications and the formation of the GSA Limnogeology Division.

Katherine Anne Giles

Professor, New Mexico State University

Katherine Giles was elected for her outstanding record and teaching in the field of sedimentary geology and especially for her work on the recognition of the backbulge basins in foreland geologic systems and on the stratigraphic facies associated with the evolution of salt welds.

Martin B. Goldhaber

Geochemist, U.S. Geological Survey, Denver Federal Center

Using stable-isotope geochemistry, inorganic chemistry, biogeochemistry, coupled fluid-flow and reaction path geochemical modeling, and experimental geochemistry approaches, Martin Goldhaber has pursued seminal studies of sediment diagenesis, sedimentary and sediment-hosted ore deposit formation, transport and fixation of toxic elements in sedimentary basins, and the environmental impact of mining.

Robert Edmund Holdsworth

Reader, University of Durham

Robert E. Holdsworth is an authority on the Moine thrust and physical processes related to weak faults and fault reactivation. His monumental work on fault reactivation and his leadership of the Reactivation Research Group at the University of Durham have enhanced the national and international recognition of his department and university. Holdsworth has provided exceptional service to the community by organizing numerous meetings, serving as president of the UK Tectonic Studies Group, and as a GSA series editor. We regard him as one of the current top five or so structural geologists in Britain.

Bruce F. Houghton

Macdonald Professor of Volcanology, University of Hawaii

Bruce Houghton was elected for his innovative and numerous contributions to the understanding of the dynamics of explosive volcanic eruptions and their impact on society, for the training of earth scientists, and for making the public aware of volcanic processes.

Julia A. Jackson

Editor, GeoWorks and American Geological Institute
Elected to Fellowship as the 2003 Public Service awardee.

Bor-ming Jahn

Professor, National Taiwan University
Bor-ming Jahn was nominated for his significant contributions to many aspects in the field of geochronology and geochemistry related to the genesis of the Greenstone belt in South Africa, the Phanerozoic growth of continental crust in East Central Asia and timing and tectonics of ultrahigh-pressure metamorphic belts in Central China and western Africa. Now at the National Taiwan University in Taiwan, he has established an excellent geochronological lab and trained many graduate students at Rennes University in France.

Chacko J. John

Director, Louisiana Geological Survey
Chacko John has published extensively on the oil and gas reserves in the Tertiary Gulf Coast basin—publications which the numerous independent geologists of the Gulf Coast rely on for geologic information concerning subsurface reservoirs. He is extremely active in a large number of geological societies and has served as president or vice-president of numerous professional societies and editor of several scientific journals.

Clark M. Johnson

Professor, University of Wisconsin
Clark Johnson is a geochemist who has made significant contributions to earth sciences through application of stable and radiogenic isotopes to a diversity of geological problems, including crust and mantle evolution, UHP metamorphism, geomicrobiology, exobiology, the origin and diagenesis of sedimentary rocks, and migrations of ancient people.

Miriam Kastner

Professor, Scripps Institution of Oceanography
Miriam Kastner was elected in recognition of her forefront contributions to the understanding of diagenetic and low-temperature geochemical processes, the origin of methane hydrates, and fluid flow in convergent margins.

Charles F. Kluth

Distinguished Scientist, Colorado School of Mines
Charles Kluth was elected for leadership in geoscience research over a quarter of a century, with special note of his sustained efforts to promote sound geoscience in the petroleum industry, both nationally and internationally.

H. Richard Lane

Program Manager, Division of Earth Sciences, National Science Foundation
H. Richard Lane was elected for his research contribution in conodont biostratigraphy and international chronostratigraphic boundaries, administrative contributions as manager of worldwide paleontology for Amoco Production Company and as program director at the National Science Foundation, and professional contributions to "Paleontology in the 21st Century" and the North American Commission on Stratigraphic Nomenclature.

Michael Manga

Associate Professor, University of California, Berkeley
Elected to Fellowship as the 2003 Donath medalist.

Kathleen Marie Marsaglia

Assistant Professor, California State University, Northridge
Kathleen Marsaglia is one of the world leaders in sand(stone) petrography, especially the petrography of volcaniclastic sand(stone). She has been shipboard scientist on several ODP legs to diverse settings. She is expert at paleogeographic and paleotectonic reconstruction, both on land and at sea, and especially the application of petrographic data to solve fundamental problems. She also excels in the training of undergraduate and graduate students, especially underrepresented minorities and women.

Julia K. Morgan

Assistant Professor, Rice University
Julia Morgan was elected for significant research contributions to the fields of sediment deformation in subduction zones and landsliding on the flanks of submarine volcanoes.

Samuel B. Mukasa

Professor, University of Michigan
Samuel Mukasa was elected for his continuing contributions to our understanding of the evolution and dynamics of Earth's crust and mantle, and for the example that he has set by combining extensive field work with detailed elemental and isotopic geochemistry in his research.

Eugene F. Pearson

Professor, University of the Pacific
Eugene Pearson was elected for his 30 years of innovative, award-winning teaching of undergraduate students at the University of the Pacific, for his active participation in and leadership of the Far Western Section of the National Association of Geoscience Teachers, for his outreach to K–12 science teachers, and for his outstanding service to his geology department, the University of the Pacific, and its faculty.

Roger J. Phillips

Professor, Washington University, St. Louis
Elected to Fellowship as the 2003 G.K. Gilbert awardee.

Thomas M. Scott

Florida Assistant State Geologist for Programs, Florida Geological Survey
Thomas Scott was elected to fellowship because of his exemplary record of publishing on Florida geology, administering geological programs,

GSA Fellows

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promoting public awareness of geology, serving in leadership roles in professional organizations, and for his editorial work. He is highly motivated and loves training the next generation of geologists.

Geoffrey Owen Seltzer

Associate Professor, Syracuse University

Geoffrey O. Seltzer has spearheaded efforts to acquire and decipher records of climate change in the tropics, with a special emphasis on the tropical Andes. He has been integral in the coring of Lake Titicaca and other lakes in Bolivia and Peru. He has been training the next generation of geologists for more than 10 years.

Gerilyn S. Soreghan

Associate Professor, University of Oklahoma

Gerilyn Soreghan was elected for her vigorous research and superior teaching in the field of sedimentary geology and especially for her work in elucidating varied aspects of glacioeustatic cyclostratigraphy in Paleozoic strata.

Carl W. Stock

Professor, University of Alabama

Election of Carl Stock to GSA Fellowship is based on his outstanding research contributions in stromatoporoid systematics, paleobiogeography, and paleoecology, his exceptional dedication to the education of undergraduate and graduate students about the principles and concepts of paleontology, and his distinguished service to the profession and science of paleontology.

Lisa Tauxe

Professor, Scripps Institution of Oceanography

Election to Fellowship as the 2003 George P. Woollard awardee.

M. Ray Thomasson

President, Thomasson Partner Associates, Inc.

Ray Thomasson is a true visionary and is recognized for his lifetime contributions to the geosciences profession through his superior technical skills and business acumen. Over the past 40 years he has been a recognized leader in the geoscience community and has unselfishly given his time, support, and energies to appropriate geoscience causes.

Michael Underwood

Professor, University of Missouri

Michael Underwood was elected for his significant contributions to the understanding of convergent margin sedimentation and the behavior of these sediments during deformation and dewatering, and for his dedication and commitment to undergraduate and graduate education.

Roy B. Van Arsdale

Professor, University of Memphis

Roy Van Arsdale's publications include numerous important papers on active faulting, seismicity, liquefaction, geomorphic analysis, and seismic hazard related to the New Madrid seismic zone. He has also published papers on active faults, neotectonics, mantle plumes, and other structural problems elsewhere in both the United States and Australia.

Michael R. Waters

Professor, Texas A&M University

Elected to Fellowship as the 2003 Kirk Bryan awardee.

Paul Weimer

Benson Professor in Geological Sciences, University of Colorado

Paul Weimer has 24 years of professional experience with the petroleum industry and Colorado University, where he holds the Bruce Benson Chair in Geological Sciences. He is a recognized international leader in research of deep-water sedimentation and petroleum occurrences in continent margin basins throughout the world. Advances in education and research have been recognized by AAPG, SEPM, and SEG by his selection as a distinguished lecturer and officer.

Joseph L. Wooden

Research Geologist, U.S. Geological Survey–SUMAC, Stanford University

Joseph Wooden's contributions to understanding evolution of the Earth's crust in the western United States have been both numerous and profound. As co-leader of the USGS-Stanford SHRIMP ion microprobe, he has also been largely responsible for this facility's extraordinary production of new isotopic results applied to diverse geologic problems.

Zhongbo Yu

Assistant Professor, University of Nevada at Las Vegas

Zhongbo Yu was elected for fundamental contributions to the understanding of hydrologic processes in large basins through the development and application of distributed modeling techniques.

James C. Zachos

Professor, University of California at Santa Cruz

James Zachos was elected a Fellow to the Geological Society of America for significant scientific contributions to Cenozoic paleoceanography, paleoclimatology, and abrupt climate change during the Late Paleocene Thermal Maximum as well as recognition for outstanding mentorship of graduate students and postdoctoral researchers in the geosciences.

GSA Fellows Elected by Council on April 25, 2004

Greetings from Washington, D.C.

Science and Politics:
An Uneasy Mix

Michèle Koppes, *2004–2005 GSA–U.S. Geological Survey Congressional Science Fellow*

As a scientist, especially an earth scientist versed in environmental processes, this is a particularly interesting time to be an in-house observer to the congressional process. There is an escalating battle on Capitol Hill over the use of science in the making of public policy. The debate centers on the use of "sound science" in determining federal regulatory policy and on whether sound science is an achievable standard or simply a political slogan. To say that sound science is a campaign slogan may seem absurd, but it appears to be par for the course on the Hill these days. In a contentious election year, every issue, no matter how small, turns into campaign material.

Partisanship in both houses of Congress is unusually fierce at the moment. And partisanship in a one-party majority system, when both houses of Congress and the White House are dominated by the same party, tends to encourage what some would term "undemocratic" behavior, such as the predominance of party-line voting, holding open of voting times to encourage vote-switching and passage of contentious bills, or blocking of the minority party from legislative debates. These behaviors seem to occur no matter which party is in control of Congress and the executive branch, though memory appears to be extremely short when the formerly dominant party finds itself in the down-trodden minority, and vice versa. I was quick to learn the latter aspect in my very first issue area, forest health. Congressman Jay Inslee, whom I am spending my year working for, is the ranking member of the Forest Subcommittee and last November was nominated by the House Democratic Leadership to help draft the joint conference report of the Healthy Forests Restoration Act, a bill to authorize forest thinning to prevent wildfire. I was surprised to discover that the deliberation of the joint conference report was a closed process that took place between the original sponsors of the bill and the chairmen of the respective committees. Congressman Inslee and other appointed conferees were not invited to attend any of the pre-conference deliberation, in which the main differences between the House and Senate versions of the bill were hashed out, including the quality of environmental analysis that would be needed prior to approving forest thinning projects, or the definition and proportion of authorized funds to be spent on the wildland-urban interface where forest fires have the most impact on humans. That debate took place between the Chairmen of the House Resources and Agriculture Committees, the Chairman of the Senate Agriculture Committee, and Senators Wyden and Feinstein, who co-authored the Senate bill. The actual conference was a short, public affair in which votes were cast for a pre-deliberated report, with no discussion of amendments by the other members who were not party to the prior deliberations.

Not to be deterred by my first experience in the political realities of the debate process, I moved on to other issues beyond forest health. In my first few months on the Hill, I have been tasked with following and providing the kind of role that I believe the Founding Fathers envisioned for Congress: overseeing the ways in which the administration and federal agencies are using science and defining the process of determining scientific validity. Last September, the Office of Management and Budget (OMB), the office within the executive branch that oversees how federal tax dollars and information are used by the government and that produces the president's budget every year, proposed to clarify the way all science used to write federal regulations would be reviewed. The OMB proposal redefined the criteria for selection of experts to serve on federal peer review panels and provided OMB with the authority to restrict or delay the dissemination of any agency findings if it concluded the findings were not adequately peer reviewed. While such an oversight role is an excellent means to verify that only the best available science is used in drafting federal regulations, the OMB proposal has caused a great deal of consternation among the scientific community, as well as on Capitol Hill. During the public comment period that is required by such proposed rule changes, the OMB received more than 6,000 comments from scientists both inside the government and out, including letters from many scientific societies. The "mafia" of current and former congressional science fellows on the Hill has been instrumental in getting members of Congress to understand the peer review process and to respond to the OMB requesting elaboration of the proposed rule. In April, the OMB published a vastly revised bulletin in which many of the public comments were incorporated or addressed, demonstrating that each of these comments was vital to the agency's decision, as a statistic if not as an anecdote. (The revised bulletin on federal peer review, as well as the OMB's response to the public comments, can be found under Information Quality at: www.whitehouse.gov/omb/inforeg/infopoltech.html.)

The consternation about the OMB proposal to oversee the federal peer review process stems from a growing concern among the broad, nonpartisan scientific community in how the government handles science.

In February, the Union of Concerned Scientists (UCS) published a 36-page report protesting what members viewed as the current administration's policy of interjecting politics into the scientific process. The UCS report cited such practices as censoring and delaying scientific reports produced by federal agencies, filling agency review panels with political appointees, and neglecting to seek external approval on policy. Examples used in the report include the replacement of experts on bioethics panels when their scientific positions did not match administration policies, suppression of data alluding to climate change in an Environmental Protection Agency annual report on the environment, and distortion of scientific findings on reproductive health issues such as the success rate of abstinence-only education or the link between abortion and breast cancer.

The 62 scientists who signed the report, many of whom are leaders in their respective fields and several who formerly held high office in the federal government, conclude that these actions constitute an "alarming pattern" of political interference. They argue that the current administration has shown unprecedented political and ideological interference with independent scientific inquiry, resulting in misguided policies on a range of critical issues.

The administration's response, offered by John Marburger, director of the President's Office of Science and Technology Policy, counters that no such pattern exists. He argues that the examples cited in the report are simply a congruence of explainable, nonpolitical events.

Widely divergent viewpoints aside, the report has had one interesting effect: it is engendering a lot of talk on Capitol Hill about the current role of science in the policy-making process. The question on the collective mind of Congress is whether science can truly be divorced from politics. If science is to be used as a tool to determine good policy, how weighty a role should it play in the final decision-making, should the science used be purely empirical or a mixture of observation and (inherently more uncertain) modeling, and which scientists should be listened to?

Representative Richard Pombo, Chairman of the House Resources committee, recently stated, "...there is no doubt that science becomes political. It's easy to politicize if you just find the study that supports your argument." Policies are inherently political—they are social decisions made by weighing the priorities of the major stakeholders and deciding on an equitable balance of the public's needs through analysis and a democratic process. Can science, as a social endeavor with societal repercussions, be apolitical? All scientific analysis stems from the individual assumptions and biases of the researcher. There is no absolute fact. With such a large body of existing research, each based on individual biases, there are often many perspectives on any given phenomenon. The dominant paradigm shifts in every scientific discipline are therefore a process of social acceptance of these objective analyses, consensus and change—all achieved through peer review, the process of scientific validation by democratic means. Such shifts require dominant, vocal personalities, and social networks (e.g., conferences, peer-reviewed publications) in which new ideas and methodologies are shared.

The same is true of the legislative process. Debates in Congress are based on the power and acceptance of the loudest voice. With such an immense country and so much information flowing into the offices on the Hill every minute, many crucial issues can get overlooked. Those issues that do come up often require immediate attention and cannot receive the time and depth to make the kind of well-thought-out decisions which are the mainstay of academia. Congress therefore counts on the timely contributions of constituents and experts who are willing to share their views on any given issue as it comes up. The power of local, constituent voices with credentials is especially forceful in shaping the debate on the floors of the House and Senate. For that reason alone, I urge each GSA member to become an active, engaged citizen and constituent. Make it part of your routine to let your representatives and senators know your opinion on matters that count. Encourage them to sponsor legislation and lend them your expertise, as that may gain them entrance into the final deliberation process. As earth scientists, this is especially critical as the role of science continues to be debated on the Hill, and Congress attempts to define "sound science." They are your representatives, and your voice does count.

This manuscript is submitted for publication by Michèle Koppes, 2004–2005 GSA–U.S. Geological Survey Congressional Science Fellow, with the understanding that the U.S. government is authorized to reproduce and distribute reprints for governmental use. The one-year fellowship is supported by GSA and by the U.S. Geological Survey, Department of the Interior, under Assistance Award No. 02HQGR0141. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. government. Koppes can be reached at michele.koppes@mail.house.gov.

Comment and Reply
CO_2 as a primary driver of Phanerozoic climate
Dana L. Royer, Robert A. Berner, Isabel P. Montañez, Neil J. Tabor, and David J. Beerling, GSA Today, v. 14, no. 3, p. 4–10.

Comment

Nir Shaviv, *Racah Institute of Physics, Hebrew University of Jerusalem, Jerusalem, 91904 Israel*

Ján Veizer, *Institut für Geologie, Mineralogie und Geophysik, Ruhr-Universität Bochum, 44801 Bochum, Germany, and Ottawa-Carleton Geoscience Centre, University of Ottawa, Ottawa, Ontario, K1N 6N5 Canada*

Royer et al. (2004), in their recent article in *GSA Today*, dispute the conclusion of Shaviv and Veizer (2003) that celestial forcing may have been the major driver of Phanerozoic climate, arguing instead for CO_2 as the dominant force. The $\delta^{18}O$ of calcareous shells reflects the ambient temperature of seawater and the quantity of water locked in the polar ice caps, each contributing about one half to this signal, but lately it has been realized that seawater pH drives the $\delta^{18}O$ in the opposite direction. Royer et al. utilized this for reconciling the GEOCARB III and the $\delta^{18}O$ trend of Veizer et al. (2000) by assuming that any discrepancy of the two variables is due to pH. This is an interesting proposition that has some merit, but note that such a correction is entirely arbitrary, because we do not have any constraints for the pH of Phanerozoic seawater, except possibly some boron isotopes for the youngest portion of this record. Moreover, the pH correction itself basically reflects the GEOCARB III CO_2 model, such that the correlation obtained between the corrected $\delta^{18}O$ and CO_2 cannot be claimed to be a CO_2 fingerprint. Furthermore, the model of Royer et al. does not consider the mitigating "ice volume" effect. Once included, the required pH correction (and GEOCARB III CO_2 levels) would have to be about doubled for CO_2 climate "driving" to be on par with the CRF. For all these, and the reasons listed in our detailed response (see www.gsajournals.org; go to "Online Journals," then "Online Forum"), we argue that the $\delta^{18}O$ trend is still chiefly a reflection of the temperature history of the past oceans, controlled principally by the celestial driver.

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Reply

Dana L. Royer, *Department of Geosciences and Institutes of the Environment, Pennsylvania State University, University Park, Pennsylvania 16802, USA, droyer@psu.edu*

Robert A. Berner, *Department of Geology and Geophysics, Yale University, New Haven, Connecticut 06520, USA*

Isabel P. Montañez, *Department of Geology, University of California, Davis, California 95616, USA*

Neil J. Tabor, *Department of Geological Sciences, Southern Methodist University, Dallas, Texas 75275, USA*

David J. Beerling, *Department of Animal and Plant Sciences, University of Sheffield, Sheffield S10 2TN, UK*

A major purpose of our paper was to show that paleotemperature records do not support the presence of prolonged cold intervals (similar in magnitude and duration to the Permo-Carboniferous glaciation) during the Ordovician/Silurian (460–400 Ma) and mid-Mesozoic (220–120 Ma), as required by the $\delta^{18}O$ record of Veizer et al. (1999). The fact that our pH-corrected curve better matches the more robust record of glacial sediments should be taken as a positive result, considering an alternative explanation of diagenesis. Crucially, diagenetic overprinting can be present even when screening samples using the petrographic and trace element criteria adopted by Veizer et al. (1999) (cf. Montañez et al., 2000; Wenzel, 2000; Mii et al., 2001; Pearson et al., 2001).

Shaviv and Veizer claim that we correlate the CO_2 and pH-corrected temperature records. This is simply untrue. Also, their "ice volume" effect, to be applied to our pH correction, is based on an average slope for the change in temperature with $\delta^{18}O$, for the entire Phanerozoic. This approach is incorrect. The ice volume correction is applicable only to periods of major glaciation, but at these times our pH correction was minor.

The correspondence between the Phanerozoic records of atmospheric CO_2 and glacial sediments, and the revision of the $\delta^{18}O$ paleotemperature record toward values better matching the glacial sediment record, strongly implicate CO_2 as a primary driver of climate over these timescales. Cosmic ray flux is likely only of second-order significance (see also Rahmstorf et al., 2004).

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Online Comments and Replies

Visit www.gsajournals.org for comments and replies on *GSA Today* articles. Click on "Online Journals" then "Online Forum," then "GSA Today: Comments and Replies."

ATTENTION Voting Members:

GSA Election Starts August 11, 2004

The success of GSA depends on the work of the elected officers who serve on its Executive Committee and Council. Make your wishes for GSA known by voting.

In mid-August, you'll receive a postcard with instructions on how to access a secure Web site and your electronic ballot listing officer nominees for 2005 and councilor nominees for the term 2005–2009. Biographical information on each candidate will be available for review at www.geosociety.org beginning in mid-July. Paper versions of the ballot and candidate information will be available to those unable to vote online.

Watch for your ballot information and vote! Ballots must be submitted electronically or postmarked by September 10, 2004.

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Nevada Bureau of Mines & Geology

COMMENTARY

Toward the Unification of Disciplines

Craig M. Ashbrook, *Professor and Program Head of Environmental Management, Southwest Virginia Community College, craig.ashbrook@sw.edu*

How frequently have we heard arguments between geologists and physical geographers as to the differences in their disciplines? As scientists, we should be addressing similarities and forgo the folly of academic preeminence of disciplines. Recurrently, physical geographers encounter geologists who acknowledge certain areas of physical geography as being "geology related," but vigorously refuse to recognize those physical geographers as colleagues in the same disciplinary field. Moreover, we frequently hear that physical geography is "this" while geology is "that." Many geologists are past due in recognizing the fact that geography is not necessarily memorizing the states and their capitals nor is it a watered-down version of geology, somehow lacking any analytically systematized approach to research and scholarship. Likewise, physical geographers need to recognize that geology is not necessarily memorizing rocks and minerals, and geologists, too, use a spatial (geographic) approach for understanding our planet.

The disciplines of physical geography and of geology are multifaceted earth sciences. It is correct to say each discipline constantly paraphrases the other. Geology has several specialty areas that are removed from physical geography and vice versa. However, numerous topics not only overlap, they are, by literal definition, exactly the same subject. That subject, from both a physical geography perspective and a geology perspective, is the study of the Earth—geology. To suggest that physical geography and geology are not comparable is to limit both disciplines and their disciples to a select set of preprogrammed information, which creates academic tunnel vision and hinders our understanding of planet Earth.

This professor has endured several arguments by many geologists (and, to a lesser extent, physical geographers) in their unbending endeavors to keep these disciplines separate. Those geologists or physical geographers who disagree typically argue some insubstantial point in an effort to keep the disciplines divided, unequal, and splintered. That bias splintering only serves to create shards of renunciation and impairment to the geoscience field and many of its partisans. I feel confident that a number of hard-core, old-school, proverbial geologists (or geographers as the case warrants) are now spouting platitudes of dissension at this philosophy; however, their platitudes will neither change these facts nor change the definitions. Those geologists who continue to oppose these disciplinary definitions remind me of the spiritual aficionado who churns out the notion that if you "don't do what I do, think what I think, and know what I know, then you are not worthy"; in this case, to be called a geologist. I am comfortable with welcoming geologists into the world of physical geography. It is my most sincere hope that the reverse will develop into reality rather than remain idealism. For a geologist or geological organization to deny this right to physical geographers seems noticeably prejudicial.

During fifteen years of ongoing college and university level teachings of both physical geology and physical geography, I continue to encounter copious opportunities to read and review a profusion of geology and geography textbooks along with their numerous definitions. For instance, geomorphology, a geography specialty area, is defined as the science of geology dealing with Earth's surface. Physiography is defined as physical geography. Physiography is also defined as geomorphology. Therefore, physical geography is geomorphology, and geomorphology is geology. If you are a physical geographer, who specialized in geomorphology, it is not only a specialty of geology, it is geology, and you, then, are a geologist. The generally accepted definition of physical geography is *the study of the physical systems of the Earth with emphasis on humans.* Amusingly, environmental geology is accurately defined as *the study of the interactions of the physical systems of the Earth with emphasis on humans.* Sounds like we should redefine environmental geology as physical geography. As a matter of definition, physical geography offers a more complete understanding of the study of Earth (geology) because it includes more of the earth systems such as the atmospheric sciences and phytogeography along with all those other subjects geologists like to claim as their own (e.g., glaciology, volcanism, tectonics, fluvial processes, hydrology, coastal processes). Only a few geology texts cover the atmospheric sciences. The inclusion of the atmospheric sciences in geology is a developing trend in many college and university geology departments. I direct the reader to Virginia Polytechnic Institute and State University or Penn State University, or James Madison University for verification (to name a few). Meteorology and climatology (originally geography) are now being offered for dual geology/geography credit, as are Geographic Information Systems (GIS) and remote sensing (also geography).

To have completed much coursework in physical geography does not make one a lesser geologist. Rather, he or she is a specialized geologist and should be recognized accordingly. Physical geography is, unmistakably, geology. I invite the reader to ponder this quote from the June 1990 issue of the *Times* (London): "Geography is queen of the sciences, parent to chemistry, geology, physics and biology, parent also to history and economics."

GSA's well-developed, perceptive new vision and matching logo accurately embrace more areas of geology by including physical geographies such as the atmospheric sciences and phytogeography. This is a superior move with regard to changing times, and obviously demonstrates exceptional judgment, which is incontrovertibly a step in the right direction for unifying these disciplines. GSA's judgment is visibly above and beyond the geoscience norm.

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The Times, 7 June 1990, p. 13.

Letter . . . .

Dear *GSA Today*:

Subaru is a Corporate Sponsor of GSA, and runs advertisements in GSA publications. Subaru is also engaged in what I consider to be unsavory business practices to manipulate the Clean Air Act, by making superficial modifications to the Subaru Outback sedan so that it falls under the Federal fuel economy classification system as a light truck (21.2 mpg rather than 27.5 mpg). So my question to you is this—does GSA have any criteria by which we (the membership) evaluate selecting or continuing to select corporate sponsors? Thank you.

James E. Evans

GSA responds:

Subaru reports that the Outback was reclassified as a light truck in response to customer requests for higher vehicle clearance and tinted windows. As for changes in mileage performance, the Subaru Web site shows mileage for the 2004 2.5 liter Subaru Outback (automatic transmission) at 22/28 for city/highway conditions. This reflects no change in mileage performance, and a few reports from Subaru owners we talked with support this.

We are pleased to report that GSA does have mechanisms for evaluating corporate sponsorships. Contracts are reviewed first by staff at Headquarters, and then approved by Council. If members, upon learning of a particular issue that causes them concern, wish to influence such approval, they can and should raise this with their elected Council Members. It seems to us that more direct evaluation options by individual members is impractical, given that we have more than 17,000 members.

Rob Van der Voo, President
Jack Hess, Executive Director

ANNOUNCEMENTS

MEETINGS CALENDAR

2004

July 27–31	Geo-Trans 2004, the Geo-Institute Conference on Geotechnical Engineering for Transportation Projects, Los Angeles, California, USA. **Information:** www.asce.org/conferences/geotrans04/.
Aug. 29–Sept. 1	Geothermal Resources Council 2004 Annual Meeting, Indian Wells, California, USA. **Information:** GRC, P.O. Box 1350, Davis, CA, 95617-1350, USA, (530) 758-2360, fax 530-758-2839, grc@geothermal.org, www.geothermal.org.
September 1–3	IGCP 503: Early Palaeozoic Palaeogeography & Palaeoclimate, Erlangen, Germany. **Information:** Symposium Chairman: Axel Munnecke, Institute of Palaeontology, Erlangen University. Loewenichstr. 28, D-91054 Erlangen (Germany), +49 (0)9131/85-26957, fax +49 (0)9131/85-22690, palaeo2004@pal.uni-erlangen.de, www.pal.uni-erlangen.de/IGCP503/first_circular.html/.
October 21–23	Field Symposium on Stratigraphic and Structural Evolution of the Ouachita Mountains and Arkoma Basin: Applications to Petroleum Exploration, Poteau, Oklahoma. **Information:** Neil Suneson, Oklahoma Geological Survey, (405) 325-3031, or nsuneson@ou.edu.

2005

January 24–26	Geo-Frontiers 2005 Congress and Exposition: Geo-Institute 2005 Congress & Geosynthetics 2005 Conference, Austin, Texas, USA. **Information:** http://www.asce.org/conferences/geofrontiers05/.
May 8–11	Solutions to Coastal Disasters Conference 2005. Charleston, South Carolina. **Information:** www.asce.org/conferences/cd05/, Christina Childs, cchilds@asce.org.
June 5–11	The Seventh International Congress on Rudists: Cretaceous Rudists and Carbonate Platforms: Environmental Feedback, Austin, Texas. **Information:** Debra Sue Trinque, Treasurer, 7th International Congress on Rudists, PO Box B, Austin, TX 78713-8901, USA, www.tmm.utexas.edu/npl/rudist2005/. (*Abstracts, registration deadline: February 15, 2005.*)
November 13–15	Geology Forum 05: Focus on Mineral Exploration (Sponsored by Mining Review Africa). **Information:** Jon Wills, Minerals Engineering International, +44 7900 676701, fax +44 1326 318352, jon@min-eng.com, www.min-eng.com/geologyforum05/index.html.

2006

November 12–16	International Annual Meetings of the American Society of Agronomy–Crop Science Society of America–Soil Science Society of America, Indianapolis, Indiana, USA. **Information:** www.asa-cssa-sssa.org/anmeet, headquarters@agronomy.org, (608) 273-8080.

Visit www.geosociety.org/calendar/ for a complete list of upcoming geoscience meetings.

Limnogeology Division Establishes the Kerry Kelts Research Awards

The Limnogeology Division announces the establishment of student research awards, named in honor of **Kerry Kelts**, a visionary limnogeologist and inspiring teacher. Our inaugural round will comprise two awards of $250 each for use in research related to limnogeology. Application for this award is simple: a summary of the proposed research and its significance (five-page maximum). Please send your summary in PDF format along with your name and associated information to the chair of the Limnogeology Division: Elizabeth Gierlowski-Kordesch (gierlows@ohio.edu).

Deadline: September, 15, 2004. Awards will be announced at the Limnogeology Division Business Meeting/Reception at the 2004 annual GSA meeting in Denver this November.

We hope to increase the amount of the awards in succeeding years. If you are interested in supporting this awards program, please send your donations, designated for the Kerry Kelts Research Awards of the Limnogeology Division, to GSA, P.O. Box 9140, Boulder, CO 80301-9140.

Call For Geological papers: 2005 GSA Section Meetings

Northeastern Section
March 14–16, 2005
Prime Hotel and Conference Center, Saratoga Springs, New York
Abstract Deadline: December 14, 2004
Information: Kurt Hollocher, Union College, Department of Geology, Olin Building, Nott Sreet, Schenectady, NY 12308-3107, (518) 388-6518, hollochk@union.edu

Southeastern Section
March 17–18, 2005
Grand Casino Biloxi, Biloxi, Mississippi
Abstract Deadline: December 14, 2004
Information: Gail Russell, University of Southern Mississippi, Department of Geology, Box 5044, Hattiesburg, MS 39406-2000, (601) 266-4077, Gail.Russell@usm.edu

South-Central Section
April 1–2, 2005
Trinity University, San Antonio, Texas
Abstract Deadline: December 17, 2004
Information: Diane Smith, Trinity University, Department of Geosciences, #45, One Trinity Place, San Antonio, TX 78212-4674, (210) 999-7656, dsmith@trinity.edu

Cordilleran Section
(*Joint meeting with American Association of Petroleum Geologists*)
April 29–May 1, 2005
Fairmont Hotel, San Jose, California
Abstract Deadline: February 1, 2005
Information: Jonathan Miller, San Jose State University, Department of Geology, 1 Washington Square, San Jose, CA 95192-0102, (408) 924-5015, jsmiller@email.sjsu.edu

North-Central Section
May 19–20, 2005
University of Minnesota, Minneapolis, Minnesota
Abstract Deadline: February 22, 2005
Information: Carrie Jennings Patterson, University of Minnesota, Minnesota Geological Survey, 2642 University Ave. W., St Paul, MN 55114-1032, (612) 627-4780, ext. 220, carrie@umn.edu, or Barbara Lusardi, University of Minnesota, Minnesota Geological Survey, 2642 University Ave. W., St Paul, MN 55114-1032, (612) 627-4780, ext. 212, lusar001@umn.edu

Rocky Mountain Section
May 23–25, 2005
Mesa State College, Grand Junction, Colorado
Abstract Deadline: February 22, 2005
Information: Rex Cole, Mesa State College, Department of Physical & Environmental Science, 1100 North Ave., Grand Junction, CO 81501-3122, (970) 248-1599, rcole@mesastate.edu

www.geosociety.org/sectdiv/sections.htm

GSA Foundation Update

Donna L. Russell, *Director of Operations*

Field Forums: The Program Revisited

GSA Foundation Field Forum Subcommittee

The idea of field forums grew out of a need to carry forward the field-based tradition of the Geological Society of America in a Penrose Conference–type setting.

Penrose Conferences began in the late 1960s, and at least two field-based meetings were convened during the 1970s, one by Bob Coleman on ophiolites and another by Bob Hatcher on the Brevard fault zone. Many Penrose Conferences since then have had associated field trips or were convened in geologic settings appropriate to the topic of the conference. The concept and identity of a technical conference emphasizing field processes and phenomena never crystallized until Sharon Mosher proposed the Field Forum concept that GSA Council approved in 1998. The first Field Forum was held in 2000. Five have been held so far and one is scheduled for 2004 in locales ranging from the Virginia Piedmont to South Island, New Zealand.

Field Forums provide opportunities to exchange current knowledge and new ideas on particular geologic topics in a specific area. They are intended to stimulate and enhance individual and collaborative research and to accelerate the advancement of the geological sciences by interactions in an informal field atmosphere. Field Forums are modeled after Penrose Conferences, with a combination of invited and other interested attendees, but with a format similar to GSA Annual Meeting field trips. They are independent of any meeting or conference. Historically, the forums focus on a scientific problem best explored in a field setting by bringing together active scientists from national and international science communities and students.

The forums attract a manageable group in the range of 20 (minimum) to 40 participants over about a week. Field Forums—like Penrose Conferences—must be self supporting. The idea for the forum, justification of its location, logistics, and financial structure are proposed by one or more conveners and submitted to and approved by the Penrose Conference Committee.

Some financial support for Field Forums is currently being provided for students from the Pretorius Fund, with the understanding that these funds are to be returned to the Society. If the Field Forums are to be successful over the long term, the Pretorius Fund must be increased so that this permanent endowment can support student participants and subsidize the other cost of the conferences. Contributions should be made to the Pretorius Fund, managed by the GSA Foundation.

Most memorable early geologic experience:

Attending a field trip along the Round Top section in Maryland with Ernst Cloos and Francis Pettijohn. A once in a lifetime experience.

—Randolph W. Bromery

GSA FOUNDATION

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We would like to express our sincere appreciation and gratitude to all those Penrose Circle Donors during 2003. (*Penrose Circle Members: gifts of $250+ from January 1–June 30, 2003, and gifts of $500+ from July 2003–December 31, 2003.*)

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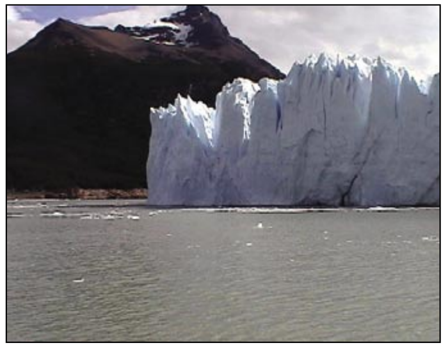
GeoTrip
Only for Students!
New Year's at the End of the World: The Geology of Southern Patagonia, Including Tierra del Fuego

December 26, 2004–January 11, 2005
15 days, 14 nights

Scientific Leader: James Reynolds, Brevard College, Brevard, North Carolina. Reynolds has spent the past 20 years investigating the uplift history of the Andes using magnetostratigraphy. He has traveled extensively in Patagonia and has a strong admiration for the land and its people. He has led international field trips since 1996.
Description: Join GSA for a spectacular, student-only, 15-day trip through some of the most breathtaking scenery on Earth, in southern Patagonia, Argentina, and Chile. The trip includes 11 nights of camping and more than 80 km of hikes through incredible geological settings. After a night in Buenos Aires, we'll fly to Calafate, at the foot of the Argentine Patagonian Andes and spend our first night in the field camped in front of the Perito Moreno glacier, descending from the Patagonian ice sheet, in Glaciares National Park. The next day, we'll take a day-long cruise on Lago Argentino, traveling past numerous icebergs and surrounded by fantastic folding and faulting deep within the fold-thrust belt. We'll then visit the area around Cerro Fitzroy, making several day-long treks from the campground. Our third site is the nearby Torres del Paine National Park, Chile, where we'll hike trails in and around the famous towers. After a night in a hotel in Punta Arenas, the southernmost mainland city, we'll take a ferry across the Straits of Magellan to Tierra del Fuego and camp on beautiful Lago Fagnano, the boundary between the South American and Scotia plates. We'll then proceed across the Cordillera Darwin to Tierra del Fuego National Park outside of Ushuaia, the world's southernmost city, where we'll hike and enjoy a boat excursion on the Beagle Channel. The complete itinerary is available at www.geosociety.org/geoVentures/04stu/patagonia.htm.



The Perito Moreno glacier descends from the Patagonian Ice Sheet and enters Lago Argentino in Glaciares National Park, Argentina. Photo by J. Reynolds.

Glacially carved Cretaceous intrusions are the prominent features in Torres del Paine National Park, Chile. Photo by J. Reynolds.

REGISTER TODAY!

Send a deposit to hold your reservation; please pay by check or credit card. You will receive further information soon.

Name ____________________

Institution/Employer ____________________

Mailing Address ____________________

City/State/Country/ZIP ____________________

Phone (business/home) ____________________

E-mail ____________________

Guest Name ____________________

GSA Member # ____________________

	DEPOSIT PER PERSON	NO. OF PERSONS	TOTAL PAID DEPOSIT
PATAGONIA	$200	____	$_________
	TOTAL DEPOSIT		$_________

☐ VISA ☐ MasterCard ☐ American Express ☐ Discover

Credit Card # ____________________ Exp. Date ________

Signature ____________________

MAIL OR FAX REGISTRATION FORM AND CHECK OR CREDIT CARD INFORMATION TO:
2004 GSA GeoVentures, GSA Sales and Service
P.O. Box 9140, Boulder, CO 80301
Fax 303-357-1071
MAKE CHECKS PAYABLE TO: GSA 2004 GeoVentures

Fees and Payment: $2,700 for GSA student members, $2,800 for nonmembers. $200 deposit is due with your reservation and is refundable (less $75) through November 1. Balance is due November 1. *Firm* minimum number of participants: 12, maximum: 36. **Included:** International airfare (Miami, Florida to Buenos Aires), flights within Argentina, all ground transportation, meals, hotels, campground and park entrance fees. **Not included:** Airfare to and from Miami, camping equipment (tent and sleeping bag), alcoholic beverages, optional side excursions, personal expenditures, and any other expenses not specifically included in the itinerary. Academic credit for this adventure is available through Brevard College for an extra charge.

For more information, contact Edna Collis at GSA at ecollis@geosociety.org or Jim Reynolds at reynoljh@brevard.edu.

For complete details on GeoVentures or for full itineraries, contact Edna Collis, Program Officer, 1-800-472-1988, ext. 1034, fax 303-357-1072, ecollis@geosociety.org. Participants must be 18 or older and in good health. Any physical condition requiring special attention, diet, or treatment must be reported in writing when reservations are made. We'll do our best to accommodate special needs, including dietary requirements and physical disabilities. Deposits and payments are refundable less a processing fee, up to the cutoff date. Termination by an individual during a trip in progress for any reason will not result in a refund, and no refund will be made for unused parts of trips.

CORRECTION

GSA Annual Meeting Field Trip #1 begins and ends in Grand Junction, Colorado. This information was left off of the announcement in the June issue of *GSA Today*.

PREMEETING FIELD TRIP

1. Navajo Sand Sea of Near-Equatorial Pangea: Tropical Westerlies, Slumps, and Giant Stromatolites [401]

Tues.–Sat., Nov. 2–6. Cosponsored by *GSA Sedimentary Geology Division*. David Loope, Dept. of Geosciences, University of Nebraska, Lincoln, NE 68508, (402) 472-2647, fax 402-472-4917, dloope1@unl.edu; Len Eisenberg; Erik Waiss. Max.: 15; min.: 10. Cost: $475 (5L, R, 4ON, vans). *Begins and ends in Grand Junction, Colorado.*

Up-close and personal, full-day inspections of two spectacular Navajo Sandstone outcrops form the core of this trip. One outcrop lies on the Utah/Arizona border along the west edge of the Paria Plateau, and the other is near the crest of the Waterpocket Fold in Capitol Reef National Park. Emphasis will be on cyclic crossbedding, trace fossils, giant stromatolites, mass flows, and paleowind reconstructions.

Register for the 2004 GSA Annual Meeting at www.geosociety.org.

Ads (or cancellations) must reach the GSA Advertising office one month prior. Contact Advertising Department, (303) 357-1053, 1-800-472-1988, ext. 1053, fax 303-357-1070, acrawford@geosociety.org. Please include address, phone number, and e-mail address with all correspondence.

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live link: add $25		

Positions Open

ASSISTANT/ASSOCIATE PROFESSOR-RESEARCH (HYDROLOGY)

The Louisiana Geological Survey–Louisiana State University invites applications for a research faculty position in hydrogeology at Assistant or Associate Professor—Research level. Research will be focused on Louisiana groundwater in terms of a variety of physical or chemical issues as the applicant selects as well as a variety of larger projects that will involve other members of the Geological Survey. **Required Qualifications:** Ph.D. in Hydrogeology or in a related field of geosciences from an accredited institution before application; understanding of aquifer systems in terms of an aquifer's properties that impact water movement at field scales; proven experience in successful grantwriting at the local and national level in one or more aspects of hydrogeology, interactions with diverse constituents and stakeholders, and a strong academic record. **Additional Qualifications Desired:** familiar with creation of groundwater models in the sense of knowing what geologic, hydraulic, hydrogeologic parameters are necessary for model creation and understand the limitations of models; familiar with creating and interpreting geologic maps and cross-sections; working knowledge of applying GIS to geologic/hydrogeologic research. **Special Requirements:** field research projects require travel to various locations, over a few days at a time; other travel as necessary and assigned by the LGS Director. The applicant will be expected to present research results at appropriate conferences and to submit papers in appropriate journals or Geological Survey publications. Salary and rank will be determined based on qualifications and experience.

Application review will begin immediately and will continue until July 30, 2004, or until candidate is selected. Applicants should send a full resume (including e-mail address), a one-page statement outlining short-term and long-term visions of research while at the Geological Survey, and contact information for three references to: Search Committee, Louisiana Geological Survey, Rm. 3079, Energy, Coast, and Environment Building, Louisiana State University, Ref: #026171, Baton Rouge, LA 70803.

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TECHNICIAN, GEOLOGY DEPARTMENT
POMONA COLLEGE

Seeking a full time technician, preferably with a degree in earth sciences. Aptitude for mechanical and computing tasks, and attention to the safe use and care of equipment and facilities, is vital. Contact: Dr. Eric Grosfils 909-621-8673. Salary: $30,000. Full job description and requirements available at: http://www.geology.pomona.edu.

NATIONAL SCIENCE FOUNDATION
DIVISION OF EARTH SCIENCES

The National Science Foundation's Division of Earth Sciences is seeking qualified applicants for three Program Director positions in the following programs:

The ***Geophysics Program*** supports laboratory, field, theoretical, and computational studies related to composition, structure, and processes of the earth's interior.

The ***Petrology and Geochemistry Program*** supports studies that explore the nature, origin, and temporal evolution of the solid Earth's crust, mantle, and core.

The ***Hydrologic Sciences Program*** supports research in the continental water processes and global water balance. It is interactive on a wide range of space and time scales with the ocean, atmospheric, solid earth, and plant and animal sciences.

Appointment to any of these positions may be made on a permanent or temporary basis. Temporary appointments can be made either as one or two-year Visiting Scientist, or as a Federal Temporary employee, with a salary range of $85,210 to $132,791. Alternative temporary appointments may be filled under the terms of the Intergovernmental Personnel Act (IPA). Individuals that wish to be considered for permanent and temporary appointments should apply separately in both categories.

Applicants for each of these positions must have a Ph.D. or equivalent experience in one of the disciplinary fields covered by the program. In addition, 6 or more years of research or research management experience beyond the Ph.D. is required.

For the ***Geophysics Program,*** applicants interested in a permanent position may see announcement E20040081. Applicants interested in a Visiting Scientist, IPA, or Federal Temporary appointment may see announcement E20040083-Rotator.

For the ***Petrology and Geochemistry Program,*** applicants interested in a permanent position may see announcement E20040086. Applicants interested in a Visiting Scientist, IPA, or Federal Temporary appointment may see announcement E20040084-Rotator.

For the ***Hydrologic Sciences Program,*** applicants interested in a permanent position may see announcement E20040082. Applicants interested in a Visiting Scientist, IPA, or Federal Temporary appointment may see announcement E20040085-Rotator.

All announcements, with position requirements and application procedures, are located on the NSF Home Page at www.nsf.gov/jobs. Applicants may also obtain the announcements by contacting Maria Sutton at 703-292-4364. Hearing-impaired individuals should call TDD at 703-292-8044. Applications must be received by August 23, 2004.

UNIVERSITY OF NEVADA LAS VEGAS
TERTIARY AND MODERN CLASTIC BASIN FILL

The Department of Geoscience at the University of Nevada Las Vegas seeks a post-doctoral scholar for a 2-year appointment dealing with Tertiary and modern clastic basin fill in parts of Clark County, Nevada commencing fall 2004. The successful candidate will have the opportunity to develop aspects of the research project, which will be coordinated with, and compliment, an aggregate minerals assessment being jointly conducted with the USGS and the Nevada Bureau of Mines and Geology. As such, the position presents a great opportunity to establish and carry out research that draws upon the candidates' strengths, interests, and background. Applicants with a Ph.D. from an accredited college or university in sedimentology/stratigraphy, aggregate studies/economic geology, or other relevant backgrounds will be given preference. Review of applications will commence on June 25, 2004.

The successful candidate must have their Ph.D. completed prior to start date. Position contingent upon funding. Salary will be commensurate with qualifications and experience. Please send a cover letter, resume, and relevant information (i.e., name, phone number, email and physical addresses) for three reference providers to: Dr. Andrew Hanson at andrewh@unlv.nevada.edu. For more information, see the UNLV World Wide Web site at: http://www.unlv.edu. Information regarding the Geoscience department may be found at http://geoscience.unlv.edu. Women and minority post-docs are encouraged to apply. UNLV is an equal opportunity / affirmative action employer committed to achieving excellence through diversity.

Department of Geosciences
PRINCETON UNIVERSITY

DEI SVB NVMINE VIGET

The Department of Geosciences at Princeton University is seeking applications for a new tenure-track faculty position in the areas of solid-earth geophysics or geochemistry. We anticipate hiring at the assistant professor level, although candidates at a higher rank may be considered under exceptional circumstances. We are particularly interested in outstanding individuals who will interact with and complement existing research programs in global seismology, mineral physics, the physics of earthquakes, and structural geology (see our website at http://geoweb.princeton.edu). Examples of appropriate research areas include, but are not limited to, computational dynamics of the mantle and/or lithosphere, crustal deformation and active tectonics, physical or chemical evolution of the Earth or terrestrial planets, mantle petrology, earthquake seismology, and mineral or rock physics.

Applicants should send a curriculum vitae, including a publication list, a statement of research and teaching interests, and contact information for three references to: Search Committee, Department of Geosciences, Guyot Hall, Princeton University, Princeton, NJ 08544. The starting date is flexible, ranging up to September 2006. Evaluation of applications will begin immediately; interviews of candidates will begin in September 2004 and continue until the position is filled. Princeton University is an Affirmative Action Equal Opportunity Employer; women and members of minority groups are encouraged to apply. For general information about applying to Princeton and how to self-identify, please link to http://web.princeton.edu/sites/dof/ApplicantsInfo.htm.

Opportunities for Students

Ph.D. Students Wanted. Program in Infrastructure and Environmental Systems. University of North Carolina—Charlotte. The interdisciplinary program in **Infrastructure and Environmental Systems** at UNC Charlotte is accepting applications for PhD students for the 2004–2005 academic year. Full funding, including out-of-state tuition waivers, is available. Areas of student research include: biogeochemistry, applied climatology, coastal processes, contaminant transport, engineering geology, environmental geology, fluvial processes, geochemistry, geotechnical engineering, surface and groundwater hydrology, landfill design, tropical meteorology, mineralogy, Quaternary geology, sedimentology, stratigraphy, site remediation, slope stability, soil geomorphology, structural geology, surficial processes, vadose zone processes, waste containment in soils, watershed analysis and numerical weather prediction. Students have access to extensive field and analytical equipment and facilities including IC, ICPMS, XRD, XRF, GPR, grain size analysis and GIS laboratories. We are located in the beautiful Piedmont of North Carolina within easy access to pristine beaches and to the Blue Ridge Mountains of North and South Carolina. Application deadline: 7/15/04 or until positions are filled. For more information contact jadiemer@email.uncc.edu or visit http://www.uncc.edu/gradmiss/inesindex.html.

Memorial Volumes and Reprints

"One of Gabriel's first jobs was consultation on the construction of the Caracas-Maiquetia highway. He had mapped the Venezuelan Coast Ranges through which the highway passed. During construction of the first tunnel, Gabriel told the engineers that they would eventually reach serpentine and that without shoring, the tunnel would probably collapse. The serpentine was reached where he predicted, and he was praised as a great geologist. But the engineers took no special precautions, and the tunnel collapsed. Now they called Gabriel 'the greatest geologist in Venezuela' because of the accuracy of his predictions. They tunneled on and Gabriel told them they would intersect another serpentine body. Again the engineers reached the serpentine, and again the tunnel collapsed. Now Gabriel was not only the greatest geologist in Venezuela, he was 'the greatest geologist in the world.' But, as Gabriel, with his wry humor, observed years later, 'They never did pay any attention to me!'"

—Excerpted from Memorial to Gabriel Dengo (1922–1999)
by John James Prucha and James E. Case, *Memorials*, v. 33, p. 14.

GSA publishes memorials to deceased Fellows and offers them as individual reprints or in an annual volume. Written by associates, friends, or relatives, *Memorials* contains fascinating stories and selected bibliographies of the deceased.

Individual reprints are available free of charge. Contact GSA Sales and Service, gsaservice@geosociety.org, or call 1-888-443-4472 or (303) 357-1000, option 3. You may also fax a request to 303-357-1071 or mail one to GSA Sales and Service, P.O. Box 9140, Boulder, CO 80301-9140, USA. The paperback volumes are available for purchase, either through the GSA Bookstore, www.geosociety.org, or through GSA Sales and Service.

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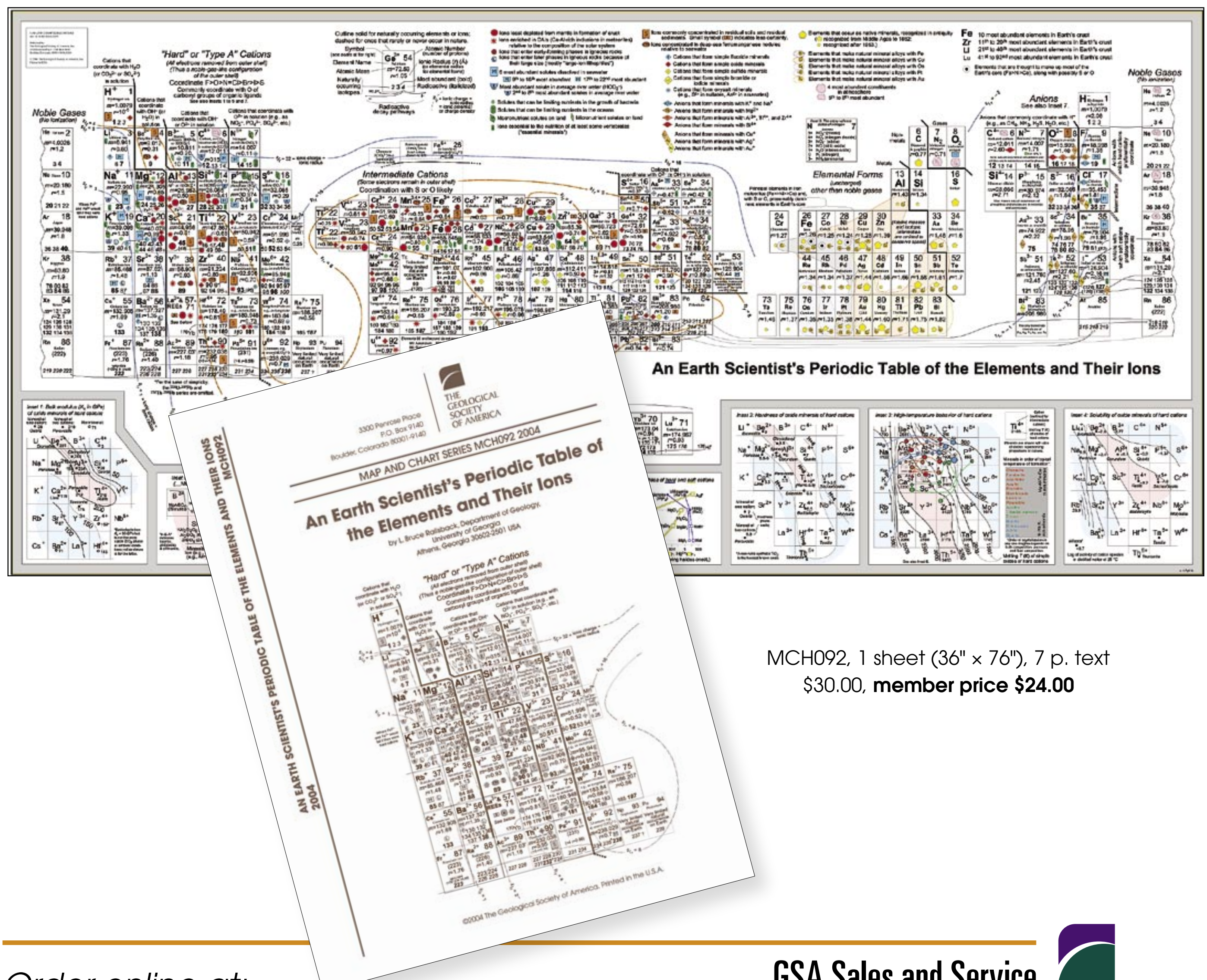
An Earth Scientist's Periodic Table of the Elements and Their Ions

by L. Bruce Railsback

An Earth Scientist's Periodic Table of the Elements and Their Ions is a new periodic table designed to contextualize trends in geochemistry, mineralogy, aqueous chemistry, and other natural sciences. First published as an insert in the September 2003 issue of *Geology*, this version is updated and supersized—36" by 76"!

This new periodic table of the elements is more useful to earth scientists than the conventional periodic table used by chemists. The periodic table presented here acknowledges that most natural matter occurs in charged form as ions rather than in elemental form. The immediate result is a completely rearranged table in which many elements appear multiple times, because many elements assume different charge under different natural conditions. The practical result is that many trends in mineralogy, seawater chemistry, soil chemistry, the chemistry of Earth's crust and mantle, the chemistry of sediments, and nutrient chemistry become apparent in ways that are not recognizable on conventional, elementally constructed, periodic tables.



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