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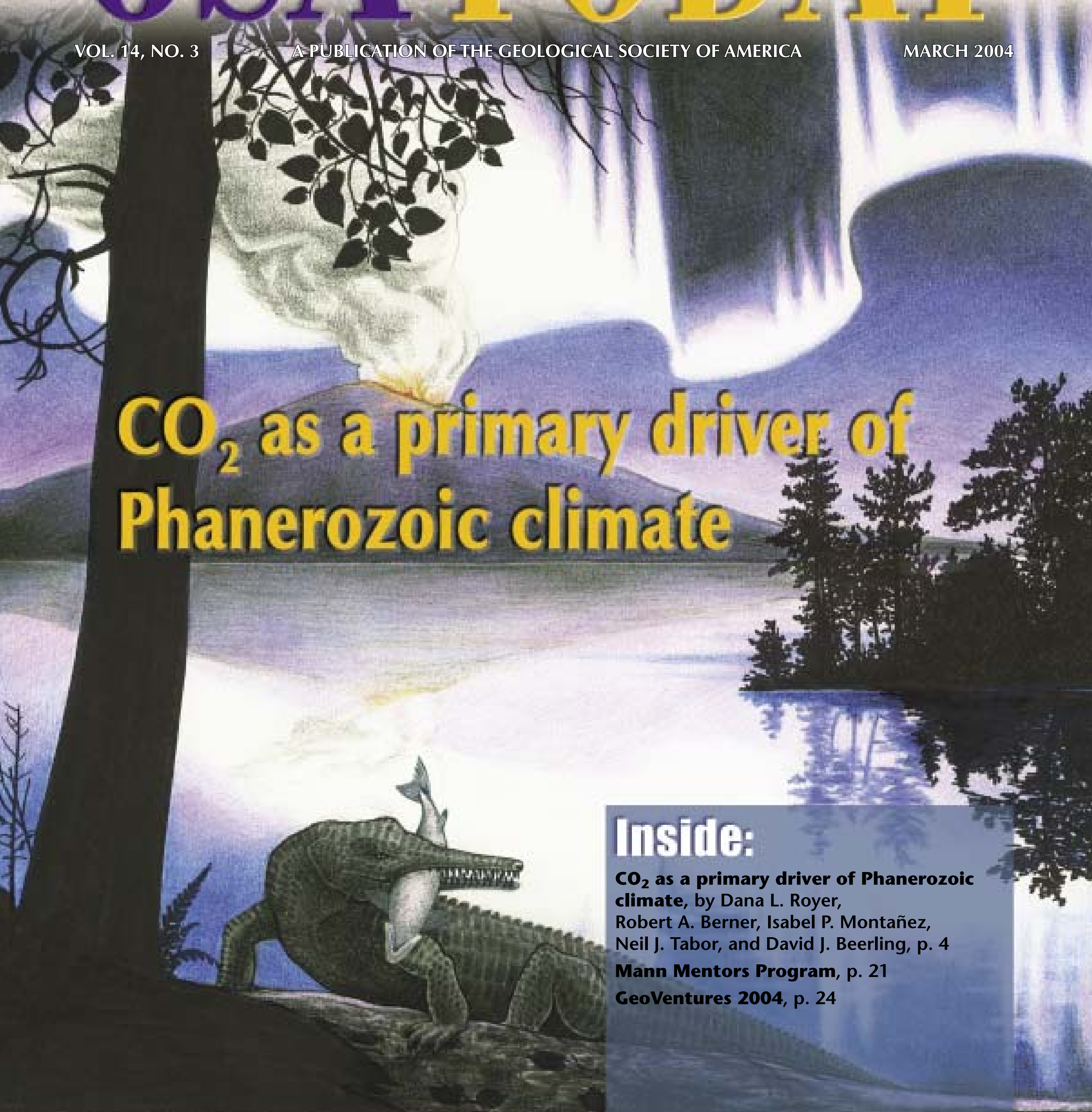

CO_2 as a primary driver of Phanerozoic climate

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Cover: A polar, circum-Pacific landscape from the early Late Cretaceous (Turonian, ca. 90 Ma). An early-autumn aurora borealis casts a blue glow on the landscape, which includes an active volcano. A champsosaur is visible catching its freshwater prey against a backdrop of representative angiosperms, conifers, and cycads. Geologic evidence suggests that the Turonian was a time of globally warm temperatures and elevated levels of atmospheric CO_2. Art by Rebecca Horwitt. See "CO_2 as a primary driver of Phanerozoic climate," by Royer et al., p.4–10.

SCIENCE ARTICLE

CO_2 as a primary driver of Phanerozoic climate

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ABSTRACT

Recent studies have purported to show a closer correspondence between reconstructed Phanerozoic records of cosmic ray flux and temperature than between CO_2 and temperature. The role of the greenhouse gas CO_2 in controlling global temperatures has therefore been questioned. Here we review the geologic records of CO_2 and glaciations and find that CO_2 was low (<500 ppm) during periods of long-lived and widespread continental glaciations and high (>1000 ppm) during other, warmer periods. The CO_2 record is likely robust because independent proxy records are highly correlated with CO_2 predictions from geochemical models. The Phanerozoic sea surface temperature record as inferred from shallow marine carbonate $\delta^{18}O$ values has been used to quantitatively test the importance of potential climate forcings, but it fails several first-order tests relative to more well-established paleoclimatic indicators: both the early Paleozoic and Mesozoic are calculated to have been too cold for too long. We explore the possible influence of seawater pH on the $\delta^{18}O$ record and find that a pH-corrected record matches the glacial record much better. Periodic fluctuations in the cosmic ray flux may be of some climatic significance, but are likely of second-order importance on a multimillion-year timescale.

INTRODUCTION

Atmospheric CO_2 is an important greenhouse gas, and because of its short residence time (~4 yr) and numerous sources and sinks, it has the potential to regulate climate over a vast range of timescales, from years to millions of years. For example, the 30% rise in atmospheric CO_2 concentrations over the past 100 years has been accompanied by significant global warming (Mann et al., 1999, 2003). Most studies incorporating all known climate forcings implicate CO_2 as the primary driver for this most recent rise in global temperatures (Mann et al., 1998; Crowley, 2000; Mitchell et al., 2001). At the longer timescale of glacial-interglacial cycles (10^5 yr), a tight correlation between CO_2 and polar temperatures has long been established (Barnola et al., 1987; Petit et al., 1999). Although debated for many years, it is clear that CO_2 acted as either a climate driver or an important amplifier (Shackleton, 2000). For pre-Quaternary climates, ice core records do not exist, but a multitude of CO_2 proxies and models have been developed. As with the Recent (10^1 yr) and Quaternary (10^5 yr) records, a close correspondence between CO_2 and temperature has generally been found for the Phanerozoic (e.g., Crowley and Berner, 2001). Taken together, CO_2 appears to be an important driver of climate at all timescales.

The role of CO_2 in regulating climate over Phanerozoic timescales has recently been questioned using $\delta^{18}O$ records of shallow marine carbonate (Veizer et al., 2000) and modeled patterns of cosmic ray fluxes (Shaviv and Veizer, 2003). The low-latitude $\delta^{18}O$ compilation (Veizer et al., 1999, 2000), taken to reflect surface water temperatures, is decoupled from the CO_2 record and instead more closely correlates with the cosmic ray flux data. If correct, cosmic rays, ostensibly acting through variations in cloud albedo, may be more important than CO_2 in regulating Phanerozoic climate.

Here we scrutinize the pre-Quaternary records of CO_2, temperature, and cosmic ray flux in an attempt to resolve current discrepancies. We first compare proxy reconstructions and model predictions of CO_2 to gauge how securely we understand the major patterns of Phanerozoic CO_2. Using this record of CO_2 and Ca concentrations in Phanerozoic seawater, we then modify the $\delta^{18}O$ record of Veizer et al. (1999, 2000) to account for the effects of seawater pH. This modified $\delta^{18}O$ record is then compared to records of continental glaciations and cosmic ray fluxes.

COMPARISON OF PROXY CO_2 RECORDS TO GEOCARB MODEL RESULTS

Multiple geochemical models of atmospheric CO_2 evolution have been developed in recent years; the most complete models track the exchange of carbon between buried organic and inorganic sedimentary carbon and the atmosphere plus oceans (Berner, 1991; Tajika, 1998; Berner and Kothavala, 2001; Wallmann, 2001; Kashiwagi and Shikazono, 2003). The CO_2 predictions from these models are highly convergent; for the purposes of this study, we will use GEOCARB III (Berner and Kothavala, 2001), which predicts CO_2 over the whole Phanerozoic in 10 m.y. time-steps. The GEOCARB model (Berner, 2004) is based on quantifying over time the uptake of CO_2 during weathering of Ca and Mg silicates and its release during the weathering of sedimentary organic matter. Also considered is the burial of carbonates and organic matter in sediments and the fluxes

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of CO_2 to the atmosphere and oceans from the thermal decomposition of carbonates and organic matter at depth. Weathering fluxes are modified over time as changes occur in global temperature, continental size, position and relief, and land plant colonization. This includes incorporating solar radiation, due to the slow stellar evolution of the sun, and the CO_2 greenhouse effect in general circulation model (GCM) calculations of global mean surface temperature and river runoff. Volcanic degassing is guided by the abundance of volcanics, seafloor spreading rates, and the carbonate content of subducting oceanic crust.

The paleo-CO_2 results of Rothman (2002) and U. Berner and Streif (2001), presented by Shaviv and Veizer (2003) as additional models, are in fact not based on carbon cycle modeling, but constitute an extension of the $\delta^{13}C$ plankton CO_2 proxy (see below). These authors apply $\Delta^{13}C$, the difference between the $\delta^{13}C$ of bulk organic matter and carbonates (Hayes et al., 1999), to directly calculate paleo-CO_2. However, bulk organic matter can include non-photosynthetic compounds as well as terrestrial material derived from rivers, and the original method was based strictly on marine photosynthetic compounds (Freeman and Hayes, 1992; cf. Royer et al., 2001a). In addition, changes in $\Delta^{13}C$ over time can be due to changes in seawater temperature (Rau et al., 1989) or O_2 concentrations (Beerling et al., 2002), and not only atmospheric CO_2.

Four proxies for pre-Quaternary CO_2 levels have been developed over the past 15 years (consult Royer et al. [2001a] for further details).

1. The $\delta^{13}C$ of pedogenic minerals (calcium carbonate [Cerling, 1991] or goethite [Yapp and Poths, 1992]). The carbonate in certain pedogenic minerals is formed from biologically and atmospherically derived soil CO_2. Because these two components differ in their carbon isotopic compositions, the concentration of atmospheric CO_2 (pCO_2) can be estimated assuming some knowledge of the biologically derived pCO_2 in the soil, and the $\delta^{13}C$ of the atmospheric and biologic constituents. Reliable pedogenic minerals are available back to the Devonian, and the range of errors is comparably small at high CO_2. Some disadvantages of this proxy include comparably high errors at low CO_2, and the difficulty of extracting organic carbon from the paleosols that contain these minerals.

2. The $\delta^{13}C$ of phytoplankton (Freeman and Hayes, 1992; Pagani et al., 1999). Most phytoplankton exert little or no active control on the CO_2 entering their cells. Because of this, the $\Delta^{13}C$ between seawater CO_2 and phytoplankton photosynthate is affected by seawater pCO_2 and can thus be used as a CO_2 proxy. High resolution CO_2 records are obtainable from appropriate marine sediment cores, but factors such as cell geometry and growth rate, which also influence the $\delta^{13}C$ of phytoplankton, must be carefully considered.

3. The stomatal distribution in the leaves of C_3 plants (Van der Burgh et al., 1993; McElwain and Chaloner, 1995). Unlike phytoplankton, most higher land plants have pores that enable them to control the flux of CO_2 entering their leaves. Because the proportion of these stomatal pores to all the cells on the leaf epidermis inversely relates to pCO_2, information on the ancient CO_2 content of the atmosphere can be extracted using fossil plants. High resolution, high precision CO_2 records are possible, but because the stomatal response to CO_2 is species-specific, care must be exercised in pre-Cretaceous material.

4. The $\delta^{11}B$ of planktonic foraminifera (Pearson and Palmer, 2000). The relative proportions of the two dominant species of boron in seawater are partially pH-dependent. Because these two species differ in their isotopic compositions, pCO_2 information can be retrieved from carbonate tests containing trace amounts of boron. As with the phytoplankton proxy, high resolution CO_2 records are possible, but only after vital effects and the influence of the total alkalinity and $\delta^{11}B$ of the ocean are removed.

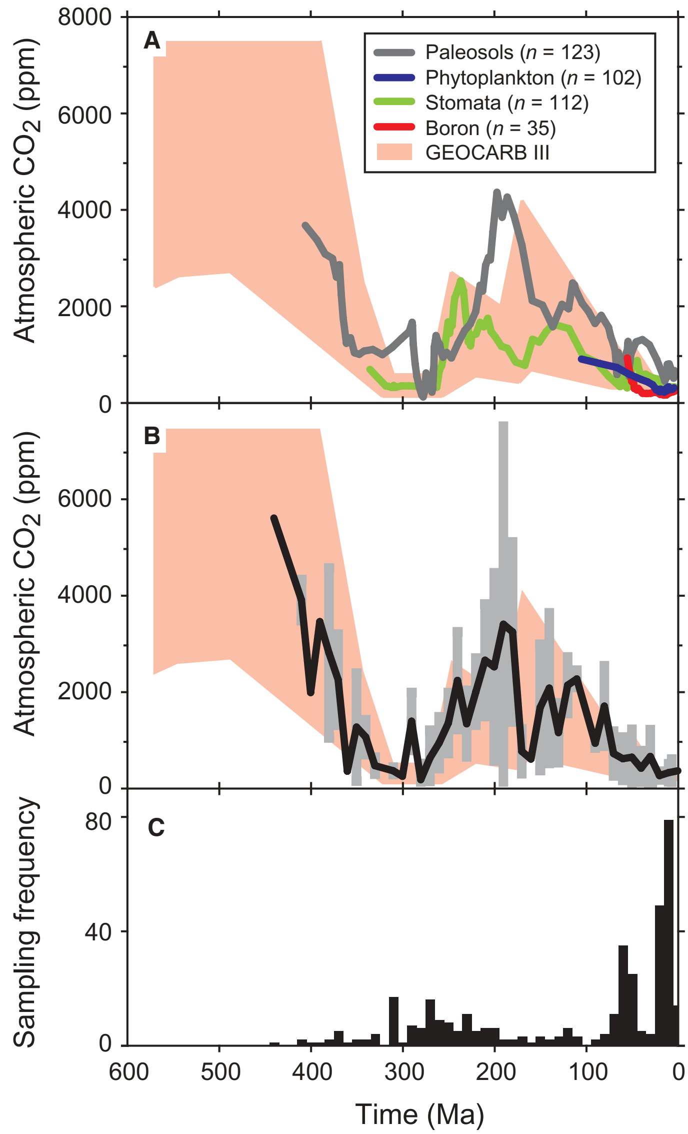

Figure 1. Details of CO_2 proxy data set used in this study. **A:** Five-point running averages of individual proxies (see footnote 1). Range in error of GEOCARB III model also shown for comparison. **B:** Combined atmospheric CO_2 concentration record as determined from multiple proxies in (A). Black curve represents average values in 10 m.y. time-steps. Gray boxes are standard deviations ($\pm 1\sigma$) for each time-step. **C:** Frequency distribution of CO_2 data set, expressed in 10 m.y. time-steps. All data are calibrated to the timescale of Harland et al. (1990).

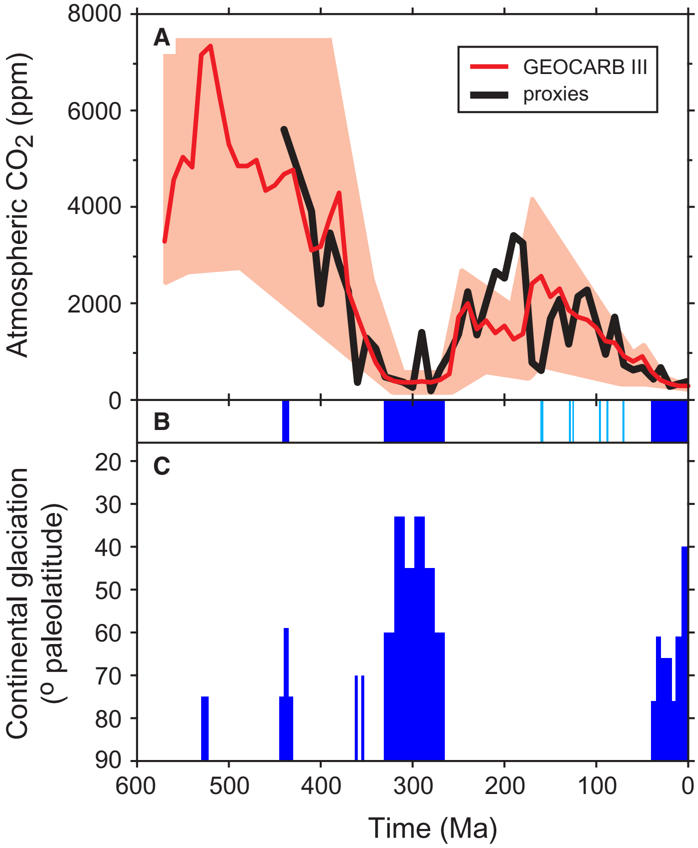

Figure 2. CO_2 and climate. **A:** Comparison of model predictions (GEOCARB III; Berner and Kothavala, 2001) and proxy reconstructions of CO_2. 10 m.y. time-steps are used in both curves. Shaded area represents range of error for model predictions. **B:** Intervals of glacial (dark blue) or cool climates (light blue; see text). **C:** Latitudinal distribution of direct glacial evidence (tillites, striated bedrock, etc.) throughout the Phanerozoic (Crowley, 1998).

Here we have compiled 372 published observations of paleoatmospheric CO_2 (Figs. 1A-B; see GSA Data Repository[1]). The most well-represented intervals are the late Carboniferous to Triassic (315–205 Ma) and Cenozoic (past 65 m.y.) (Fig. 1C). This proxy record differs from previously published compilations (e.g., Crowley and Berner, 2001; Royer et al., 2001a) most significantly in that the Permo-Carboniferous CO_2 estimates of Ekart et al. (1999) have been revised downward based on a higher resolution, more comprehensive data set. In addition, the Paleogene CO_2 estimates of Pearson and Palmer (2000) have also been lowered (Demicco et al., 2003), which reduces the previously large disparities among CO_2 proxies at this time (Fig. 1A; cf. Royer et al., 2001b). The various proxies are in general agreement for the Phanerozoic; the moderate mismatches during the early Mesozoic are likely due to sparse coverage (Fig. 1).

In order to compare the proxy record to the model output, the raw proxy data were combined and averaged into 10 m.y. time-steps. The combination of CO_2 data from different techniques maximizes the statistical power of the resulting data set. Because the various methods produce similar estimates of CO_2 over multimillion-year timescales (Fig. 1A), method-dependent biases are not significant. The binning of the proxy data into 10 m.y. time-steps reduces their ability to discern short-term events, but makes for the fairest comparison to the GEOCARB output. The resulting proxy-based curve is highly correlated with the "best-guess" predictions of GEOCARB III (Fig. 2A; $r = 0.71$; $P = 0.0002$)[2], indicating that the multimillion-year scale patterns are a reasonable approximation of the overall trend of Phanerozoic CO_2.

COMPARISON OF CO_2 RECORDS TO PHANEROZOIC CLIMATE

The rock record of glacial deposits offers the most conservative approach for reconstructing Phanerozoic climate. It is difficult to envision globally warm climates coexisting with long-lived, widespread continental ice masses, particularly when the ice reached mid-latitudes. The Phanerozoic record of tillites and other direct evidences for glaciation (compiled by Crowley [1998]) is shown in Fig. 2C. It is important to note that the length of the late Ordovician glaciation has been revised downward from 35 m.y. as reported by Frakes et al. (1992) and adopted by Veizer et al. (2000) and Shaviv and Veizer (2003) to <15 m.y. (Brenchley et al., 1994; Crowell, 1999; Pope and Steffen, 2003). The CO_2 record compares predictably with the glacial record, with low values (<500 ppm) during periods of intense and long-lived glaciation (Permo-Carboniferous [330–260 Ma] and late Cenozoic [past 30 m.y.]) and high values (>1000 ppm) at all other times. The late Ordovician (~440 Ma) represents the only interval during which glacial conditions apparently coexisted with a CO_2-rich atmosphere. Critically, though, widespread ice sheets likely lasted <1 m.y. (Brenchley et al., 1994, 2003; Sutcliffe et al., 2000). Given the coarse temporal resolution of the GEOCARB model (10 m.y.) and poor proxy coverage across this interval (Fig. 1C), it is perhaps unsurprising that a short-lived drop in CO_2 has not yet been captured. Moreover, geochemical evidence is consistent with a late Ordovician CO_2-drawdown (Kump et al., 1999), suggesting that CO_2 and temperature did in fact remain coupled. Further work, however, is needed to more clearly decipher this important period.

The traditional view of a uniformly warm Mesozoic has been increasingly questioned. For example, Frakes et al. (1992) consider the middle Jurassic to early Cretaceous (~183–105 Ma) a "cool mode." If correct, these purported cool climates must be reconciled with the high reconstructed CO_2 levels (Fig. 2A). While a cool mode designation is useful for differentiating it from a uniformly warm mode, this has the unfortunate side-effect of conflating it with other classic cool modes, such as the Permo-Carboniferous and late Cenozoic. Critically, the climate mode of the middle Jurassic to early

[1]GSA Data Repository Item 2004041, compilation of Phanerozoic CO_2 records, is available on request from Documents Secretary, GSA, P.O. Box 9140, Boulder, CO 80301-9140, USA, editing@geosociety.org, or at www.geosociety.org/pubs/ft2004.htm.

[2]The correlation coefficient, r, was calculated by correlating the first differences of the two series ($y_t - \rho y_{t-1}$), where ρ is the lag-one autocorrelation coefficient. The significance test, P, was calculated using the actual series, but with the degrees of freedom (n) modified by: $n' = n(1 - \rho_1\rho_2)/(1 + \rho_1\rho_2)$. Bins represented by ≤3 proxy observations were not included in the analyses

Cretaceous is fundamentally different from the Permo-Carboniferous and late Cenozoic. The existence of productive polar forests during much of the Mesozoic (e.g., Vakhrameev, 1991; Huber et al., 2000) is incompatible with the long-lived ice caps that characterize true glacial periods. Indirect evidence for seasonal or alpine ice exists, but these intervals were likely brief "cold snaps" within an otherwise warm Mesozoic (e.g., Price, 1999). Moreover, indirect evidence such as ice-rafted debris should be treated cautiously, as such deposits are found in every Phanerozoic Period except the Triassic (Frakes et al., 1992).

The best indirect evidence for Mesozoic ice combines sea-level considerations with oxygen isotope and strontium content records (Stoll and Schrag, 1996, 2000; Dromart et al., 2003; Lécuyer et al., 2003; Miller et al., 2003). These studies corroborate the notion of brief icy intervals (<2 m.y.; see light blue bands in Fig. 2B) within a globally warm Mesozoic. The possible presence of brief cold snaps should therefore not be used as a sole criterion for a cool mode: It is increasingly being recognized that globally warm climates previously considered stable are in fact quite dynamic (e.g., mid-Cretaceous: Wilson and Norris [2001]; Eocene: Wade and Kroon [2002]; Holocene: Indermühle et al. [1999]). For example, although the Turonian (~90 Ma) is one of the best-documented intervals of extreme global warmth in Earth's history (Wilson et al., 2002; Bice et al., 2003), it is straddled by two of the proposed icy intervals (Fig. 2B). This entire "cool-warm-cool" sequence lies within the late Cretaceous to early Tertiary "warm mode" of Frakes et al. (1992).

Regardless of semantics, the important issue is determining the forcings responsible for global climate change. To this end, Dromart et al. (2003) reported evidence for a temporary drawdown in atmospheric CO_2 across the 160 Ma icy event. If correct, a CO_2-driven reverse greenhouse effect appears responsible for this brief cool period. The proxy record of CO_2 not only records a local CO_2 minimum during this event, providing independent support for the findings of Dromart et al. (2003), but also during the other five proposed icy events (Fig. 2, A and B). These brief perturbations in the carbon cycle are likely not resolvable with GEOCARB because of the model's coarse time resolution. As with the bulk of the Phanerozoic, a coupling between CO_2 and temperature appears strong for the Mesozoic Era.

THE EFFECT OF SEAWATER pH ON THE $\delta^{18}O$ OF MARINE CARBONATE

The rock record of glacial deposits can only be qualitatively compared to other records of climate, such as CO_2. It is within this context that the low-latitude paleotemperature data of Veizer et al. (2000) and Shaviv and Veizer (2003), based on the shallow-marine $\delta^{18}O$ carbonate record of Veizer et al. (1999; Fig. 3A), is so appealing. These data are compiled from a range of taxa, including belemnites, brachiopods, conodonts, and foraminfera. The most well-represented intervals are the middle Paleozoic (445–285 Ma), late Jurassic (165–145 Ma) and Cenozoic (Fig. 3B). The signal:noise ratio in this data set can be assessed by comparing the proportion of the plotted standard deviations (1σ; Fig. 3A) to the total range in values (11.2‰). These proportions range from 0.02 to 0.29 (median = 0.10). For comparison, in the CO_2 proxy data set, proportions range from 0.01 to 0.36 (median = 0.11; total range = 5354 ppm; data point at 190 Ma excluded). The oxygen isotope and CO_2 curves are therefore comparable in terms of their signal:noise ratios.

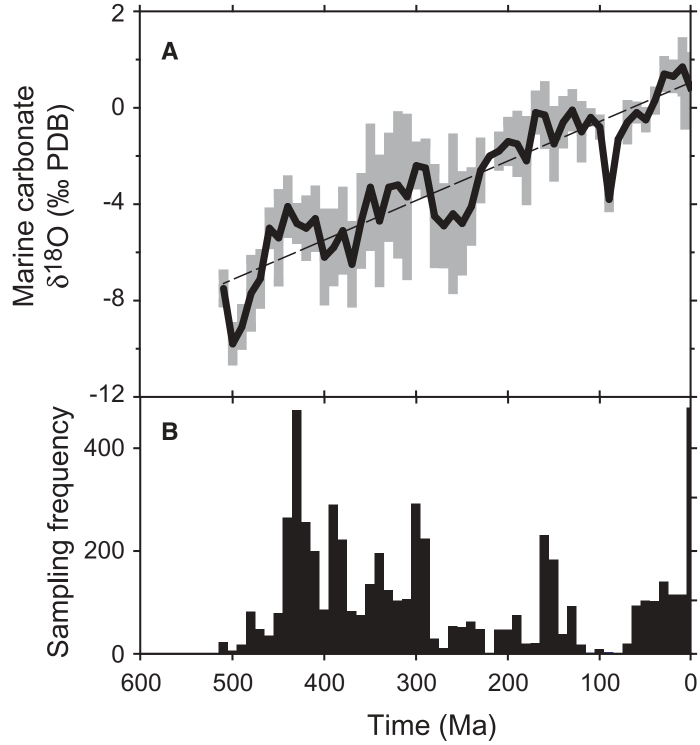

Figure 3. Details of $\delta^{18}O$ data set used in this study. **A:** Low-latitude, shallow-marine $\delta^{18}O$ carbonate record of Veizer et al. (1999). The statistical parameters represented by the black curve and gray boxes are as in Fig. 1B. Dashed line represents linear regression of data points composing black curve. **B:** Frequency distribution of $\delta^{18}O$ data set, expressed in 10 m.y. time-steps. All data are calibrated to the timescale of Harland et al. (1990).

After detrending the secular 8‰ shift in $\delta^{18}O$ across the Phanerozoic (Veizer et al., 2000; Fig. 3A), however, the resulting paleotemperature curve fails two first-order tests with the more robust glacial deposit record: the Ordovician-Silurian and Mesozoic intervals are too cold for too long. The oxygen isotope record suggests a 50 m.y. cool interval of equivalent severity to the Permo-Carboniferous and late Cenozoic between 450 and 400 Ma, but other climate indicators only support a 15 m.y. long intermittent cool phase at this time (Crowell, 1999; Pope and Steffen, 2003), with widespread glaciation likely lasting <1 m.y. (Brenchley et al., 1994, 2003; Sutcliffe et al., 2000). During the Mesozoic, oxygen isotopes suggest another 100 m.y. cool interval of similar severity (220–120 Ma), but, as discussed above, independent evidence for a long-lived glaciation at this time is completely lacking. Other factors must therefore influence the $\delta^{18}O$ of marine calcite such as alteration during diagenesis (Schrag et al., 1995). Here we explore an additional possible bias of $\delta^{18}O$-derived temperatures due to the carbonate ion effect on oxygen isotope incorporation in carbonates controlled by temporal changes in the pH of seawater (Zeebe, 1999).

Zeebe (2001) derived the expression:

$$\Delta T_{pH} = b\, s\, \Delta pH \quad (1)$$

where:

ΔpH = pH at present – pH at some past time;
ΔT_{pH} = correction for change in "temperature" due to the effect of change in pH on $\delta^{18}O$ of carbonates ($\Delta T = T$ at present – T in past);
b = coefficient of the linear term of the $\delta^{18}O$ paleotemperature equation (b = –4.80 °C per ‰); and
s = slope of $\delta^{18}O$ versus pH from theory and experiments (s = –1.42 ‰ per unit pH).

For a surficial ocean which, over time, is saturated with $CaCO_3$ (or at constant supersaturation—see below) and equilibrated with atmospheric CO_2, for the reactions:

$$CO_2 + H_2O \leftrightarrow 2H^+ + CO_3^{--}$$

and

$$CaCO_3 \leftrightarrow Ca^{++} + CO_3^{--}$$

we have the equilibrium expressions

$$[H^+]^2\,[CO_3^{--}]\,/\,pCO_2 = K_oK_1K_2 \quad (2)$$

and

$$[Ca^{++}]\,[CO_3^{--}] = K_{sp} \quad (3),$$

where the brackets represent activities, pCO_2 the partial pressure of CO_2 in the atmosphere and K_0, K_1, K_2 and K_{sp} are, respectively, the constants for solubility equilibrium of CO_2, the first and second dissociations of carbonic acid and the solubility of calcium carbonate. Combining (2) and (3) and taking common logarithms:

$$2 \log [H^+] - \log pCO_2 - \log [Ca^{++}] = \log (K_oK_1K_2/K_{sp}) \quad (4).$$

For a past time (t) and the present (0), using the definition of pH = –log [H$^+$] and assuming that the equilibrium constants do not change appreciably with time due to minor temperature changes:

$$2\,pH(0) - 2\,pH(t) - \log [pCO_2(t)/pCO_2(0)] - \log [(Ca)(t)/(Ca)(0)] = 0 \quad (5)$$

Introducing the definitions

$$RCO_2 = pCO_2(t)/pCO_2(0) \quad (6)$$

and

$$\Delta pH = pH(0) - pH(t) \quad (7)$$

we obtain

$$\Delta pH = 0.5\,\{\log RCO_2 + \log [(Ca)(t)/(Ca)(0)]\} \quad (8),$$

where RCO_2 is the ratio of mass of atmospheric CO_2 at a past time to that for the pre-industrial present (280 ppm), and (Ca) is the mean concentration of dissolved calcium in seawater.

It is assumed that the ratios of Ca concentrations in seawater at time (t) and the present (0) are essentially the same as the ratios of their activities, which is reasonable for small changes in temperature and chemical composition or salinity.

In actuality, the surficial oceans, where those carbonates analyzed for oxygen isotopes formed, were probably supersaturated with respect to both calcite and aragonite as at present. If the oceans remained at the same degree of supersaturation over time, cancellation of the terms involving the equilibrium constants of equation (4) for the past and present would still be justified. However, the value $\Omega = [Ca^{++}][CO_3^{--}]/K_{sp}$ for calcite may have varied over time from past values of 2–4 to the present value of 6 (Demicco et al., 2003). To consider this variation, equation (8) based on equation (4) is modified to:

$$\Delta pH = 0.5\,\{\log RCO_2 + \log [(Ca)(t)/(Ca)(0)] + \log (\Omega(0)/\Omega(t))\} \quad (9).$$

Here we assume that values of $\Omega(0)/\Omega(t)$ for "calcite seas" (500–330 Ma, 180–60 Ma) were equal to 2 and for aragonite seas (550–500 Ma, 330–180 Ma, 60–0 Ma) were equal to 1 (Demicco et al, 2003).

Finally, to obtain the correction for the false "temperature" change due to a change in pH we obtain from expressions (1) and (8) upon substituting the values for b and s in (1):

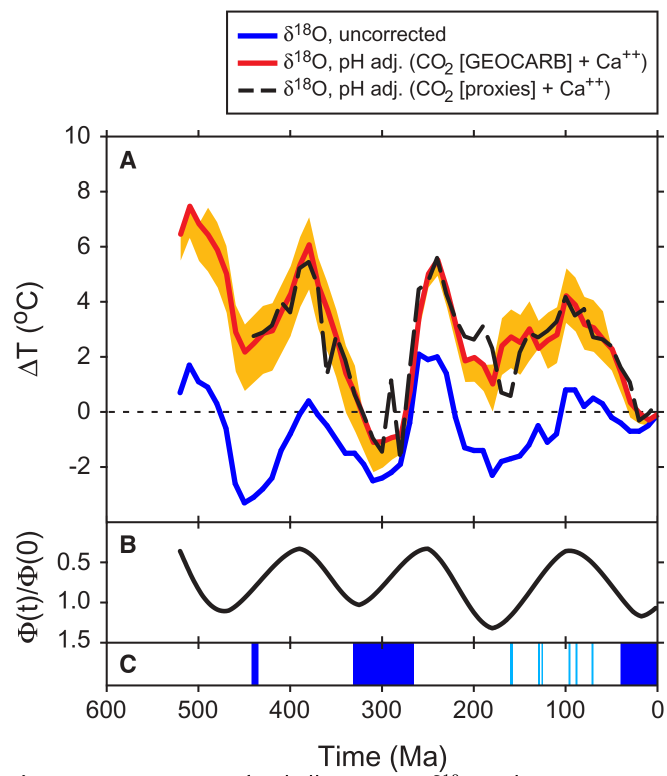

Figure 4. pH-correction for shallow-marine $\delta^{18}O$ carbonate curve. **A:** The blue curve corresponds to temperature deviations relative to today calculated by Shaviv and Veizer (2003) from the "10/50" $\delta^{18}O$ compilation presented in Veizer et al. (2000), where the original data (Veizer et al., 1999) were detrended and then averaged in 10 m.y. time-steps using a 50 m.y. moving window. In the two remaining curves, data from the blue curve have been adjusted for pH effects due to changes in seawater Ca^{++} concentration (after Horita et al., 2002), and CO_2 based either on GEOCARB III or proxies. A sensitivity analysis was performed on the GEOCARB + Ca^{++} curve by holding Ca^{++} levels constant (lower bound of orange band), or by allowing the saturation state of $CaCO_3$ in the ocean to vary through time (Ω; upper bound; see text for details). **B:** Cosmic ray flux (relative to the present day) as reconstructed by Shaviv (2002). **C:** Intervals of glacial and cool climates, as in Fig. 2B.

$$\Delta T_{pH} = 3.4\{\log RCO_2 + \log[(Ca)(t)/(Ca)(0)]\} \quad (10),$$

or alternatively:

$$\Delta T_{pH} = 3.4\{\log RCO_2 + \log[(Ca)(t)/(Ca)(0)] + \log(\Omega(0)/\Omega(t)\} \quad (11).$$

These are the expressions that can be applied to correcting inferred paleotemperatures, based on carbonate $\delta^{18}O$ values, for changes in pH of the oceans due to changes in the CO_2 level of the atmosphere and changes in Ca concentrations and calcium carbonate saturation state in seawater.

Based on the CO_2 data from GEOCARB III and proxies (Fig. 2A), plus data for paleo-concentrations of Ca in seawater (Horita et al., 2002; Lowenstein et al., 2003), equations (10) and (11) have been used to calculate pH corrections that can be applied to the low-latitude ΔT data of Veizer et al. (2000) and Shaviv and Veizer (2003). (Alternative use of the Horita vs. the Lowenstein data leads to almost indistinguishable differences in results.) A comparison of the original Veizer ΔT curve with pH-corrected ΔT curves is shown in Fig. 4A. The corrected curves incorporate changes in pH due to changes in CO_2 alone (constant Ca^{++} concentration), changes in Ca^{++} and CO_2 using GEOCARB and proxy CO_2 data, and inclusion of the additional term for changes in $CaCO_3$ saturation state. (Calculated ΔpH values for the Eocene of 0.3–0.4 are in the middle of the range 0.1–0.7 calculated via the boron isotope paleo-pH method by Pearson and Palmer [2000].)

The corrected curves record, on average, higher past temperatures than that at present, which is in accord with paleoclimatological observations, especially for the Mesozoic (Vakhrameev, 1991; Huber et al., 2000, 2002). The original uncorrected Veizer curve and the cosmic ray flux curve record too cold a Phanerozoic past (Fig. 4). Also, the large coolings of the uncorrected curve for the Ordovician-Silurian (480–400 Ma) and the Triassic-Cretaceous (220–100 Ma) that correlate with intense cosmic ray fluxes, are, with corrections for pH, only lesser coolings superimposed on generally warm periods (Fig. 4). The cosmic ray fluxes and the uncorrected ΔT curve predict long-lived and extensive glaciations during these time periods but there were none, except for a very short glaciation lasting at most a few million years at the end of the Ordovician (Fig. 4C). By contrast, the corrected Veizer curves predict the two major glaciations correctly. These are during the two times when low latitude temperature was about the same as, or less than, that at present: the Permo-Carboniferous glaciation (centered around 300 Ma) and the late Cenozoic glaciation (past 30 m.y.).

CONCLUSIONS

We conclude the following from these considerations.

1. Proxy estimates of paleo-CO_2 agree, within modeling errors, with GEOCARB model results.

2. There is a good correlation between low levels of atmospheric CO_2 and the presence of well-documented, long-lived, and aerially extensive continental glaciations.

3. The uncorrected Veizer temperature curve predicts long periods of intense global cooling that do not agree with independent observations of paleoclimate, especially during the Mesozoic. When corrected for pH effects, however, the temperature curve matches the glacial record much better.

4. The global temperatures inferred from the cosmic ray flux model of Shaviv and Veizer (2003) do *not* correlate in amplitude with the temperatures recorded by Veizer et al. (2000) when corrected for past changes in oceanic pH. Additional problems with this correction have been shown by Rahmstaff et al.(2004). Changes in cosmic ray flux may affect climate but they are not the dominant climate driver on a multimillion-year time scale.

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Call for Nominations:

Thirteenth Annual Biggs Award

for Excellence in Earth Science Teaching for Beginning Professors

The Biggs Award was established by GSA to reward and encourage teaching excellence in beginning professors of earth science at the college level.

Eligibility

Earth science instructors and faculty from all academic institutions engaged in undergraduate education who have been teaching full-time for 10 years or fewer. (Part-time teaching is not counted in the 10 years.)

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An award of $750 is made possible as a result of support from the Donald and Carolyn Biggs Fund (maintained by the GSA Foundation), the GSA Geoscience Education Division, and GSA's Education and Outreach Programs. In addition, this award also includes up to $500 in travel funds to attend the award presentation at the GSA Annual Meeting.

Deadline and Nomination Information

Nomination forms for the 2004 Biggs Earth Science Teaching Award are posted at www.geosociety.org/aboutus/awards/biggs.htm. Or, contact Diane Lorenz, (303) 357-1028, dlorenz@geosociety.org. Nominations must be received by May 1, 2004.

Mail nomination packets to:

Diane Lorenz
Program Officer, Grants, Awards, and Medals
GSA
P.O. Box 9140
Boulder, CO 80301-9140

UPCOMING DEADLINES

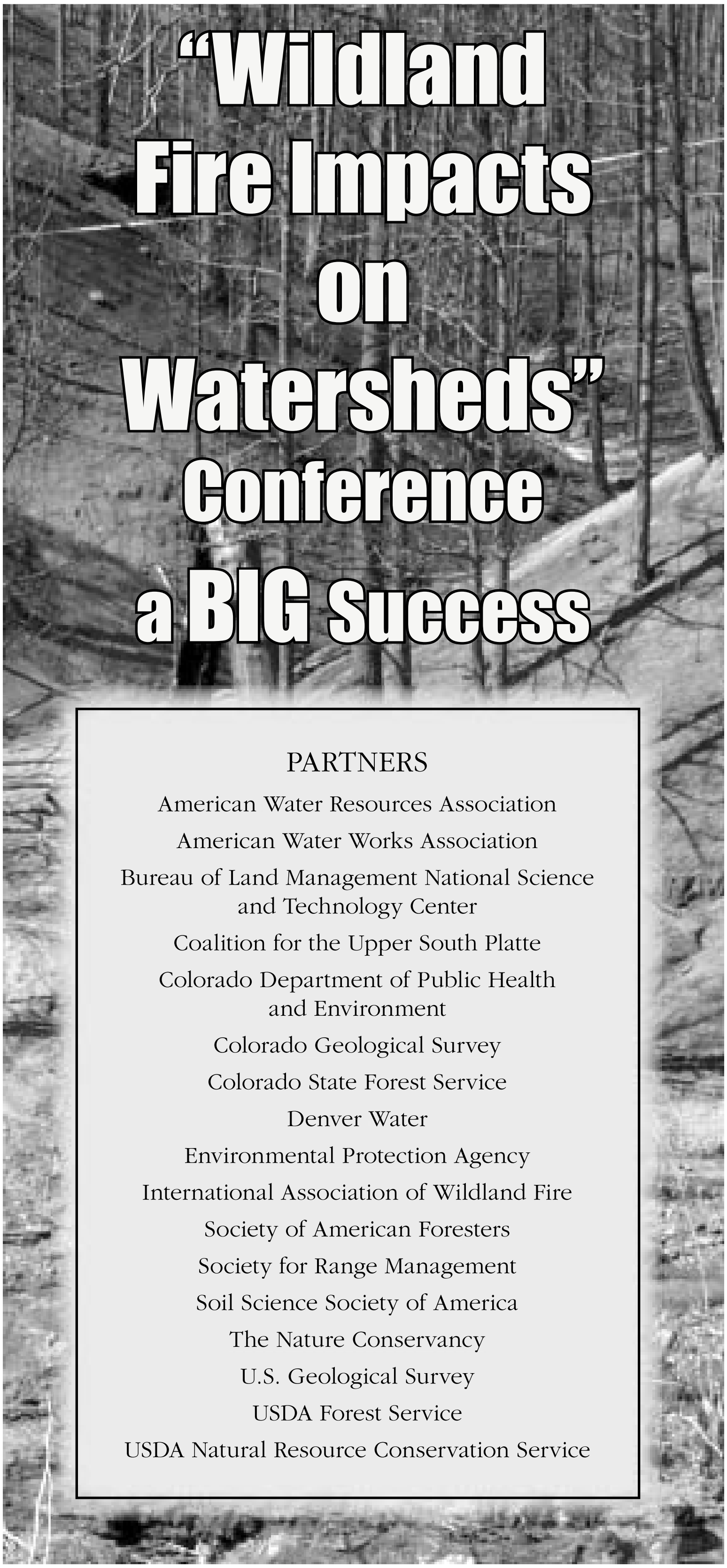
Nominations for the **John C. Frye Environmental Geology Award*** are due March 31, 2004. Nominations for the following national awards are due April 30, 2004: **William T. Pecora Award, National Medal of Science, Vannevar Bush Award,** and **Alan T. Waterman Award.** Details and nomination procedures for these awards are posted at http://www.geosociety.org/aboutus/awards/. You may also contact Diane Lorenz, (303) 357-1028, awards@geosociety.org, Grants, Awards, and Medals, P.O. Box 9140, Boulder, CO 80301-9140, or see the October 2003 issue of *GSA Today*.

For details on the following awards, see the January 2004 issue of *GSA Today* or visit www.geosociety.org/sectdiv/divisions.htm.

- **Don J. Easterbrook Distinguished Scientist Award,*** Quaternary Geology and Geomorphology Division: Nominations due by April 1, 2004, to Ellen Wohl, ellenw@cnr.colostate.edu, Colorado State University, Dept. of Earth Resources, Fort Collins, CO 80523-1482.
- **Farouk El-Baz Award for Desert Research**,* Quaternary Geology and Geomorphology Division: Nominations due by April 1, 2004, to Alan Gillespie, alan@ess.washington.edu, Dept. of Earth & Space Sciences, PO Box 351310, University of Washington, WA 98195-1310.

*Funds supporting these awards are administered by the GSA Foundation.

"Wildland Fire Impacts on Watersheds" Conference a BIG Success



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Hayman, CO, July 5, 2002 — A mud slide occurred just off HW 67 in the Hayman Fire burn area. Photo by Michael Rieger/FEMA News Photo.

Ann Cairns, *Director, GSA Communications*

GSA is actively committed to moving geoscience information and expertise into the hands of those who need it. Last October, the Society offered a knowledge-transfer specialty conference, "Wildland Fire Impacts on Watersheds," in Denver, Colorado. Nearly 200 resource managers and fire mitigation specialists from around the world joined geoscientists in exploring the geomorphological consequences of wildland fire.

The conference evolved from a topical session at GSA's 2002 Annual Meeting. "Geomorphic Impacts of Wildfire" drew 46 volunteered papers, resulting in two oral sessions and one poster session. Session organizers Sue Cannon and Deborah Martin of the U.S. Geological Survey and Charlie Luce of the USDA Forest Service met with GSA staff at the meeting. All agreed the leading-edge information presented would be valuable for those who deal with the aftermath of wildland fire. But significant questions remained: Who, specifically, are those people? What information, exactly, do they need? And how do we reach them?

Identifying the Audience

A partial answer to those questions came to Diane Matt, GSA's director of strategic partnerships, in conversation with Carl Norbeck of the Water Quality Control Division, Colorado Department of Public Health and Environment. "It was right after the catastrophic Hayman fire in Colorado," said Matt. "Carl told me that people were calling CDPHE and saying, 'The water running into the treatment plant looks like chocolate milk. What do we do?'"

Thus was born a context for knowledge transfer on soil erosion, debris flows, flooding, degraded water quality, and other impacts of wildland fire on watersheds.

Cannon, Luce, Martin, and Matt began networking in earnest. An extensive community of water, wildlife, and other resource specialists, geoscientists, land managers, and fire management planners revealed itself in the process. A technical program committee was formed with members from federal, state, and local governments, associations, and other not-for-profit organizations.

Who Attended?

Conference participants came from the United States, British Columbia, and Australia. Virtually all had background in some aspect of the natural sciences (i.e., biology, forestry, hydrology, geology, and chemistry).

A number of participants held high-level positions, including national program managers for the USDA Forest Service and the Bureau of Land Management

PARTICIPANT FEEDBACK

"I will use the information to improve current and future fire fuels research."

"I now better understand the entire framework in which managers have to deal with fire."

"I'm currently working on rehabilitation of a burned area. Most of the information shared at the conference will be used in this effort."

"Excellent! Probably one of the most stimulating and interesting conferences I have attended."

Burned Area Emergency Rehabilitation program. Other attendees were specialists in land and other resource management. A combination of professionals who work with immediate after-effects of wildland fire and specialists in long-term rehabilitation further diversified the group.

Presentations, Discussion Groups, and a Day in the Field

Scientific content began with foundational work on how different geological terranes respond after a fire. Broad geological, geomorphological, and fire-related topics followed, such as burn severity and vulnerability to erosion. From there, specific elements of vulnerability, erosional styles, and mitigation strategies were addressed.

Conference format was varied. It included invited speakers in technical sessions and smaller breakout groups that encouraged informal discussion and networking.

Paul Perkins of the Centre for Resource and Environmental Studies, Australian National University, delivered the conference keynote address. He shared very recent experience of the devastating 2002 Australian bushfires and their impact on watersheds.

Day three of the conference was spent in the field. Participants visited recent burn areas in Colorado, viewing research plots where long-term mitigation strategies are under study. Discussion ranged from viewing soils and watersheds as protectable resources, to determining the best type of mulch for minimizing post-fire erosion until vegetation grows back.

What GSA Learned

Conference participants weren't the only ones who received an education. This was GSA's first meeting for a completely new audience. Much was learned about the importance of partnering. Building relationships with organizations that serve and routinely communicate with the target audience made for relevant, valuable content. Those organizations also provided the means for effectively promoting the conference.

Participant feedback was very favorable. Attendees expressed strong interest in holding another meeting in a couple of years, and GSA is taking the suggestion into consideration.

More to Follow

GSA plans to continue offering meetings that transfer geoscience knowledge to professionals who need that knowledge in their work. Members are encouraged to offer suggestions for topics and supporting rationale to Director of Strategic Partnerships Diane Matt (dmatt@geosociety.org), or to Annual Program Committee Chair Barbara Tewksbury (btewksbu@hamilton.edu).

FUNDING & ADDITIONAL SUPPORT

Colorado Department of Public Health and Environment (through a grant from the U.S. Environmental Protection Agency)

Denver Water

Rite in the Rain

Society of American Foresters

Joint Fire Science Program

U.S. Environmental Protection Agency

Comment and Reply
An alternative Earth, Warren B. Hamilton, GSA Today, v. 13, no. 11, p. 4–12.

Comment

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Since 1988, Warren Hamilton has crusaded against the widespread acceptance of uniformitarianism in the Archean and raised some valid concerns; most notably that Archean crust shows many significant differences to post–2.0 Ga crust formed in plate subduction-accretion zones (Hamilton *in* Reed et al., 1993; Hamilton, 1998). But his "Alternative Earth" model (Hamilton, 2003), in which he states that "Plate tectonics did not operate within preserved Archean crust," or " before 2.0 Ga," and that "Plumes do not exist," mirrors the 1980s Earth evolution models based on the first description of a ca. 2.0 Ga Wilson cycle in the Wopmay orogen (Hoffman, 1980) and is based on selective criteria that ignores a wealth of compelling multidisciplinary geological evidence in support of Archean plate tectonics (e.g., Friend et al., 1988; Calvert et al., 1995; White et al., 2003) and mantle plumes (e.g., Lawver and Muller, 1994; Wolfe et al., 1997; Bijwaard and Spakman, 1999). Geological processes operative over the 2 G.yr. Archean Era (4.5–2.5 Ga) were diverse (Van Kranendonk, 2004, and references therein) and included impact tectonics (Glikson, 2001), non-uniformitarian tectonics including the *local* partial convective overturn of crust (Collins et al., 1998) and possibly the mantle (Davies, 1995), *and* plate tectonics that was probably characterized by shallow subduction in its early stages (pre–3.3 Ga: Smithies et al., 2003) and evolved to steeper subduction from ca. 3.1 Ga (Smithies et al., 2004). No one can argue that secular processes have not affected the Earth, even over the past 2 G.yr., and it is the relationship between the range of tectonic processes that has changed over time. Perhaps it is now Hamilton who needs to adopt a broader view.

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Reply

***Warren B. Hamilton**, Department of Geophysics, Colorado School of Mines, Golden, Colorado, 80401, USA*

doi: 10.1130/1052-5173(2004)014<14:AAER>2.0.CO;2

Martin Van Kranendonk (to whom I am indebted for a superb Pilbara field trip) and Kevin Cassidy have much company in arguing that plate tectonics operated during Archean time. Archean plate rationales satisfy uniformitarian assumptions but appeal to processes that left no clear field evidence. No one has demonstrated that trailing-edge stratal sequences were deposited on sundered cratons, which were then rotated and recombined with accretionary and oceanic debris caught in sutures, or that magmatic arcs, thrust belts or crustal thrusts, or other products of plate convergence and collision were developed. When I began looking at Archean geology, I expected to find some semblance (hotter, smaller, faster?) of the products of Phanerozoic plate tectonics with which I had long worked in western North America, Eurasia, and Indonesia, and surrounding regions—but no semblance is there.

Plumes from deep mantle? All tectonic, petrologic, geochemical, and modeling rationales are circular and are only made more complex and ad hoc as their assumptions and predictions are disproved. Tomography? Even advocates Wolfe et al. (2002) claimed to see a plume down only to 400 km, which is not at issue. Bijwaard and Spakman (1999) presented an eye-catching cross section in the only place in a poorly constrained model where continuity, however irregular, could be depicted, saturated it with colors that made small deep "anomalies" look like large upper-mantle ones, and truncated it at both ends to omit "plumes" under flanking cratons. Supposed plume images claimed for finite-frequency tomography also are suspect.

I reaffirm my message. Subtract bad and weak assumptions, add multidisciplinary data, and Earth's evolution and behavior can be read as startlingly different from the standard model.

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Comment

Andrew Glikson, *Research School of Earth Science, Australian National University, Canberra, A.C.T. 0200, Australia, Andrew.glikson@anu.edu.au*

Reply

Warren B. Hamilton, *Department of Geophysics, Colorado School of Mines, Golden, Colorado 80401, USA, whamilto@mines.edu*

The Geological Society of America

2003 OEST Award Recipients Named

The following 2003 Outstanding Earth Science Teacher (OEST) award recipients were announced in December 2003.

SECTION WINNERS

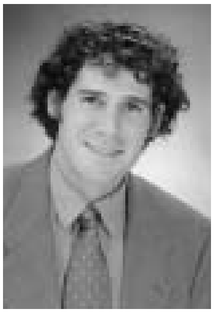
Glenn Dolphin
Shelly F. Snyder
Craig Wolter
Shawn E. Doan
Rita Grusemeyer
Christine Henry
Michael Milburn
Joan Hacken Carter

STATE WINNERS

Bernard Picklo
Deano Smith
Mary Sue Burns
Glenn Dolphin
Kevin Leineweber
Christine Henry
Robert Nicholson
Craig Wolter
Chris Lock
Donna Petty

The OEST Award, recognized by the National Association of Geoscience Teachers (NAGT), is given out to pre-college teachers who have made exceptional contributions to the stimulation of interest in the earth sciences and who are outstanding teachers. Each NAGT section selects a section winner. Sections may also have state winners.
For more information on this award and NAGT, please visit www.nagt.org/awards.html.

This award, administered by GSA, gives section recipients $500 in travel money to attend a GSA meeting. Winners can also apply for up to $500 for classroom supplies. The award also includes a certificate and a complimentary membership in GSA (three years for section recipients and one year for state recipients).
For more information on the administration of these awards, please visit www.geosociety.org/aboutus/awards/oest.htm.



Final Report: 2002–2003 Congressional Science Fellow

Raphael D. Sagarin, *2002–2003 GSA–U.S. Geological Survey Congressional Science Fellow*

My fellowship year was spent in the office of Congresswoman Hilda L. Solis, representing the 32nd district of California. Congresswoman Solis is a second-term Democrat with political views that put her at the far left of the current congressional spectrum. While previous fellows have chosen to work in more powerful and more politically moderate offices, such as that of Senator Joe Lieberman, my choice to work in this untested office was made for a number of reasons, and I am happy to recommend this office to future fellows. Some background on the congresswoman will help justify my position.

Congresswoman Solis is the daughter of Mexican immigrants who raised her in the district she now represents. The 32nd district is largely made up of low-income Hispanic and Asian recent immigrants. The congresswoman served in the California Legislature for 8 years before she was encouraged to run for a seat in the U.S. House of Representatives against an incumbent Democrat in her district. She won both her general elections by a wide margin. As a Latina with strong loyalty to the Democratic Party and strong support of unions and recent immigrants, Congresswoman Solis is being watched closely by Democratic Party leadership. This was most clearly illustrated by her selection to serve on the powerful Energy and Commerce Committee at the beginning of her second term, an almost unprecedented achievement. Moreover, on that committee, she was entrusted to serve as the ranking member (highest ranking member from the Democratic Party) of the Subcommittee on Environment and Hazardous Materials.

What do all these political considerations have to do with earth sciences? As it turns out, quite a bit. As is often the case in areas of poverty, Congresswoman Solis' district is marked by some of the worst environmental degradation in the country, including poor air quality, lack of open space, and groundwater that is characterized as a Superfund site due to industrial contamination. Looming environmental problems in the district include heavy perchlorate contamination related to rocket fuel production, contamination from the gasoline additive MTBE, and failure to comply with Total Maximum Daily Load (TMDL) limits set by the Clean Water Act. In this regard, Congresswoman Solis' rise to the ranks of the Energy and Commerce Committee is extremely important. Her subcommittee has jurisdiction over Superfund issues, leaking underground storage tanks, and the Clean Drinking Water Act.

During the year I spent with Congresswoman Solis, we worked on trying to provide more money for cleanup of MTBE and developing new regulations to prevent future spills. This money has been tied to passage of the comprehensive energy bill, which is still stalled in Congress as of this writing. Some of our modest proposals, such as requiring installation of secondary containment for underground storage tanks at the time when they are replaced, were stalled by objections from private interests, such as representatives of the convenience store operators. On the issue of perchlorate, we were also frustrated by attempts to exempt the military—by far the largest producer of perchlorate waste—from federal environmental laws.

Our one success on the environmental front was seeing the passage of Congresswoman Solis' San Gabriel River Watershed Study Act. This act would require the Secretary of Interior to study the San Gabriel River Watershed for inclusion in the federal system of National Parks, scenic trails, historic sites, recreation areas or other designation. Although a modest step, the congresswoman was very excited about passage of this law because her district has less than one-half acre of open space for every 1,000 people, making it one of the most urbanized areas of the country.

Even on issues where the congresswoman did not have a leadership role, such as global climate change, her interest in maintaining a strong environmental record and being informed on environmental issues gave me the opportunity to keep close watch on developments. During my year in Washington, no firm commitments to reduce greenhouse gases were proposed by the White House. However, a major climate change science initiative known as the Climate Change Science Program (CCSP) was introduced for discussion at a conference attended by thousands of scientists from across the spectrum of the earth sciences. The initiative was also reviewed by the National Academies, whose initial report echoed the concerns of many scientists I conferred with: that the initiative lacked clear goals or timetables, left out vital areas of research, and most important, was severely underfunded. Although the funding issue will be ongoing, a revision of the CCSP that begins to address the criticisms was recently released.

At the same time, meaningful progress in reducing greenhouse gas emissions was stalled and in many cases, reversed. Efforts to mandate increases in Corporate Average Fuel Efficiency (CAFE) standards for light trucks and cars were repeatedly defeated while tax breaks for the largest sport utility vehicles were increased to $100,000. I was especially disappointed that the Environmental Protection Agency's draft report on the state of the environment completely left out global climate change (despite including other global issues such as ozone depletion) under pressure from the White House.

As a congressional science fellow, I had the unique opportunity to witness these events near the source. I sat on committee hearings and in behind-closed-doors negotiations, and I directly questioned representatives from executive agencies on matters related to regulations, policy proposals, and budgets. I learned that science rarely carries the day in policy decisions. I saw that well-researched, empirically derived figures, such as the rate of spread of an MTBE plume or the extent of perchlorate contamination in western groundwater, mean little when put up against the lobbying power of industry groups or political pressure from party leaders. This could leave a scientist in a cynical state, but I see it as justification to continue sending scientists to work on the Hill and serve as policy advisors. I believe that relative to other professions, scientists have barely made inroads into the political process. Although a number of professional societies support congressional science fellows, there are still far more congressional offices that do not have a scientist on staff than those that do.

I felt that in this regard, working for a new congresswoman was especially important, as it made her comfortable with the idea of having a scientist on staff. If there is a change in party control, she will have the most power of any congressperson when it comes to issues of vital concern to earth scientists. I trust that she will turn to a scientist and consider their advice carefully when she is forced to make a decision between data and politics.

This manuscript is submitted for publication by Raphael Sagarin, 2002–2003 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.

2004 GSA Section Meetings

South-Central Section

March 15–16, 2004

Texas A&M University, College Station, Texas

Information: Christopher Mathewson, Texas A&M University, Department of Geology & Geophysics, 3115 TAMU, College Station, TX 77843-3115, (979) 845-2488, mathewson@geo.tamu.edu

Northeastern–Southeastern Sections Joint Meeting

March 25–27, 2004

Hilton McLean Tysons Corner, Washington, D.C.

Information: George Stephens, George Washington University, Department of Earth & Environmental Sciences, 2029 G St., NW, Washington, D.C. 20052-0001, (202) 994-6189, geoice@gwu.edu; Rick Diecchio, George Mason University, Department of Environmental Science & Policy, MS 572, 4400 University Dr., Fairfax, VA 22030-4444, (703) 993-1208, rdiecchi@gmu.edu

North-Central Section

April 1–2, 2004

Millennium Hotel, St. Louis, Missouri

Information: Joachim O. Dorsch, Saint Louis University, Department of Earth & Atmospheric Science, 3507 Laclede Ave., St. Louis, MO 63103-2010, (314) 977-3124, dorsch@eas.slu.edu

Rocky Mountain–Cordilleran Sections Joint Meeting

May 3–5, 2004

Boise Centre on the Grove, Boise, Idaho

Information: C.J. Northrup, Boise State University, Department of Geosciences, 1910 University Dr., Boise, ID 83725, (208) 426-1009, cjnorth@boisestate.edu

www.geosociety.org/sectdiv/sections.htm

Students:
Mark your Calendars!

Shlemon Mentor Programs for 2004

Students: If you have career-related questions, plan to attend a Shlemon Mentor Program at a 2004 GSA Section Meeting to chat one-on-one with practicing geoscientists. These volunteers will answer your questions and share insights about how to get a job after graduation. When programs are scheduled for multiple days, each day's program will offer a different set of mentors. These programs are made possible by the Roy J. Shlemon Fund, administered by the GSA Foundation.

FREE LUNCHES will be served (to students only) at the following Shlemon Mentor Programs at the spring GSA Section Meetings. Stop by the GSA registration desk to get the location of the luncheon.

South-Central Section Meeting

Mon. and Tues., March 15–16
11:30 a.m.–1 p.m.
College Station, Texas

Northeastern–Southeastern Sections Joint Meeting

Thurs. and Fri., March 25–26
11:30 a.m.–1 p.m.
Tysons Corner, Washington, D.C.

North-Central Section Meeting

Mon. and Tues. April 1–2
11:30 a.m.–1 p.m.
St. Louis, Missouri

Cordilleran–Rocky Mountain Sections Joint Meeting

Mon. and Tues., May 3–4
11:30 a.m.–1 p.m.
Boise, Idaho

Students will receive a **FREE LUNCH** ticket along with their registration badge to attend each Shlemon Program. However, space is limited. First come, first served.

2004–2005 Congressional Science Fellow Report

***Michèle Koppes**, 2003–2004 GSA–U.S. Geological Survey Congressional Science Fellow*

Greetings from Washington, D.C., the self-designated center of All Things Important. Before arriving here, I was told by those who had come before me that my life would become "all political, all the time." Little did I know what that meant. A few months into the Congressional Science Fellowship, I now have a much clearer idea. Every article I read in the morning newspaper plays out in some fashion in the day's work on Capitol Hill. All conversations, be they at a bus stop, in a bar, or in a meeting on the Hill make reference in some way to one's political affiliation and opinions. Coming from the realm of science and academia, where everyone is most careful to remain as objective as possible, declaring one's biases on all issues at the start of any conversation is quite a culture shock.

Another shocking aspect of my transition to the congressional work life has been the dynamic change in pace from the deliberative, almost plodding, approach of academic research to frenetic decisions made with scant data and relying on a heavy dose of intuition in Congress. Adapting to life on Capitol Hill can only be described as trial by fire. Staffers are definitely here for the passion and commitment to civil service and public interest, and most definitely not here for the money or a humdrum existence. The turnover of congressional staff is remarkably quick, and common is the perception that one month should be long enough for a new person to be deemed the "institutional memory" of the establishment. The turnover of legislative issues is even more rapid. Given the flux of information flowing across my desk, I have quickly learned that institutional memory is the ability to read as quickly as possible and remember the phone numbers of the right people to call at the right time.

My institutional memory bank started with a three-week orientation from the American Association for the Advancement of Science for the 33 congressional fellows in the program. Following a tremendous course in the role of Congress, the executive branch, lobbyists, and the media in driving the federal government, and shedding all preconceived notions of the value and use of science in policy decisions, my fellow Fellows and I embarked on a year-long study of the federal policy process. We pounded the pavement to find an office in which we could both learn about the legislative process and contribute in some small way as science advisors to the policymakers.

I have chosen to join the office of Congressman Jay Inslee, a Democrat from the 1st District in Washington State. Having spent the past six years in Seattle and being familiar with the issues and general opinions of the people of "the other Washington," I feel an affinity with my current office. Representative Inslee is an active member of the House Resources Committee, is ranking member of the Forest and Forest Health Subcommittee, and is familiar with many natural resource issues. I joined Rep. Inslee's office as his legislative assistant for resources and education, where my background as an earth scientist and educator would be of most use. Issues I am currently working on include the conservation of wilderness areas and inventoried roadless areas, mining issues, the Magnuson-Stevens reauthorization and national ocean policy, climate change issues, the promotion of alternative energy generation, the generation and disposal of nuclear waste, Native American trust fund and land acquisition issues, the scientific peer review process, wildfires and the protection of at-risk communities from forest fire, the Higher Education Act reauthorization, public education reform, and women's health—as well as any other issues I would like to pursue in my spare time.

I am very excited about the opportunity to tackle such a motley assortment of issues, and I hope to bring a little of the analytical eye of an earth scientist to promote sound policy. Science is currently at a crossroads. Once the cornerstone of public policy, it is in danger of becoming politicized and its perception by the public as an infallible measuring stick for determining public risk eroded. There is a popular misconception that proper use of the scientific method should lead us to absolute truth, free of assumptions. It is in our best interest for each of us to educate non-scientists about the value of the analytical process and its inherent uncertainties. Thanks to GSA and the U.S. Geological Survey, I am trying to do my small part here on the Hill.

This manuscript is submitted for publication by Michèle Koppes, 2003–2004 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. Michèle Koppes can be reached at michele.koppes@mail.house.gov.

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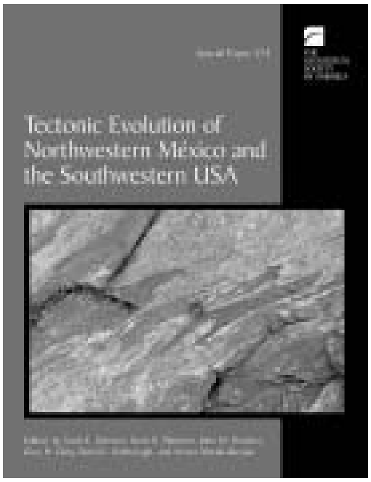

Tectonic evolution of northwestern México and the southwestern USA, edited by Scott E. Johnson, Scott R. Paterson, John M. Fletcher, Gary H. Girty, David L. Kimbrough, and Arturo Martín-Barajas

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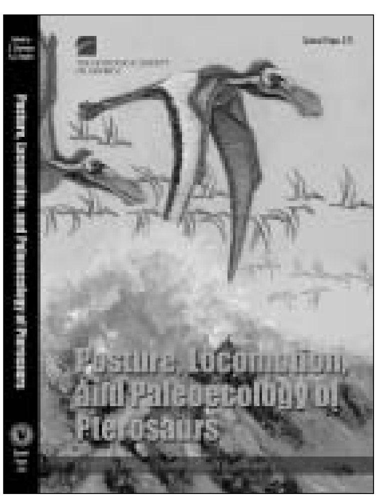
This volume was assembled as a dedication to the career achievements of R. Gordon Gastil. The papers focus primarily on the Mesozoic and Tertiary tectonic evolution of Baja California and nearby regions of mainland México and southern California. The volume begins with an extensive tectonic overview with the goals of summarizing our present understanding of the geology of Baja California, addressing several controversial issues and providing a framework for more detailed discussions in some of the remaining papers. The volume contains a wealth of modern analytical data and authoritatively explores regional issues. The accompanying CD-ROM contains valuable geochronological and geochemical data, color images, and out-of-print Geological Society of America maps. In particular, the CD-ROM contains the highly sought after geologic maps of northern Baja California published by Gordon Gastil and colleagues in 1975 as part of the Geological Society of America Memoir 140, *Reconnaissance Geology of the State of Baja California.*



Posture, locomotion, and paleoecology of pterosaurs by Sankar Chatterjee and R.J. Templin

SPE376, 64 p.
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Pterosaurs were flying archosaurs that lived during the age of dinosaurs from 225 million to 65 million years ago. The ecology of pterosaurs was similar to those of modern seabirds, spending much time in coastal areas for feeding. Small and medium-size pterosaurs probably foraged by plunge diving like modern pelicans. Large pterodactyloids were probably active waders or surface riders during feeding, using their feet to propel while folding their wings sidewise. This volume investigates the flight performance of pterosaurs using 10 genera in a wide size spectrum during their 160 million years of evolution. With body masses ranging from 0.015 kg to 70 kg and wingspans from 0.4 m to 10.4 m, the largest pterosaur weighed about 4700 times more than the smallest species, and the longest wingspan was 25 times the shortest. The authors adapted helicopter momentum stream tube theory to estimate the scaling of aerial locomotion of pterosaurs and to minimize the complexities of animal physiology. Detailed figures illustrate findings on gliding performance, angles, and airspeed, styles of flight, and takeoffs and landings. Possible functions of the pterosaur's physiological features also are explored.

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2004 Jahns Distinguished Lecturer Named

Jeffrey R. Keaton has been named the 2004 Jahns Distinguished Lecturer. The GSA Engineering Geology Division and the Association of Engineering Geologists jointly established the Richard H. Jahns Distinguished Lectureship in 1988 to commemorate Jahns and to promote student awareness of engineering geology through a series of lectures offered at various locations throughout the year. Richard H. Jahns (1915–1983) was an engineering geologist who had a diverse and distinguished career in academia, consulting, and government.

The 2004 Jahns lecture, "Engineering Geology Mapping in the Information Technology Age," is based on Keaton's interest in documenting, interpreting, and communicating engineering geology data since his early years in consulting practice. An abstract prepared by Keaton in 1980 first used the name Genesis-Lithology-Qualifier for a system of engineering geology mapping symbols, and R.R. Compton included Keaton's work in his 1985 manual *Geology in the Field*. Keaton changed the system's name to Unified Engineering Geology Mapping System in 1996 and also described a Stability Classification of Slopes and Landslides.

Also available are two alternative lectures, "Earthquake Ground Motion for Design of the Hoover Dam Bypass Bridge" and "Soil Stratigraphy and Surface-Water Hydrology of Part of Hualapai Valley, Mohave County, Arizona." Both of these lectures are case histories from consulting assignments. The first utilized the Composite Source Model, with which Keaton became familiar during his 1999 Professional Fellowship awarded by the Earthquake Engineering Research Institute. The second is related to litigation following a bridge failure. Abstracts are available on the Engineering Geology Division's GSA Web site (http://rock.geosociety.org/egd/index.html).

Keaton has worked for consulting engineering firms throughout his 33-year professional career. He is licensed as a professional geologist in California, Arizona, and Washington, and as a professional engineer in California, Utah, Arizona, and Alaska. He is a principal engineering geologist with the Earth & Environmental Division of AMEC in Anaheim, California. As an adjunct associate professor in the Department of Geography at the University of Utah, he taught undergraduate and graduate courses in applied geomorphology and urban natural hazards. He also held an adjunct professor appointment in the Department of Civil and Environmental Engineering at Utah State University, where he contributed to research projects on liquefaction, slope instability, and tectonic deformation.

Keaton is a Fellow of GSA, served as chairman of the Engineering Geology Division (1989–1990), and was president of the Association of Engineering Geologists (1992–1993). Keaton has been actively involved with the Transportation Research Board since 1981 and was a member of the task force that produced "Landslides: Investigation and Mitigation" in 1996.

Requests for scheduling the 2004 Jahns lecture should be directed to jeff.keaton@amec.com.

Students, This Is for You:

The John Mann Mentors in Applied Hydrogeology Program—New for 2004

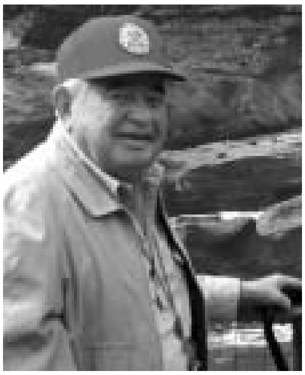
***Karlon Blythe**, GSA Outreach Program Officer*

Are you interested in hydrogeology as your career path? If your answer is yes, you'll want to check out this GSA mentor program. The John Mann Mentors in Applied Hydrogeology Program is designed to acquaint undergraduate and graduate students and recent graduates with careers in applied hydrogeology through mentoring opportunities with practicing professionals. Program events will be held in conjunction with GSA Section Meetings and at GSA Annual Meetings.

Pilot programs for this John Mann Mentors in Applied Hydrogeology Program will be conducted at two of the 2004 Section Meetings. The first program will be at the Northeastern-Southeastern Sections Joint Meeting (March 26, 2004, Tyson's Corner, Washington, D.C.). The second program will be at the Rocky Mountain–Cordilleran Sections Joint Meeting (May 4, 2004, Boise, Idaho). These relaxed but focused, small-scale events feature a FREE BREAKFAST for participants. For these pilot programs, participant eligibility is limited to students in the Northeastern-Southeastern Sections and the Rocky Mountain–Cordilleran Sections who have declared their career interest to be hydrology or hydrogeology on their GSA membership applications and who meet preregistration deadlines for the sections' meetings. An invitation will be sent via e-mail to those qualified students. Keep in mind that only a quick response to the invitation will secure you a seat, as these Mann Mentor events will be limited in attendance in order to enhance the interaction between professionals and students. **Interested? Contact Karlon Blythe, kblythe@geosociety.org, for additional information**.

 Donna L. Russell, *Director of Operations*

Parke D. Snavely, Jr., Fund Established



On November 24, 2003, U.S. Geological Survey Emeritus Geologist and 50-year GSA Fellow Parke D. Snavely, Jr., died as a result of complications following a stroke. He was 84. In his memory, Snavely's family, friends, and colleagues have established the **Parke D. Snavely, Jr., Cascadia Research Award Fund** in the GSA Foundation. The award is to be granted annually by GSA and will support field-oriented graduate student research that contributes to the understanding of geologic processes and history of the Pacific Northwest convergent margin, or the evaluation of its hazard or resource potential. The first recipient of the Snavely Cascadia Research Award Fund will be selected in April 2004.

Parke D. Snavely, Jr., received his professional training at the University of California at Los Angeles (A.B. 1941, M.A. 1950), where he developed an early affection for field geology under the guidance of Jim Gilluly and Bob Webb. In 1942, Snavely joined the USGS, where he had a long and distinguished career. His classic geologic mapping and topical research focusing in and around the Coast Ranges of Oregon and Washington spanned nearly 60 years and established much of the geologic and tectonic framework for current understanding of the Cascadia forearc basin. Early field studies led by Snavely delineated the Centralia-Chehalis coal district of Washington as a major energy resource; it now sustains a generating plant supplying enough electricity to power Seattle. Snavely's mapping is also being applied to seismic hazards and other land use problems in the region. His subsequent field and marine work, stretching from the Klamaths to Vancouver Island and west across the continental shelf, provided the foundation for a body of research that yielded more than 150 maps and scientific papers dealing with local and regional stratigraphy, structure, igneous petrology and rock chemistry, geologic history and tectonic evolution, and energy potential of western Oregon and Washington. His efforts to correlate onshore geology with offshore marine data were a lifelong research interest, and his onshore-offshore geologic profiles of the Oregon and Washington continental margin provide unique insight into its evolution.

Snavely's broad interests were reflected in his position at the time of his retirement in 1994: senior research geologist both in the Pacific Marine Geology and Western Regional Geology branches of the USGS. He also had a remarkable administrative career with the survey, having served in Menlo Park as chief of the Pacific Coast States Branch for Regional Geology and later as its first chief of the Office of Marine Geology and Hydrology. In the later role, Snavely was instrumental in establishing a marine program in the USGS and taking this new organization into a leadership position in the international marine sciences community. During that time, Snavely initiated international cooperative research programs between the USGS and the governments of Canada, Mexico, Spain, Liberia, Japan, and Taiwan. He also acted as an external advisor to academia, supported student and faculty research, and he worked with an array of industry, state, and survey colleagues in unraveling the complex geology of the Pacific Northwest. In the decade following his formal retirement, Snavely continued with the survey in an emeritus capacity, visiting field locations, editing maps and manuscripts,

Most memorable early geologic experience:

At a CalTech departmental dinner dance, Dick Jahns "won" the rigged "door prize" drawing: his own office door. The original door was replaced with the women's restroom door.

—Donald U. Wise

GSA FOUNDATION

3300 Penrose Place, P.O. Box 9140
Boulder, CO 80301-9140
(303) 357-1054
drussell@geosociety.org

Enclosed is my contribution in the amount of $_________.

Please credit my contribution for the:

- ☐ Greatest need
- ☐ Other: _________________ Fund
- ☐ Snavely Fund

☐ I have named GSA Foundation in my will.

PLEASE PRINT

Name ______________________

Address ______________________

City/State/ZIP ______________________

Phone ______________________

and generating new ideas and concepts for follow-up by the next generation of Pacific Northwest geoscientists.

Snavely received the Department of the Interior's Distinguished Service Award in 1971, and in 1997, he received the Dibblee Foundation Medal for his significant contributions to geologic mapping. He was a mentor to many young geologists, who will miss his wise counsel. Snavely is survived by his wife of 61 years, Anne, daughters Pamela and Deborah, son Parke III, four grandchildren, and one great-granddaughter.

If you would like to contribute to the Snavely Fund, see the form on page 22.

GSA FOUNDATION SEEKS PRESIDENT

The Foundation of the Geological Society of America seeks a geoscientist, preferably with national recognition for achievements in the geosciences and administration, to be its president. The individual should have a strong interest and experience in, or working knowledge of, fund raising and development. Primary responsibilities will include oversight and direct participation in fund raising for GSA programs and activities; identifying, cultivating and soliciting major donor prospects including individuals, corporations, and foundations; stewardship of funds; and staff administration. This person will be expected to have a major role in designing and implementing a strategic fund raising and development plan for the Foundation, and to closely and regularly interact with the executive director of the Geological Society of America and members of its staff, the GSA Foundation Board of Trustees, and the GSA Council. The president will report to the GSA Foundation Board of Trustees and be assisted in the Foundation by a full-time director of operations and a data manager.

The position will be approximately half time, with a flexible schedule and with the bulk of the activities to be conducted from the Society's headquarters in Boulder, Colorado, although full-time relocation to the Boulder area may not be required. A range of compensation options exists, depending on experience and qualifications of the candidate, and the length of the appointment. Interested persons should electronically transmit a letter of application, resume/vita, and the names, addresses, and telephone numbers of three references to Lara Womack, GSA Human Resources Director, lwomack@geosociety.org, or, if unable to transmit electronically, mail the information to **GSAF President Search Committee,** c/o Lara Womack, P.O. Box 9140, Boulder, CO 80301-9140. Nominations of potential candidates by members of the geoscience community are also encouraged. Effective closing date for the applications is May 15, 2004, with a target starting date of September 1, 2004. The GSA Foundation is a non-profit corporation and an Equal Opportunity, Affirmative Action Employer.

GeoVentures™ 2004

GeoHostel Geology of the Northern Margin of the Yellowstone Hot Spot, Southwest Montana

June 19–24, 2004, 5 days, 6 nights.
GuestHouse Inn Suites, Dillon, Montana

ONLY A FEW SPACES LEFT—REGISTER TODAY!

Southwest Montana. Photo by R. Thomas.

GeoClass Two Billion Years in Two Days—A Front Range Geology Primer GeoClass

June 25–28, 2004
Boulder, Colorado, Best Western Boulder Inn

Scientific leader: Alan Lester, University of Colorado, Boulder. Lester, a recipient of multiple teaching awards at the University of Colorado, is a research associate and senior instructor in the Department of Geological Sciences.

Description: Experience three days of scenic geology excursions along the eastern margin of the Front Range, south-central Rocky Mountains, Colorado. Situated at the foot of the Front Range, Boulder is a picturesque and convenient vantage point from which to launch explorations. In Boulder, home of the University of Colorado, participants, spouses, and family will find ample opportunities for dining and shopping. Our excursions, although geological in focus, will also be wonderful opportunities for bird and wildlife watching.

Fees and Payment: $650 for GSA members; $700 for spouses; $750 for nonmembers. A $200 deposit is due with your reservation and is refundable through May 1, less a $20 processing fee. Total balance is due May 1. Minimum: 12; maximum: 22. **Included:** Classroom programs and materials; field trip transportation; lodging for three nights (single occupancy or doubles for couples); breakfast on Saturday, Sunday, and Monday; boxed lunch on Saturday and Sunday, welcoming and farewell events. **Not included:** Transportation to and from Boulder, Colorado; transportation during hours outside field trips; alcoholic beverages; and other expenses not specifically included.

To register for this class, please fill out and return the registration form on page 25.

GeoTrip Iceland: A Student Only—Oriented GeoTrip

July 11–25, 2004

Scientific Leader: James Reynolds, Brevard College, Brevard, North Carolina. Jim is a magnetostratigrapher with interests in Neogene volcanism and foreland basins who has been leading international field trips since 1996.

Description: Designed for students only, this GeoTrip will visit the classic geological localities of Iceland on a low-frills budget. Participants will camp and prepare meals in a group kitchen tent. Eighty kilometers of hikes will take us through spectacular volcanic and glacial scenery.

Fees and Payment: $2,100 for GSA student members; $2,200 for nonmembers. $200 deposit is due with your reservation and is refundable (less $75) through May 1. Balance is due May 1. *Firm* minimum number of participants: 21. **Included:** Ground transportation; all meals; classroom programs and materials; guidebook; and map. **Not included:** Roundtrip airfare to Iceland from Baltimore; airfare to and from Baltimore; camping equipment (tent and sleeping bag); alcoholic beverages; and other expenses not specifically included.

To register for this trip, please contact Sandy Doss, Holbrook Educational Tours at sdoss@holbrooktravel.com, 1-888-890-0632.

GeoTrip Geological Excursion to Central and Northern Mongolia

July 24–August 11, 2004

Scientific co-leaders: Gregory S. Holden, Department of Geology and Geological Engineering, Colorado School of Mines, Golden, Colorado. Greg has 26 years of teaching experience in petrology and field geology and has led five previous GSA GeoHostels. He will provide general geological background to complement the local expertise of the Mongolian trip leaders. Greg led a student field trip to Mongolia with B. Tumenbayar and Ch. Minjin in 2001. If you would like to discuss the trip further, please contact Greg at gholden@mines.edu, (303) 273-3855. **Ch. Minjin**, Mongolian Technical University, is well published and an internationally recognized expert on the stratigraphy and paleontology of Mongolia. **B. Tumenbayar**, Mongolian Academy of Sciences; and BEMM Consulting, is a mineralogist and active consulting exploration geologist. Tumenbayar's firm, BEMM Consulting, which has provided logistical support for numerous international geological field trips and for exploration efforts by international minerals companies, will be responsible for all logistical support in Mongolia. His company has an experienced staff of coordinators, cooks, and drivers, many of whom speak English well. **J. Byamba**, Mongolian State University.

Description: Central Mongolia is a high, dissected plateau with numerous peaks over 3000 m, well above timberline. Thick birch and larch forests cover the high slopes above valleys carpeted with grass and flowers of the Central Asian steppe. Big, fish-filled rivers flow north, ultimately into Siberia's famous Lake Baikal and on to the Arctic Ocean.

The steppe supports horses, camels, and yaks, herded by nomads living in gers, their traditional round tents. Wolves and snow leopards still roam the more remote areas.

This GeoTrip provides a unique opportunity to explore the geology, flora, fauna, and culture of this amazing country in the company of two expert guides from the Mongolian Technical University and the Mongolian State University.

Fees and Payment: $2,700 for GSA members; $2,800 for spouses; $2,950 for nonmembers. $200 deposit is due with your reservation and is refundable (less $100) through May 15. Balance is due May 15. Minimum number of participants: 12; maximum: 20. *Most nights will be spent camping. Participants must supply their own mountain tent, good quality sleeping bag, and foam pad.* **Included:** Four nights in ger hotels; all meals; field trip transportation; local guides; and guidebook and program materials. **Not included:** Roundtrip airfare to Ulaan Baator from San Francisco; airfare to and from San Francisco; alcoholic beverages; and other expenses not specifically included.

To register for this trip, please fill out and return the registration form below.

For more information on these trips, visit www.geosociety.org/geoVentures or see the February issue of *GSA Today*.

GeoVentures™ 2004

for GSA Members & Friends

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. For details on accommodations and occupancies, see trip descriptions or contact Edna Collis.

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
BOULDER, COLORADO	$200	____	$_________
MONGOLIA	$200	____	$_________
DILLON, MONTANA	$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

ANNOUNCEMENTS

MEETINGS CALENDAR

2004

April 1–3	Shlemon Conference: Earth Fissures, hosted by the Engineering Geology Foundation and the Association of Engineering Geologists, El Paso, Texas. **Information:** Bill Haneberg, (206) 871-9359, bill@haneberg.com; or Jeff Keaton, (714) 779-2591, ext. 308, jeff.keaton@amec.com.
May 23–25	8th Annual DOSECC Workshop on Scientific Drilling, New Brunswick, New Jersey, USA. **Information:** Theresa Fall, 675 S. Arapeen Drive, Suite 201, Salt Lake City, UT 84108, USA, (801) 585-9687, fax 801-585-9386, tfall@dosecc.org, http://www.dosecc.org/html/workshop_2004.html.
June 19–24	Gorges, Clays, and Coulees, Clay Minerals Society 41st Annual Meeting, Richland, Washington. **Information:** Jim Amonette, (509) 376-5565, jim.amonette@pnl.gov; Paul Gassman, (509) 376-7972, pl.gassman@pnl.gov; or Jim Harsh, (509) 335-3650, harsh@wsu.edu; http://pnl.gov.cms/.
June 22–25	Air & Waste Management Association's 97th Annual Conference and Exhibition, Indianapolis, Indiana, USA. **Information:** www.awma.org/ACE2004.
June 27–July 1	2004 International Basement Tectonics Association Conference: 4-D Framework of Continental Crust—Integrating Crustal Processes Through Time, Oak Ridge, Tennessee. **Information:** Robert D. Hatcher, Jr., Dept. of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN 37996-1410, USA, bobmap@utk.edu. (*Abstract deadline: April 1, 2004.*)
July 18–25	35th COSPAR Scientific Assembly and Associated Events Paris, France. **Information:** www.copernicus.org/COSPAR/COSPAR.html, www.cospar2004.org/, cospar2004@colloquium.fr. (*Early registration deadline: May 15, 2004.*)
Sept. 26–Oct. 1	The Society for Organic Petrology (TSOP), 21st Annual Meeting, Sydney, Australia. **Information:** Neil Sherwood, CSIRO Petroleum Resources, PO Box 136, North Ryde NSW 1670 Australia, 61-2-9490-8666, 61-2-9490-8197, Neil.Sherwood@csiro.au, www.tsop.org/mtgsyd.htm.
October 3–5	Eastern Section—AAPG Annual Meeting, Columbus, Ohio. **Information:** Steve Zody, Ohio Geological Society, P.O. Box 14304, Columbus, OH 43214, (330) 262-4323, zodyoil@sssnet.com, www.dnr.state.oh.us/geosurvey/aapg04.htm. (*Call for Papers deadline: April 1, 2004; registration deadline: September 17, 2004.*)
October 18–20	Deep-Water Sedimentary Systems of Arctic and North Atlantic Margins 2004, Stavanger, Norway. **Information:** Geological Society of Norway, www.geologi.no/cgi-bin/geologi/imaker?id=1657.

2005

September 11–14	AAPG International Conference & Exhibition, Paris, France (new dates). **Information:** AAPG Convention Dept., P.O. Box 979, Tulsa, OK, 74101-0979, USA, (888) 945-2274 (USA and Canada only) or (918) 560-2679, fax 918-560-2684, convene@aapg.org, www.aapg.org.
October 10–13	Regional Geology and Hydrocarbon Systems of European & Russian Basins: Looking for Sweet Spots, AAPG European Region Conference with GSA, Prague, Czech Republic. **Information:** Juraj Francu, Energy and Geoscience Institute, University of Utah, Salt Lake City, USA, (801) 581-6739, jfrancu@egi.utah.edu; www.aapg.org/meetings/prague04/.

2006

July 9–15	Frontiers of Soil Science: Technology and the Information Age, 18th World Congress of Soil Science (Soil Science Society of America, U.S. National Committee for Soil Science, International Union of Soil Sciences), Philadelphia, Pennsylvania. **Information:** Organizing Committee Co-Chairs: Lee E. Sommers, Colorado State University, Lee.Sommers@ColoState.Edu, Larry P. Wilding, Texas A&M University, wilding@tamu.edu; www.18wcss.org.

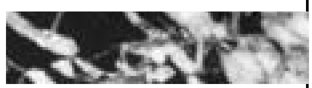
Visit www.geosociety.org/calendar/ for a complete list of upcoming geoscience meetings.

About People

GSA Fellow **Mark A. Wilson** has been named the first Lewis M. and Marian Senter Nixon Professor in the Natural Sciences at The College of Wooster. Wilson, a professor of geology and chair of the department, is an expert in evolution, paleontology, and sedimentary geology.

The Desert Research Institute awarded the 2004 Nevada Medal to GSA Fellow **Farouk El-Baz**, a research professor and director of Boston University's widely regarded Center for Remote Sensing, and a veteran of NASA's Apollo Program and pioneer in the study of Earth from space.

In Memoriam



Lawrence L. Brown
Albany, Oregon
November 3, 2003

John W. Buffington
Littleton, Colorado
August 23, 2003

James Bush
Palm Beach, Florida

Larry J. Doyle
Saint Petersburg, Florida
November 19, 2003

Richard V. Fisher
Santa Barbara, California

Gerald R. Grocock
Golden, Colorado
March 23, 2003

Viktor P. Kahr
Graz, Austria

Wilton N. Melhorn
Thorntown, Indiana
November 25, 2003

Karl Nebert
Graz, Austria
October 19, 2003

Nancy G. Ryan
Saint Michaels, Maryland
January 10, 2004

Denis M. Shaw
Hamilton, Ontario
October 6, 2003

Parke D. Snavely Jr.
Los Altos, California
November 24, 2003

Ronald K. Sorem
Pullman, Washington
December 22, 2003

Donald L. Wills
Monmouth, Illinois
October 6, 2003

Please contact the GSA Foundation at
(303) 357-1054 or drussell@geosociety.org for information on contributing to the Memorial Fund.

PHILMONT SCOUT RANCH SEEKS VOLUNTEERS

Located in the southern Sangre de Cristo Mountains of northern New Mexico, Philmont Scout Ranch, one of three national high adventure bases owned and operated by the Boy Scouts of America, is a 137,000 acre ranch dedicated to outdoor activities. Its 12-day backpacking experience serves over 21,000 high school age young men and women from all over the United States as well as several foreign countries.

Sponsored by the Rocky Mountain Association of Geologists, the Volunteer Geologist Program brings geological expertise to the scouts. Volunteers spend a week at one of three backcountry camps with the Philmont staff, living in staff housing (tents or cabins, depending on location) and eating meals with the staff. Volunteers need to bring their own sleeping bags, toiletries, hiking boots, and clothes for all weather conditions (altitudes in excess of 9,500', montane to sub-alpine forest conditions, alpine on top of Baldy Mountain). A day pack, water bottles, and emergency gear are suggested as well. Spouses welcome (sorry, no children).

The 2004 program runs from Sunday, June 13 through the week August 8. A total of 36 spots are available this summer. ***Sign up early!***

For more information, contact Ed Warner, (720) 904-0560, ewarn@ix.netcom.com, or Bob Horning, (505) 820-9290, rhorning@rt66.com.

CLASSIFIED ADVERTISING

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.

Classification	Per Line for 1st month	Per line each addt'l month (same ad)
Situations Wanted	$2.25	$1.90
Positions Open	$7.00	$6.00
Consultants	$7.00	$6.00
Opportunities for Students		
first 25 lines	$0.00	$2.85
additional lines	$1.85	$2.85
Web Only Ads	$7.00	$6.00
live link: add $25		

Agencies and organizations may submit purchase order or payment with copy. Individuals must send prepayment with copy. To estimate cost, count 54 characters per line, including all punctuation and blank spaces. Actual cost may differ if you use capitals, centered copy, or special characters.

Positions Open

**ASSOCIATE RESEARCH SCIENTIST
CLIMATE CHANGE INSTITUTE
OF THE UNIVERSITY OF MAINE**

The Climate Change Institute of the University of Maine has an immediate opening for an Associate Research Scientist. The position provides scientific support for globally conducted ice core collection activity. The candidate should have recent PhD in geoscience with demonstrated numerical and computational skills, working knowledge of scientific grant writing, and extensive field work experience. The successful applicant will require frequent and extended travel to remote field areas for coordinating ice core collection in extreme geographic locations. Application packet should contain application letter outlining research experience and research interests, CV, publication listing, and contact information for 3 references. Send application materials to: Search Committee – Associate Research Scientist, Climate Change Institute, University of Maine, 303 Bryand Global Science Center, Orono, ME 04469-5790. Additional information outlining application requirements can be found at the Climate Change Institute web site: http://climatechange.umaine.edu/Directory/position.html, or http://www/umaine/hr/jobs. Review of applications will begin March 15, 2004.

The position is funded by outside grant agencies. The position is available for two years and is renewable subject to satisfactory performance.

The Climate Change Institute encourages a diverse environment in the workplace and welcomes all applications from all qualified persons including minorities and women. The University of Maine is an Equal Opportunity/Affirmative Action Employer.

**EARTH SCIENCE EDUCATION
BRIGHAM YOUNG UNIVERSITY**

The Department of Geology at Brigham Young University is seeking to fill a permanent position (Ph.D. preferred) for a teaching specialist in earth science education to begin August 2004. The chief responsibilities of this position include the teaching and development of curriculum for physical geology service courses. Starting salary and rank will be commensurate with experience.

Applicants should send a letter of application, curriculum vitae, and the names of three references to Dr. Stephen T. Nelson, Faculty Search Committee, Department of Geology, Brigham Young University, S-389 ESC, Provo, UT, 84602. Please emphasize: (1) your teaching experience, including student and peer feedback, and (2) your vision and philosophy for undergraduate earth science education. Review of applications will begin immediately and will continue until the position is filled.

**ENERGY RESOURCES AND SUBSURFACE GEOLOGY
AT MONTANA STATE UNIVERSITY—BOZEMAN**

The Department of Earth Sciences at Montana State University-Bozeman seeks to fill a new faculty position at the assistant/associate/full level in energy resources and subsurface geology. Ph.D. in geology or related area of geosciences required. The selected individual will bring broad expertise in physical and sequence stratigraphy, depositional systems, reservoir characterization, geochemistry and diagenesis, subsurface fluid flow dynamics, and/or energy resources to bear on issues involving subsurface CO_2 sequestration, hydrocarbon exploration, enhanced hydrocarbon recovery from petroleum and natural gas reservoirs, and coal stratigraphy/coal bed methane production. The desired individual will develop a strong interdisciplinary collaboration with researchers in the Center for Zero Emissions Research and Technology (ZERT) at MSU focused on geological aspects of subsurface reservoir emissions (CO_2) sequestration. The individual will also be expected to play a leadership role in developing strong industry, agency, and academic partnerships, and play a major role in contributing to development of a new doctoral degree program in Earth Sciences through active participation in graduate student research and teaching.

Screening of applications begins March 31, 2004. For complete announcement and application directions, see: www.montana.edu/msuinfo/jobs/faculty/.

ADA/AA/EO/VET. Pref.

**STAFF, PROJECT AND
SENIOR PROJECT GEOLOGISTS
CAMBRIA ENVIRONMENTAL TECHNOLOGY**

Cambria Environmental Technology is currently seeking Staff, Project and Senior Project Geologists, Engineers or Environmental Scientists in our Emeryville and Rocklin, Calif., offices.

Purpose: Assist/manage a variety of projects by providing assessment/monitoring and closure needs.

Responsibilities: Assist with work plan preparation. Develop and track work scopes and budgets. Meet with clients and regulatory agencies for site discussion. Compile data and review various regulatory reports. Coordinate field work permitting. Prepare quarterly groundwater monitoring reports. Coordinate and conduct subsurface investigations/assessments and related soil and groundwater sampling.

Requirements: BS/BA in Geology, Environmental Engineering or Environmental Science required. Industry experience with emphasis on assessment, investigation, hydrocarbon remediation design, installation and operation, regulatory compliance for soil and groundwater contamination. 40-hour OSHA HAZWOPER. Valid CDL and vehicle to travel to various sites. Must be able to speak and write clearly and in the English language.

Send cover letter with salary requirements and resume via email to hr@cambria-env.com or fax 510-420-3392.

**STRUCTURAL GEOLOGY/TECTONICS
SCHOOL OF GEOLOGY AND GEOPHYSICS
COLLEGE OF GEOSCIENCES
UNIVERSITY OF OKLAHOMA**

The University of Oklahoma invites applications and nominations for a tenure-track faculty position in Structural Geology/Tectonics. The holder of this position is expected to (1) conduct research in structural analysis using any combination of theoretical, experimental, field, and seismic approaches; and (2) educate students in the area of structural concepts and techniques.

The University is seeking to fill this position at the Assistant or Associate Professor level. The successful candidate should have an excellent demonstrated or developing research record and the vision to establish a strong research program in pure and/or applied structural geology/tectonics. The candidate must also be an excellent educator, with commitment to both undergraduate and graduate (M.S. and Ph.D.) education. A Ph.D. degree is required for this position. Salary and benefits will be competitive and commensurate with experience and future potential.

Initial screening of applicants will begin in spring of 2004. The position will be available as early as fall 2004, and the search will remain open until the position is filled. Applicants are encouraged to submit a complete vita/resume, statement or research and teaching interests, and a list of five references, including names, phone numbers, e-mail addresses, and complete mailing addresses. Questions or requests for additional information may be addressed to Dr. Shankar Mitra, Chair of the Structural Geology/Tectonics Search Committee, at (405) 325-4462, or smitra@ou.edu. Applications and nominations should be addressed to: Structural Geology Search Committee, School of Geology and Geophysics, University of Oklahoma, 100 E. Boyd Street, Room 810, Norman, OK 73019-1008.

The University of Oklahoma is an Affirmative Action, Equal Opportunity Employer. Women and Minorities are encouraged to apply.

**HEAD, DEPARTMENT OF EARTH AND
ATMOSPHERIC SCIENCES
PURDUE UNIVERSITY**

Applications are invited for the position of Head of the Department of Earth and Atmospheric Sciences at Purdue University from individuals with substantial scientific accomplishments and outstanding leadership skills. The Department has over 30 faculty and has educational programs leading to BS, MS, and PhD degrees. These programs cover a wide range of faculty interests that address key issues in understanding atmospheric, geologic, and geophysical processes, including earth-atmosphere interactions. The Department is increasing in faculty numbers and has identified three focus areas for future growth: (1) Atmospheric Dynamics, (2) Geodynamics and Active Tectonics, and (3) Air-Surface Interactions. The future Head will help lead us to excellence in these research areas. Please consult the departmental Web site, http://www.eas.purdue.edu/, for additional information about our vision plan, and research, education, and outreach programs.

The Department is also actively involved in the School of Science initiative known as COALESCE (http://www.science.purdue.edu/COALESCE/), an interdisciplinary research thrust that will bring an additional 60 faculty into the School. The Department is a leader in three of the six COALESCE research areas: climate, computational science, and science education. COALESCE is just one part of the university's commitment to preeminence in research and scholarship by fostering the many opportunities offered by interdisciplinary science research.

The successful candidate will have demonstrated scientific leadership qualities and administrative abilities, an exemplary record of scholarly achievement, an extramurally funded research program, a dedication to teaching excellence, and a commitment to the focus areas of the Department and COALESCE interdisciplinary research initiatives. Qualified individuals should submit a letter of application; a statement of research, teaching and administrative accomplishments and philosophy; and a complete curriculum vitae with addresses, telephone numbers, and e-mail addresses of three references. Review of applications will begin March 1, 2004, and will continue until the position is filled. Send applications and inquiries to: Chair, Head Search Committee, Department of Earth and Atmospheric Sciences, Purdue University, 550 Stadium Mall Drive, West Lafayette IN 47907-2051; Phone: (765) 494-3258; Fax: (765) 496-1210.

Purdue University is an equal opportunity/equal access/affirmative action employer.

**TENURE TRACK POSITION IN
EARTH AND ENVIRONMENTAL SCIENCE
WHITTIER COLLEGE**

The Department of Environmental Science at Whittier College invites applications for a tenure-track position beginning August 2004. Salary and rank will be commensurate with qualifications and experience. We seek candidates with specialties in Earth surface or near surface processes and potential for excellent undergraduate teaching within Earth and Environmental Sciences as well as college-wide programs. The successful candidate will develop and supervise undergraduate research projects. A Ph.D. in geology or a closely related field such as physical geography or environmental science is required. Review of applications will begin on March 1, 2004. For more detailed information see www.envisci.whittier.edu Whittier College is an equal opportunity/affirmative action employer. Women and minorities are encouraged to apply.

Opportunities for Students

New Funding Initiative for Graduate Assistantships, Texas Christian University. The Geology Department announces a new funding initiative for M.S. students. Teaching assistantships available for the spring and fall semesters include nine-month stipend of $12,500, full tuition waiver, and up to $2,000 to support thesis research. Areas of department expertise include hydrology, earth-surface processes, remote sensing, environmental geology and geochemistry, carbonate and clastic sedimentology, petroleum geology, petrology and volcanology, structure and tectonics, and computer applications in geology. The department also houses the world-class Monnig Meteorite Museum. Student research is carried out in Scotland, the Sierra Nevada in California, and Africa, as well as Texas and Oklahoma. Contact Dr. R. Hanson at 817-257-7996, r.hanson@tcu.edu, or visit our website at http://www.geo.tcu.edu.

Graduate Student Research Grants, The Society for Organic Petrology (TSOP). TSOP invites applications for one or two graduate student research grants of up to $1000 each. The purpose of the grants is to foster research in organic petrology (which includes coal petrology, kerogen petrology organic geochemistry and related disciplines) by providing support to graduate students who demonstrate the utility and significance of organic petrology in solving the thesis problem.

The Grant Program supports qualified graduate students from around the world who are actively seeking advanced degrees. Preference is given to full-time students in master's (or equivalent) degree programs but applications are also encouraged from Ph.D. candidates and part-time graduate students. Grants are to be applied to expenses directly related to the student's thesis work such as summer fieldwork, laboratory expenses, etc.

Grant application deadline is May 1, 2004. Grants will be awarded in September 2004. Detailed information and an application form on the TSOP web site (http://www.tsop.org/grants.htm) or applications may be obtained from S.J. Russell, Shell UK Exploration & Production, 1 Altens Farm Rd., Nigg, Aberdeen AB12 3FY, United Kingdom; fax: +44(0) 1224 88 3689; e-mail: suzanne.j.russell@shell.com.

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The American Geological Institute, a nonprofit federation of 42 geoscience societies, is seeking a Director of Government Affairs.

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Candidates should submit a resume, including salary requirements and the names of three references, with cover letter to Government Affairs Director Search, AGI, 4220 King Street, Alexandria VA 22302-1502 or jobs@agiweb.org. For more information on the program, see www.agiweb.org/gap. Applications will be considered on a continuous basis until the position is filled. EOE

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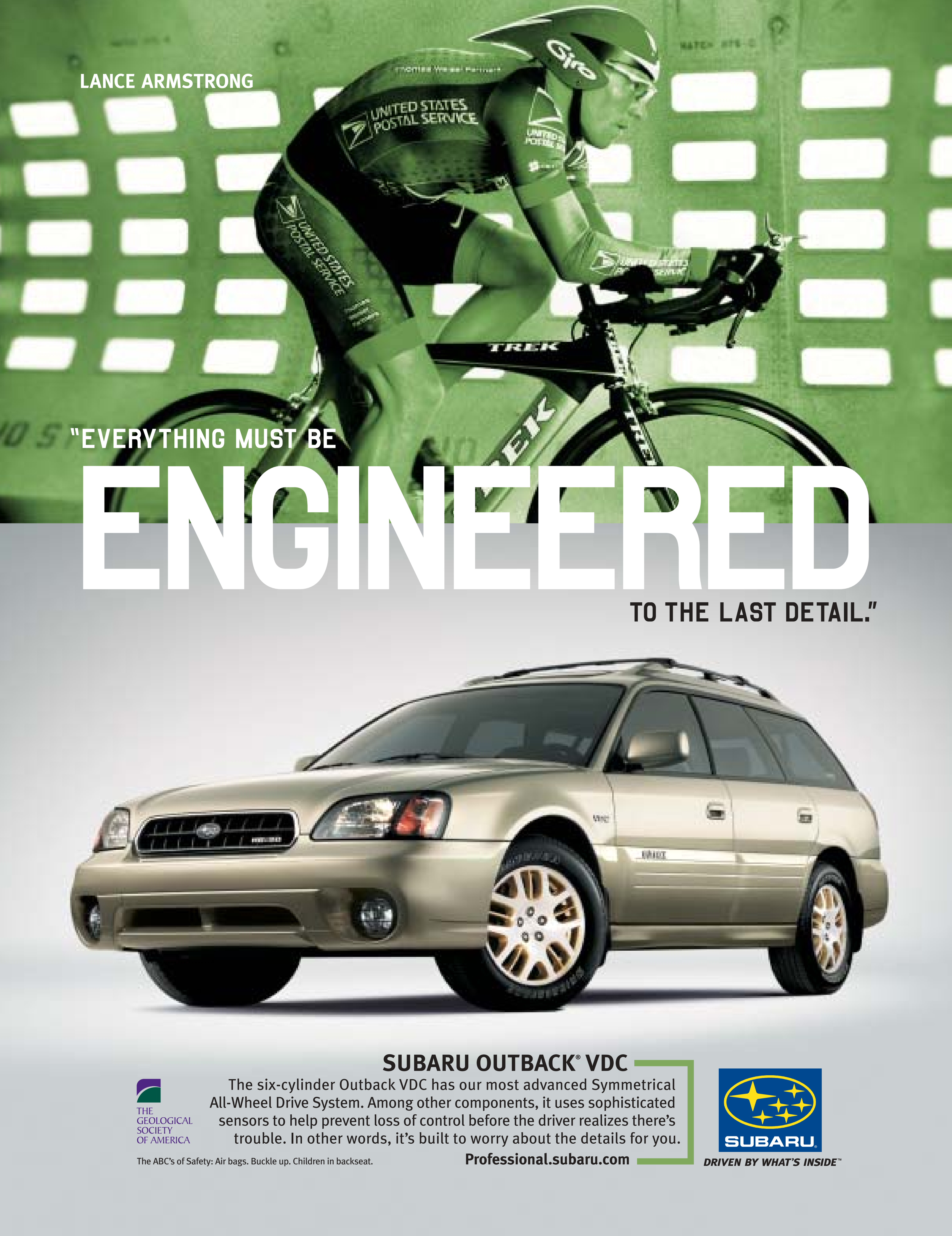
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