

GSA TODAY

A Publication of the Geological Society of America

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Waiho Loop Moraine left behind by a major advance of New Zealand's Franz Josef Glacier. Denton and Hendy (1994) used radiocarbon dating on wood carried by the glacier to show that the glacier was active at $11,150 \pm 50$ ^{14}C yr. This age is used by Denton as evidence for substantial Southern Hemisphere cooling, close to the time of the onset of the Northern Hemisphere Younger Dryas cold interval (Hajdas et al., 1995). Photo by George Denton.

Will Our Ride into the Greenhouse Future be a Smooth One?

Wallace Broecker, Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY 10964

ABSTRACT

The climate record kept in ice and in sediment reveals that since the invention of agriculture some 8000 yr ago, climate has remained remarkably stable. By contrast, during the preceding 100,000 yr, climate underwent frequent, very large, and often extremely abrupt shifts. Furthermore, these shifts occurred in lockstep across the globe. They seem to be telling us that Earth's climate system has several distinct and quite different modes of operation and that it can jump from one of these modes to another in a matter of a decade or two. So far, we know of only one element of the climate system which has multiple modes of operation: the oceans' thermohaline circulation. Numerous model simulations reveal that this circulation is quite sensitive to the freshwater budget in the high-latitude regions where deep waters form. Perhaps the mode shifts revealed in the climate record were initiated in the sea. This discovery complicates predictions of the consequences of the ongoing buildup of greenhouse gases in the atmosphere. If the major climate changes of glacial time came as the result of mode shifts, can we be certain that the warming will proceed smoothly? Or is it possible that about 100 years from now, when our descendants struggle to feed the 15 or so billion Earth inhabitants, climate will jump to a less hospitable state. It is difficult to comprehend the misery that would follow on the heels of such an event!

INTRODUCTION

The debate regarding the eventual consequences of the ongoing buildup of greenhouse gases in the atmosphere concerns the magnitude of the coming changes. Most atmospheric scientists agree that the warming during the coming century will be sufficiently great to pose serious difficulties, but because to date the warming has been smaller than predicted

by most general-circulation models, a vocal minority dismisses this supposed threat. On the other hand, little debate has occurred regarding the shape of the path climate will follow as CO_2 and other infrared-absorbing gases build up in our atmosphere. Whether the warming is great or small, nearly everyone assumes that it will be a smooth climb, and that climate will keep pace with the ever-increasing

strength of the greenhouse blanket. But will it? Certainly the Earth climate system has proven beyond any doubt that it is capable of jumping abruptly from one state of operation to another. Can we be sure that it won't respond to our push by lurching into another of its operational modes?

A MESSAGE FROM GREENLAND

A clear demonstration that the climate system can jump from one state to another comes from a record kept in Greenland ice (see Fig. 1). European and American teams have drilled through the entire thickness of the Greenland ice cap. The most recent and best documented of these records is a pair of 3-km-long ice cores from the summit of Greenland. These cores provide not only a record of climate in Greenland but also implications regarding climate in other places on the globe as far back as 110,000 yr ago. Because precise counting of individual couplets of winter and summer snow extends back to at least 45,000 yr ago, there are few questions regarding the chronology of this ice core (Meese et al., 1994).

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GSA TODAY (ISSN 1052-5173) is published monthly by The Geological Society of America, Inc., with offices at 3300 Penrose Place, Boulder, Colorado. Mailing address: P.O. Box 9140, Boulder, CO 80301-9140, U.S.A. Periodicals postage paid at Boulder, Colorado, and at additional mailing offices. **Postmaster:** Send address changes to GSA Today, Membership Services, P.O. Box 9140, Boulder, CO 80301-9140.

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This publication is included on GSA's annual CD-ROM, *GSA Journals on Compact Disc*. Call GSA Publication Sales for details.

Printed in U.S.A., using pure soy inks and recyclable paper.

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In Memoriam

Frederick Betz, Jr.
 Williamsburg, Virginia
 March 5, 1997

Dorothy J. Echols
 Ferguson, Missouri
 February 4, 1997

Roderick A. Hutchinson
 Yellowstone National Park, Wyoming
 March 1997

Charles Phillips Purdy, Jr.
 Spokane, Washington
 February 1997

NOTE: *Hildegard Howard*, was erroneously listed in the February In Memoriam; we regret the error.

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The isotopic composition of this ice is related to the air temperature over Greenland. For the past 10,000 yr, Greenland has had a very stable climate, at least compared to the previous 100,000 yr. There was one cold blip 8000 yr ago, but otherwise its climate has remained pretty much unchanged. Prior to 10,000 yr ago, though, the climate leaped back and forth between states of intermediate cold and extreme cold. The median temperature at this site during the ice age has now been well established, through thermal profiles in the ice itself, to have been on the average 16 °C colder than during the past 10,000 yr (Cuffey et al., 1995).

Further, during the past five years, evidence from a variety of investigations has clearly demonstrated that these changes were not confined to Greenland; rather, they were global! Before reviewing the evidence for these far-reaching impacts, let us consider the rapidity of these changes. This is best done by focusing on the most recent warming, the one that ushered in the present interglacial. Electrical conductivity for one of the Greenland ice cores (Taylor et al., 1993; Fig. 1 here) was measured in great detail by scratching a fresh surface of the ice with a pair of electrodes. This record provides a measure of the ratio of the fallout of acids to that of calcium carbonate—

bearing dust. During the Younger Dryas cold event, the rate of CaCO₃-bearing dust infall was so high that it totally neutralized the acid; therefore, the electrical conductivity was very low. At the onset of the present warm period, the dust input dropped way back, allowing the acids to dominate. Because the protons from the acid sustain the electrical conductivity in ice, the conductivity is high. So we see that it was not only Greenland's air temperature that changed, but also the dustiness of the air masses reaching Greenland. The isotopic fingerprint of this dust is consistent with an origin in the Gobi Desert (Biscaye et al., 1997). If that is so, Asian climates must also have undergone abrupt changes.

Annual layer counting allows the duration of the transition interval to be well documented (Fig. 1, far right). The initial change took place in only two or three years, but then the climate flickered, and the dust came back in spurts before the situation stabilized in the low-dust state. The entire transition took place in less than three decades (Taylor et al., 1993).

Ice cores also tell us something about tropical climates, because air bubbles trapped in the ice contain methane. Prior to the invention of agriculture, the major source of methane was swamps. Currently, many of these swamps are located in the temperate latitudes of the Northern Hemi-

sphere. During glacial time when the planet was very cold, all these northern swamps were either covered by ice sheets or frozen into tundra. Hence, they could not have been methane producers. So during the Younger Dryas, most methane must have been produced in the tropics. In concert with the big warming at the end of this last cold event, the methane content of Earth's atmosphere jumped from slightly below 500 up to about 750 parts per billion. I think that this rise was driven, at least in part, by a wetting of the tropics—i.e., to an increase in the size and number of methane-producing swamps and soils. It's therefore interesting to explore the relation between the timing of this methane jump and the abrupt warming in Greenland. My former graduate student, Jeffrey Severinghaus, working in the laboratory of Michael Bender at the University of Rhode Island, made a major discovery when he found a means by which in these same air bubbles he could obtain a measure of air-temperature change in Greenland. He used these measurements to show that Greenland's warming began no more than a decade or so before the onset of the increase in methane. Somehow when Greenland suddenly got much warmer, the tropics suddenly got wetter. So the impacts of this mode change extended, from Greenland at least, down into the tropics.

CLIMATE CHANGE: GLOBAL AS WELL AS LARGE AND ABRUPT

George Denton, of the University of Maine, working with a colleague, Chris Hendy, studied a very interesting moraine left behind by a major advance of New Zealand's Franz Josef Glacier. The expansion extended down the steep valley toward the Tasman Sea and created at its outer limit the Waiho Loop moraine (see photo). The rock rubble making up this moraine is underlain by lots of wood. Denton and Hendy (1994) postulated that as the glacier advanced, it moved through a forest, tearing out trees and bulldozing them to its terminus. They obtained 25 radiocarbon measurements on separate pieces of the wood and determined the age of this basal wood deposit to be $11,150 \pm 50$ ^{14}C yr. This is very close to the radiocarbon age obtained in the Northern Hemisphere for the onset of the Younger Dryas cold interval (Hajdas et al., 1995). Denton would thus say that this event affected the Southern Hemisphere; the mountain glaciers responded to a substantial lowering of the 0° isotherm. Achieving this lowering required a substantial Southern Hemisphere cooling.

A recent, spectacular set of results from sediments in a basin just off Santa Barbara, California, verifies that this phenomenon was widespread and strong, not only during the Younger Dryas, but also

for the entire series of so-called Dansgaard-Oeschger (D-O) events. These events, named in honor of two of the heroes of ice-core research, punctuated the period between about 65,000 and 25,000 yr ago. Previously it had been possible to duplicate this ice record only in ocean sediments from the northern Atlantic (Bond and Lotti, 1995), because for the most part they accumulate so slowly that stirring by worms obliterates millennial duration events. Jim Kennett, of the University of California, Santa Barbara, convinced the Deep Sea Drilling Program to spend one day drilling two shallow holes in the Santa Barbara basin. This brief effort produced a gold mine of information. Because these sediments accumulated at a rate of about 1 m per 1000 yr, they have adequate resolution to fully preserve the Dansgaard-Oeschger events—and indeed they did. For each of the warm phases, the sediment shows annual banding, while during each of the cold phases, stirring by bottom-dwelling organisms homogenized the sediment (Behl and Kennett, 1996). These results suggest that during the warm phase of each D-O cycle, the O_2 content of the water filling the Santa Barbara basin was

sufficiently low and the rain rate of organic matter sufficiently high that the sediments were anoxic. Thus, burrowing organisms were excluded. By contrast, during each of the cold phases (including the Younger Dryas), the pore waters in the upper sediments must have been oxygenated. To me, this suggests that during the cold phases conditions in the northern Pacific were quite different from conditions now. The low-salinity surface waters that currently cap this region and thereby prevent direct ventilation of the main thermocline must have been replaced with saltier water, allowing the northern Pacific to operate much as the northern Atlantic does today. Behl and Kennett (1996) found that 16 of the 17 D-O events in the Greenland ice core record are clearly evident in the Santa Barbara record.

What do these data tell us? The ventilation of the northern Pacific's thermocline (the sinking of waters from temperate latitudes to intermediate depths) increased greatly during the cold phases of the D-O events (i.e., the intervals during which laminations disappear). So the

Greenhouse continued on p. 4

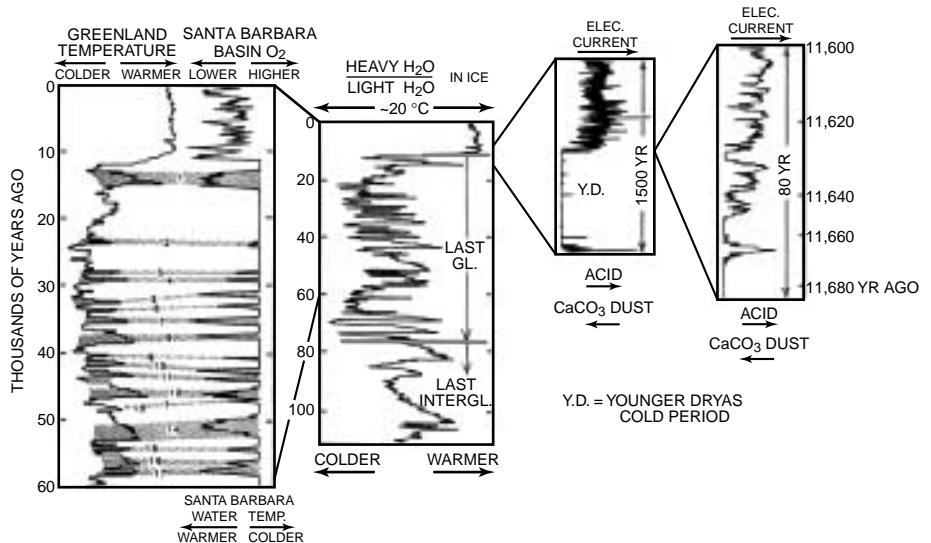


Figure 1. Oxygen isotope ratio record in ice from a 3-km-long core taken by the European GRIP group at the Summit site in central Greenland (Dansgaard et al., 1993). This ratio is related to air temperature; the greater the depletion in the heavy isotope, the colder the temperature. On the basis of measurements of temperature in the borehole, it has been possible to demonstrate that the mean air temperature in Greenland must have been 16°C colder during glacial time than during the present interglacial (Cuffey et al., 1995). The time scale was obtained by counting annual couplets in the ice (Meese et al., 1994). The electrical conductivity of Greenland ice is set by the amount of acid present. Measurements made on the GISP ice core (a duplication of the GRIP core 40 km away) reveal that during the very cold intervals the electrical conductivity fell to near zero (Taylor et al., 1993; see text). The rapidly accumulating ($1 \text{ m}/10^3 \text{ yr}$) sediments in the Santa Barbara basin record each of the so-called Dansgaard-Oeschger events seen in the Greenland ice-core record. On the basis of the alternation between sections with and without annual laminations, Behl and Kennett (1996) established this correspondence. The laminated sections represent times when the pore waters in the sediment were anaerobic, preventing burrowing by bottom-dwelling worms. The absence of laminations in the intervening sections reflects times when the pore waters were oxygenated, allowing burrowers to thoroughly stir the sediment. The alternations match almost perfectly the alternations in Greenland air temperature. During very cold intervals, such as the Younger Dryas, waters rich in O_2 must have descended into the northern Pacific's thermocline. Because the northern Pacific surface waters of today have a salt content too low to permit direct ventilation of deeper parts of the thermocline, these alternations suggest major changes in the salinity distribution in this region of our planet.

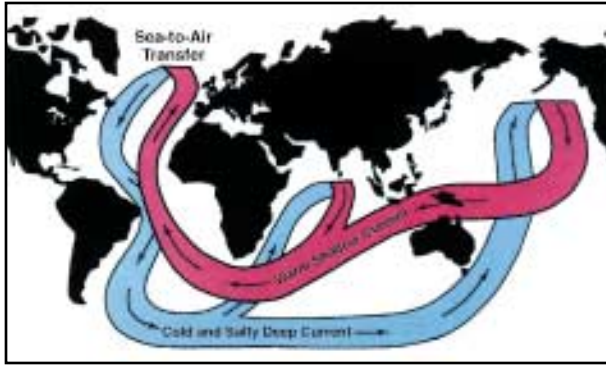


Figure 2. The great ocean conveyor carries warm water to the region around Iceland where cooling by cold Canadian air masses densifies the water, allowing it to sink to the bottom, forming a southward-moving water mass. The flow of water (20 million cubic meters per second) is equal to the amount of global rainfall. So immense is the heat released to the atmosphere that it keeps northern Europe 5 to 10 °C warmer than it would be were the conveyor to shut down.

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cold spells in Greenland are matched in the northern Pacific Ocean by what must have been a radical change in the style of upper-ocean circulation.

I've recapped what I consider to be the highlights of evidence for the global extent, large magnitude, and abruptness of these D-O events. What might have triggered these amazing changes?

CAUSES: THE OCEANIC CONVEYOR BELT

The basic idea came to me in 1984, while I was listening to a lecture given by Hans Oeschger at the University of Bern in Switzerland. He pointed out that the Greenland ice core record suggests that Earth's climate was jumping back and forth from one state of operation to another, staying in one for a millennium or so, and then jumping to the other. I began to ponder what these states might be. It soon dawned on me that they could be related to a change in a major feature of the ocean's thermohaline circulation system, which I subsequently termed its conveyor belt. People now refer to it as Broecker's conveyor belt, but I have a colleague, Arnold Gordon, who thinks it's his conveyor belt rather than mine. It doesn't really matter, though; we both agree that it's an extremely important feature of Earth's climate system.

My idea can be summarized as follows. As shown in Figure 2, one of the most prominent features of today's ocean circulation is the strong northward movement of upper waters in the Atlantic. When these waters reach the vicinity of Iceland, they are cooled by the cold winter air that streams off Canada and Greenland. These waters, which arrive at 12 to 13 °C, are cooled to 2–4 °C. The Atlantic is a particularly salty ocean, so this cooling increases the density of the surface waters to the point where they can sink all the way to the bottom. The majority of this water flows southward, and much of it rounds Africa, joining the Southern Ocean's circumpolar current.

The importance of this current to climate is the enormous amount of heat it carries. The conveyor's flow is equal to that of 100 Amazon Rivers! It's similar in magnitude to all the planet's rainfall. So if you have three pipes, one carrying North Atlantic deep water, one carrying all the rain falling on Earth, and one carrying 100 Amazon Rivers, the outflow from these pipes would be about the same. The amount of heat carried by the conveyor's northward-flowing upper limb and released to the atmosphere is equal to about 25% of the solar energy reaching the surface of the Atlantic north of the Straits of Gibraltar.

I had known about this because my career has had a dual aspect. One part of it involved a study of the ocean's deep circu-

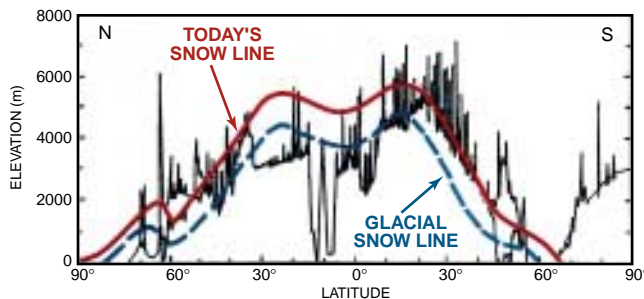
lation by means of radiocarbon and other tracers. The focus was to try to understand how rapidly fossil-fuel CO₂ would be absorbed into the ocean. The other aspect involved studies of paleoclimate. I was captivated by the observation that each of the major 100,000-yr-duration glacial cycles that have hounded us during the past million years came to a catastrophic close. So in 1984, I realized that I could merge these two studies and ask the question, "What would happen if this major current were to be shut off or turned down?" Any such modification would certainly make a major change in the climate of the northern Atlantic region. At my prodding, modelers launched computer simulations of this phenomenon and quickly showed that if the input of warm water to the northern Atlantic were cut, the mean annual temperature of the lands around the North Atlantic basin would drop by 5 to 10 °C. These climate changes would be felt in Newfoundland and Greenland and would penetrate well into northern Europe. However, the models suggested that this cooling would not extend across America to the Santa Barbara basin, nor would it extend to the tropics. It certainly would not have an impact on New Zealand.

In addition, ocean modelers followed up on the early work of Stommel (1962), who first demonstrated from a theoretical point of view that the ocean must have several distinct modes of operation. Employing a variety of simulations, they demonstrated that because of the very great sensitivity of deep-water formation to the input of fresh water in polar regions, the ocean could circulate in quite different ways. Because rain water contains no salt, addition of it lowers the density of surface waters. Further, at high latitudes, rainfall and continental runoff exceed evaporation. Because of this, the distribution of places where deep waters can and cannot be generated is sensitive to the pattern of freshwater delivery. So this new class of models verified what Stommel had predicted; indeed these model oceans could make dramatic jumps from one way of operating to another. As they did so, the amount of heat delivered to the northern Atlantic region changed greatly. While changes in the conveyor provide a likely explanation for the Greenland ice core record, however, in no case does any joint ocean-atmosphere model produce the far-field impacts displayed in the paleoclimate record.

CAUSES: IS WATER VAPOR UP TO THE TASK?

Now we must turn to a more speculative realm, because explaining the global extent of these changes is something that we're a long way from accomplishing. An important piece of information in this

Figure 3. The highest mountains at all latitudes along the cordillera of the Americas are currently capped by glaciers. At elevations above the 0 °C isotherm, more snow accumulates than melts (or evaporates). The solid line shows how the elevation marking the lower boundary of net accumulation varies with latitude. Reconstructions based on geomorphic evidence (see dashed line) show that during times of peak glacial cooling, the snow line on these mountains descended almost 1 km. Combined with oxygen isotope composition of glacial-age ice recovered by Thompson et al. (1995) from 6 km elevation on the tropical Andean mountain Huascarán, this lowering suggests not only colder but also drier conditions in the tropics during glacial time.



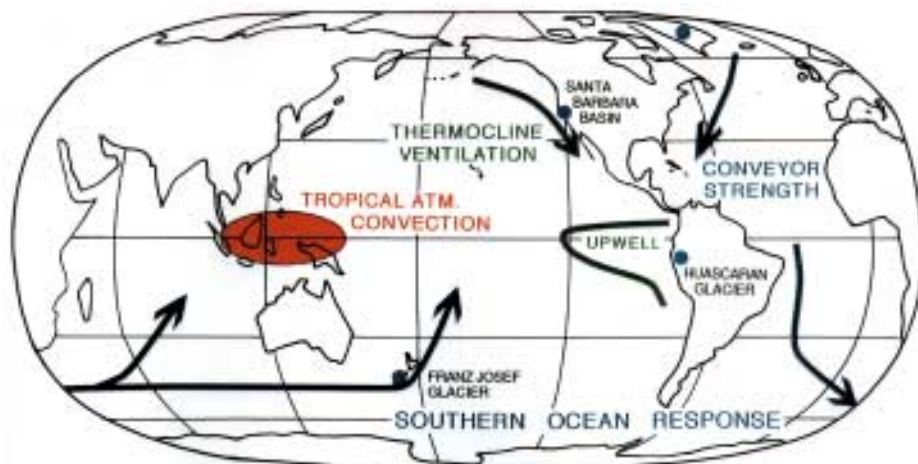


Figure 4. A possible causal chain leading to global climate change: A sizable reduction in the strength of the Atlantic's conveyor had repercussions throughout the ocean. Included were changes in operation of the upper ocean as recorded in the Santa Barbara basin. One impact of these changes may well have been an increase in the strength of upwelling in the east equatorial Pacific. We know from studies of the El Niño periods that changes in upwelling have wide repercussions in the tropical atmosphere. I propose that somehow the ocean upwelling change led to a reduction in the rate of delivery by tropical convection of water vapor to the atmosphere. Because water vapor is Earth's dominant greenhouse gas, this reduction would cool the planet.

regard is the state of Earth's system during the extreme cold millenniums of glacial times. At these times, all of Canada and a major part of the northeastern and mid-western United States were covered by a huge ice sheet. The snow line descended about 1 km on mountains everywhere on Earth. Geomorphologists have traversed the globe comparing the elevation of the present-day mountain snowlines with those for the last glaciation (reconstructed from geomorphic features). Figure 3 shows results from the American Cordillera. Everywhere from 40°S to 40°N, snowlines descended about 1 km! Thus, the southern Andes and New Zealand's South Island, which now have very small glaciers, had quite large ones.

What this tells us is that somehow Earth was in a much colder condition during glacial periods. To my way of thinking, no one has adequately explained how this could have happened. We now have new evidence from glacial-age corals (Guilderson et al., 1994) and from glacial-age ground waters (Stute et al., 1995) that the tropics may have been as much as 5 °C colder during glacial times. How could the climate of Earth have changed so much in the absence of any strong external forcing?

When I consider the mountain glacier record together with the isotope record obtained for glacial-age ice from 6 km elevation on Huascarán in the Andes (Thompson et al., 1995), I must conclude that the water vapor content of our atmosphere must have been much lower during glacial times. Hence, either the processes that deliver or those that remove water vapor from our atmosphere must have been different during glacial times. This

reduction is something that no model of the atmosphere has yet to accomplish, however. In fact, the models are powerless to produce the large global changes that the paleorecords prove to have taken place. Why water vapor?, you might ask. The answer is that water vapor is the atmosphere's most powerful greenhouse gas. If you wanted to cool the planet by 5 °C and could magically alter the water-vapor content of the atmosphere, a 30% decrease would do the job. In fact, the major debate among atmospheric scientists regarding the magnitude of the coming greenhouse warming hinges on what's referred to as the water-vapor feedback. If the water vapor in the atmosphere were to remain exactly the same as it is now, then a doubling of CO₂ would heat the planet only about 1.2 °C. However, when CO₂ is doubled in these models, the atmosphere holds more water vapor, enhancing the warming to 3.5 ± 1.5 °C. A 3.5 °C warming would certainly cause major problems for agriculture, especially where conducted in continental interiors. The debate concerns whether the models change the water vapor in the same way that it will change as CO₂ rises in the real world.

My speculation (see Fig. 4) is that despite the fact that the primary climate impacts of the change in deep-ocean circulation are restricted to the northern Atlantic basin, somehow, as a result, the water-vapor budget for the atmosphere must have been altered. Water vapor is supplied to the atmosphere primarily in the tropics, by plumes of air that ascend to the upper troposphere along the inter-tropical convergence zone. So if we invoke a change in the atmosphere's water-vapor inventory, we must look to the tropics—

in particular, to the western tropical Pacific, where convective activity feeds a major amount of water vapor into the air.

If this is so, the change in the deep circulation must have repercussions throughout the upper ocean. As evidence that this is the case, the Santa Barbara basin record indicates that, at least in the northern Pacific, there must have been a major change in the style of upper-ocean ventilation. This is important because the energy budget of the tropical atmosphere is influenced by the upwelling of cold ocean water along the equator. This cold water is fed in from the thermoclines to the North and South Pacific. The now famous El Niño cycle involves a turning on and off of this upwelling. This cycle has a strong impact on today's global climate. So I think that somehow the change in the vigor of upper-ocean circulation must have altered the strength of upwelling into the equatorial region and, in turn, the delivery of water vapor into the atmosphere.

This aspect of my argument is particularly speculative, because we don't know how it could happen. But to produce large and abrupt changes in global climate that are symmetrical around the equator, it seems to me that only the atmosphere's water vapor is up to the task. If water vapor is the cause, then we must look to the equatorial systems for the key. My guess is that changes in the freshwater budget of the surface North Atlantic threw the ocean's deep circulation into chaos. If it reformed in another mode of operation, in so doing, it triggered changes in other parts of the ocean and in turn in the delivery of water-vapor to the tropical atmosphere. Because this source maintains the atmosphere's water-vapor inventory all the way out to 35° north and south of the equator, the impact would be global. This way of looking at it suggests that we might be able to find in the paleoclimatic record a causal chain from the northern Atlantic to the equatorial Pacific and hence to the atmosphere. But I doubt that we can. The links probably act so fast that, within the accuracy of even the most precise of our dating tools, all the changes occurred at one time. We have already seen that Greenland air temperature, Asian dust production, and global methane production changed together. Some of the impacts may take longer than others to reach a new steady state, but all were probably initiated during a time interval of no more than a few decades.

OUR FUTURE

The question naturally arises as to whether this finding about past climates has any implications for the future. I think it does. Human population is rising at a

Greenhouse continued on p. 6

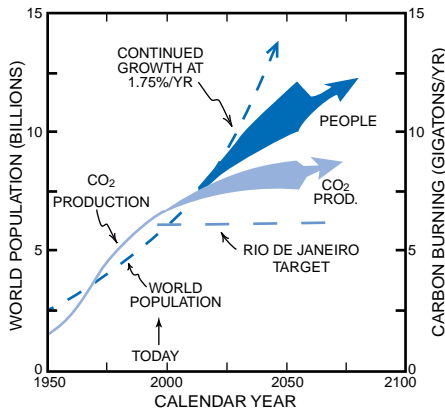


Figure 5. By the middle of the next century, Earth's population will increase to between 10 and 15 billion, and the demand for energy will rise. It will likely reach at least 7.5 gigatons of carbon per year by the mid-21st century. Rio de Janeiro Target refers to the number proposed at the 1992 Earth Summit (see text).

Greenhouse continued from p. 5

rate of 1.75% each year. If this continues, by the middle of the next century, population will reach the staggering level of 14 billion. Most predictions suggest that declining birth rates will ease somewhat this potentially desperate situation. Nevertheless, we're headed for a population of at least 10 billion people (see Fig. 5). At just the time we expect sizable greenhouse warming impacts, we'll have at least five billion more people to feed than we do now. That is an enormous challenge, even in the absence of a climate change.

The amount of CO₂ we produce depends on (1) how many people there are and (2) how much energy they use. The poorer people on Earth will seek a better standard of living, and that will require more energy. Almost all of our energy now comes from burning fossil fuels and therefore involves adding CO₂ to the atmosphere. The hope expressed at the UN Conference on Environment and Development (Earth Summit; Rio de Janeiro, 1992)

was that the production rate of CO₂ could be held to its 1990 level, but the production rate has already risen well above that level. Some politicians believe that the Earth Summit goal is achievable, but I don't. I suspect that we are going to generate 7 gigatons or more of carbon as CO₂ every year. At this rate, the CO₂ content of the atmosphere will rise at the rate of about 2 ppm per year (Fig. 6).

The CO₂ content of the atmosphere will continue to increase; how much it increases depends on many variables. Maybe there will be a miracle, and we'll find some alternate energy source that is socially acceptable and economically fundable. I have little doubt, though, that late in the next century, the CO₂ content of our atmosphere will reach 560 ppm, twice the preindustrial level. Before we're free from dependence on fossil fuels, we'll probably drive the CO₂ up to 700 ppm or more.

For this rise in CO₂, models yield a range of global warmings, because they differ in the extents of water-vapor feedback. As already stated, were there no such feedback, the warming would be only about 1.2 °C and would not produce much difficulty. If the warming were 3, 4, or 5 °C, as some models predict, then everybody would agree that there would be big trouble.

What I've injected into this already complicated situation is the realization that in the past, climate changes haven't come gradually. Whatever pushed Earth's climate didn't lead to smooth changes, but rather to jumps from one state of operation to another. So the question naturally arises, What is the probability that through adding CO₂ we will cause the climate system to jump to one of its alternate modes of operation? I contend that since we can't yet reproduce any of these jumps in computer simulations, we don't really know how many modes of operations Earth has, and we certainly don't have any idea what it might take to push the system from one mode to another. We do know, however, that a substantial

warming would surely reduce the density of polar surface water and thereby tend to cut off deep ventilation. So we're entering dangerous territory and provoking an ornery beast. Our climate system has proven that it can do very strange things. Since we've only recently become aware of this capability, there's nothing concrete that we can say about the implications. This discovery certainly gives us even more reason to be prudent about what we do, though. We must prepare for the future by learning more about our changeable climate system, and we must create the wherewithal to respond if the CO₂-induced climate changes are large, or, worse yet, if they come abruptly, changing agricultural conditions across the entire planet. We must think all this through. Even if there is only a 1% probability that such a change might occur during the next 100 years, its impact would be sufficiently catastrophic that the mere possibility warrants a lot of preparation.

My lifetime study of Earth's climate system has humbled me. I'm convinced that we have greatly underestimated the complexity of this system. The importance of obscure phenomena, ranging from those that control the size of raindrops to those that control the amount of water pouring into the deep sea from the shelves of the Antarctic continent, makes reliable modeling very difficult, if not impossible. If we're going to predict the future, we have to achieve a much greater understanding of these small-scale processes that together generate large-scale effects.

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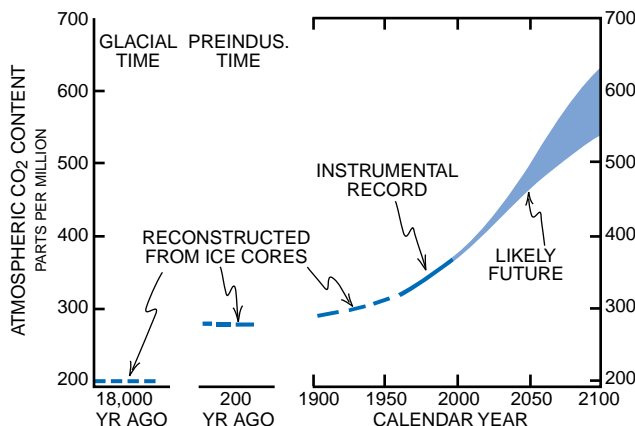
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Figure 6. During the last glacial period, the CO₂ content of our atmosphere was only 200 ppm. Upon deglaciation it rose to about 280 ppm and hovered at about this value until the onset of the industrial revolution. Owing mainly to fossil-fuel burning, the level has risen over the past 100 yr to the current 365 ppm. This rise will continue, reaching double the preindustrial value by the end of the next century.



Greenhouse continued on p. 7

Call for Nominations

The EDUCOM Medal

The EDUCOM Medal was established in 1994 to improve the quality of the undergraduate learning experience and to promote the effective use of information technology in higher education. Each year, Educom partners select disciplinary societies, whose representatives select a winner. This year, Educom has chosen GSA as a partner in selecting an individual who has made a significant contribution to transforming undergraduate learning in geology through information technology. Educom will provide the winner with a check for \$2,500, a silver medal, a bronze desk statue, and travel expenses to participate in the awards presentation at the Educom annual meeting October 28–31 in Minneapolis, Minnesota.

Eligibility

Awards are made to individuals rather than to the institution, publisher, or organization to which they may belong. The award program is limited to technological applications used by undergraduate students and includes all forms of information technology used in undergraduate instruction, e.g., computer software, telecommunications networks, video applications, etc. To be considered for an award, the technological application should:

- address a significant pedagogical problem fundamental to the discipline (e.g., sustainable and scalable applications would be more favorably regarded than those representing a singular effort applicable in only one instructional setting);
- provide an innovative solution offering clear advantages over other techniques (e.g., alternative instructional delivery models

or new instructional environments that incorporate information technology which may offer advantages over traditional instructional models in such areas as increasing student access to and acquisition of a particular subject matter, improving the cost-effectiveness of undergraduate instruction, encouraging collaborative learning, or enhancing communication between students and faculty);

- demonstrate substantial impact on improved student learning (e.g., demonstrations of substantial impact may include evidence of accelerated learning, significant numbers of students affected, improved learning outcomes, or increased cost-effectiveness compared to traditional approaches).

How To Nominate

Nominations for the award must include:

- a brief biographical sketch, such as used in *American Men and Women of Science* and *Who's Who in America*,
- supporting letters from five scientific educators in addition to the person making the nomination,
- a summary of the candidate's contribution to the transformation of undergraduate learning in geology through information technology, with special attention to the criteria listed above.

The deadline for receipt of nominations at the office of the Executive Director, is **June 15, 1997**. Send nominations to: Donald M. Davidson, Jr., Geological Society of America, P.O. Box 9140, Boulder, CO 80301.

Greenhouse *continued from p. 6*

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Manuscript received February 6, 1997; revision received March 12, 1997; accepted March 12, 1997 ■

Each month, *GSA Today* features a short science article on current topics of general interest. For guidelines on submitting an article, contact
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(607) 255-4701, fax 607-254-4780,
E-mail: kay@geology.cornell.edu.

Bromery Honored by National Academy of Sciences

Randolph W. (Bill) Bromery, a past president of GSA and recently retired chair of GSA's Second Century Fund campaign, was honored at the 1997 African-American History Program cosponsored by the National Academy of Sciences, the National Academy of Engineering, the Institute of Medicine, and the National Research Council. A portrait of Bromery joins those of such luminaries as Ralph J. Bunche, George Washington Carver, William E. B. DuBois, and Daniel Hale Williams in the NAS collection of distinguished African Americans in science, engineering, and medicine. Bromery is the first earth scientist to receive such recognition.



The presentation cited Bromery's 45 years of service in higher education and government with the U.S. Geological Survey, the University of Massachusetts, Westfield State College, and Springfield College, where he is now president. Bromery is an alumnus of Howard University, of Johns Hopkins University, which recently bestowed upon him its distinguished alumnus award, and the celebrated Tuskegee Airmen of the U.S. Air Force.

About People

GSA Fellow and former president and Foundation trustee **Peter T. Flawn** has been named interim president of the University of Texas, Austin.

Fellow **Richard E. Gray**, GAI Consultants, Monroeville, Pennsylvania, has received the Society for Mining, Metallurgy, and Exploration (SME) Distinguished Member Award.

GSAF UPDATE

Valerie G. Brown, Director of Development, GSA Foundation

FOR IMMEDIATE RELEASE

GSA's Fund Raising Program: Another Successful Year

Last month we highlighted two important gifts to GSA.

This month we highlight the 1,228 other special donors who collectively gave **\$958,056** in 1996.

To each of those donors—and you know who you are: Please give yourself a big pat on the back and accept the heartfelt thanks you so richly deserve.

All added up, the outstanding generosity of GSA's members and friends has produced total contributions of **\$8,244,194** since the kick-off of the Second Century Fund campaign in 1992.

The 1996 gifts reflect the wonderful diversity of this enterprise:

- **Some are unrestricted**, given with the thought that GSA's leadership can apply the revenue to the activities that will best profit from supplemental assistance.
- **Some are directed to existing funds**, adding to what is available for research awards, recognition of professional excellence, student travel grants, SAGE's educational outreach, or IEE's environmental initiatives.
- **Some are invested in creation of new funds**, sowing seeds in GSA's fertile program agenda.
- **Some are given in memory** of deceased colleagues.
- **Some are given in honor** of productive and eminent colleagues.

All are given from commitment to advancing the geologic sciences and promoting their application to thoughtful stewardship of Earth.

This month's bumper sticker: *The world stands on three foundations—on study, on service, and on benevolence.*

GSA Foundation
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Digging Up the Past

Most memorable early geological experience:

R. C. Moore's 1958 GSA Presidential Address (in St. Louis, Missouri). A sharp earthquake punctuated the middle of his talk, which was devoted to demonstrating that the earth's crust was geologically stable. Although the humorous event was featured in the cartoon strip "Pogo," Moore was not entertained.

—Stanley N. Davis



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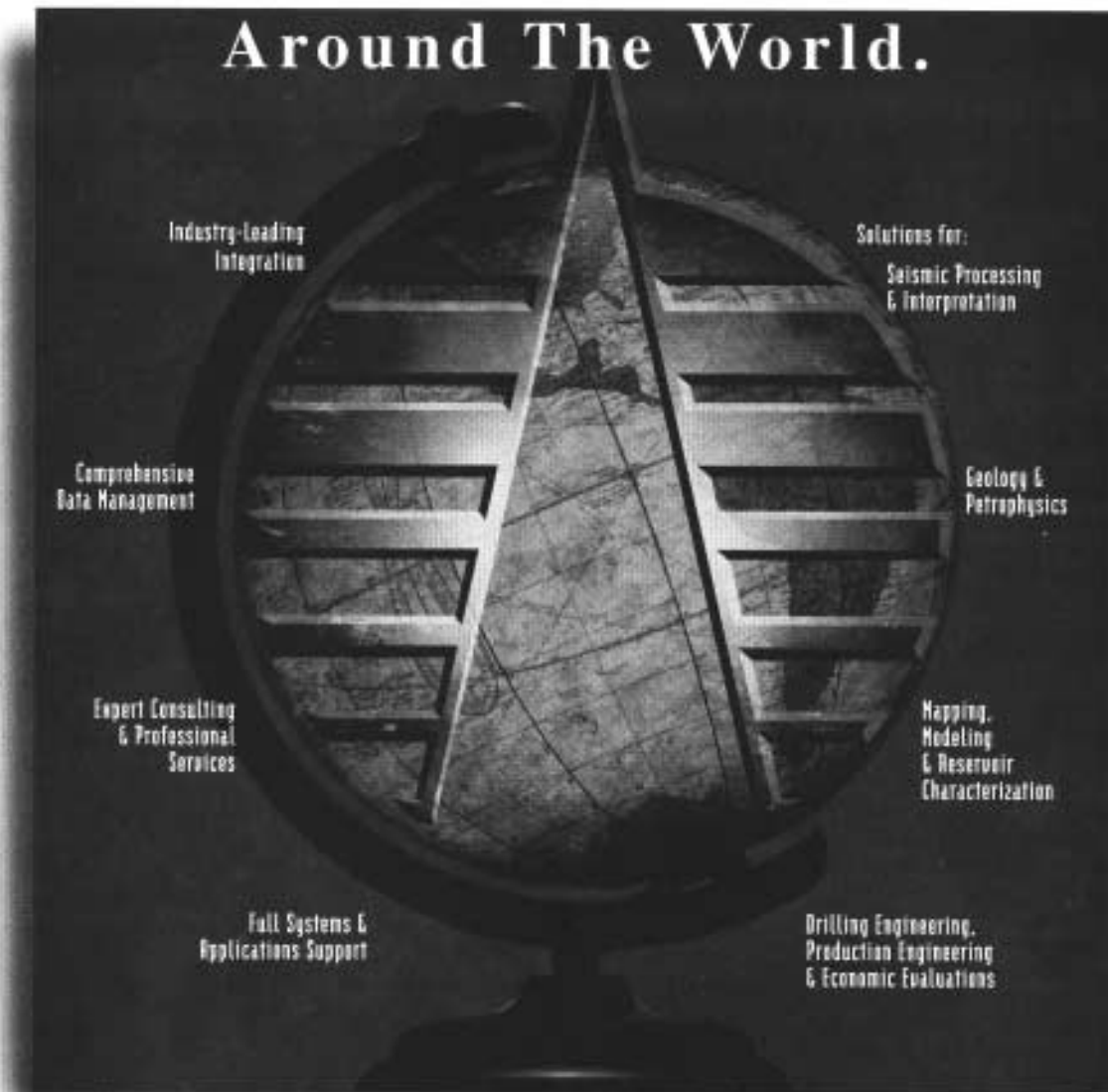
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Annual Meeting Costs—A Perspective

Donald M. Davidson, Jr., Executive Director
Sue S. Beggs, Meetings Manager

Given the increases in costs for most goods and services, it's no surprise that costs for the GSA Annual Meeting are rising. How is the Society dealing with this escalation?

GSA strongly believes that it is essential to provide cost-effective venues for the Annual Meeting, particularly as most of the membership faces restricted travel budgets. Thus, the issue of cost containment is paramount. However, many complex factors directly affect costs or limit GSA in the delivery of services.

Our goals have been to have the Annual Meeting at least break even financially, to keep professional registration fees as low as possible, and to significantly subsidize student fees. The good news is that between 1986 and 1995 revenues exceeded expenses 50% of the time. The disturbing news is that losses over that same time frame are of greater magnitude than surpluses.

Registration Fees: 10 Year Overview (1986–1995)

Attending the GSA Annual Meeting currently costs about \$1,000 for a "typical" professional member, including registration, airfare, hotel rooms, meals, and other expenses. Of this amount, \$195 was the actual advance professional registration fee in 1996.

Attendees inquire, Why can't GSA lower registration costs, now near the \$200 level? The reason is simply that over the past decade, expenses for the Annual Meeting have increased an average of 97%, whereas revenues have increased 91%. As nonregistration-related income and expenses can be tightly controlled and predicted, GSA must meet in locations that will generate a sufficient number of *paid* registrations to cover related meeting costs, for the meeting to break even every year. Accurately predicting and attracting those registrations relative to related costs ultimately determines the economic outcome of annual meetings.

Total attendance at the Annual Meeting has averaged 5,500 in the past 10 years; however, there is a significant difference between *total* and *paid* registrations. The reality is that paying registrants have averaged just 83% of the total. (The majority of the nonpaying registrants are exhibitors and student assistants who work at the meeting.) For example, in 1995, of the 5,115 total registrants, 4,255 paid registration fees. Moreover, registration revenues represent but 55% of the total meeting income. The remaining 45%

is derived from exhibitors, year-round continuing education programs, and various GSA Meetings Department services.

Another important factor is that registration revenues represent a mix of fees. Not everyone pays the advance professional member fee. While it's true that nonmembers and on-site registrants pay \$40 more, 26% of the registrants pay less. These are the student registrants, who currently pay 36% of the professional fee (\$70 in 1995 and 1996), as well as K–12 teachers, who pay a token fee. As a result, while the student fee has gone from \$40 to \$70 (75% increase), professional fees have increased by more than 100% to help cover the difference.

GSA Annual Meetings held in the U.S. Southeast and mid-continent have not covered registration-related expenses. Although these locations are less expensive both for GSA and for attendees, they do not attract a sufficient number of paying registrants to break even. Thus, GSA has underwritten meetings in these areas because it was deemed important to rotate the meeting around the country.

Registration fees for GSA Section Meetings have escalated considerably over the last decade also.

SECTION PREREGISTRATION FEES
1986 TO 1995

	1986 \$	1995 \$	Change
Cordilleran			
Member	40	60	50%
Student	10	20	100%
North-Central			
Member	25	45	80%
Student	7	20	186%
Northeastern			
Member	12	60	400%
Student	5	20	300%
Rocky Mountain			
Member	30	55	83%
Student	8	10	25%
South-Central			
Member	25	45	80%
Student	9	15	67%
Southeastern			
Member	25	55	120%
Student	9	15	67%

These fees are set by the Sections, not by headquarters.

Annual Meeting Costs

Why have Annual Meeting costs escalated by almost 100% over the past 10 years? A major reason is that costs for

contracted services (13% of total expenses) have increased 500%. These services include building security, ADA compliance, projectionists, and short-course contracts. GSA is now legally required to provide some of these services. Freight and shipping costs have also increased 500%. Holding the meeting in Denver every third year will keep costs down over time because GSA headquarters is in nearby Boulder, Colorado. Costs of printing, including meeting notices, programs, and signage, have gone up 160%, a bit less than the amount of increase in facilities rentals (180%). Moreover, equipment rentals, mainly projection equipment and computers, have escalated significantly (140% and rising), and charges for acceptance of credit cards were virtually nonexistent 10 years ago. Such cost increases account for the net increase of 100%+ since 1986.

If you find yourself comparing the Annual Meeting costs to those of other meetings (such as GSA Section Meetings), remember that the GSA Annual Meeting no longer fits into a central hotel or campus setting, nor does it meet in the industry off-season. Given the current number of attendees and vendors, GSA must hold its Annual Meeting in a facility that has 210,000–225,000 square feet of exhibit and meeting space. We have traditionally met when demand for hotel rooms is at a peak (October), and we pay a premium for the privilege. Moreover, because GSA has a majority of academic members (read: "nonbuying"), industry support for the Annual Meeting historically has not been robust (compared to, for example, AAPG).

Since 1986, the number of groups needing services has increased significantly: 17 vs. 7 associated societies and 12 vs. 8 divisions. Growth in activities also includes management of short courses and field trips as well as about 250 business and social events at the meeting. These concerns are in addition to the technical program, which has increased from 1,865 presentations in 1986 to 2,880 in 1996, and from 12 concurrent sessions to 18. To handle these increased services, one full-time position, a minimal increase, has been added to the Meetings Department staff at headquarters.

Hotel Costs

Lodging costs are a major factor for attendees at an annual meeting, and the price of hotel rooms is a major issue for all nonprofit organizations that hold major meetings. The GSA Meetings Department

ANNUAL MEETING EXPENSE COMPARISON

	1986 San Antonio 4,452 registrants	1995 New Orleans 5,115 registrants	Notes
Contracted Services: Student Projectionists, Security, Temps	\$9,973	\$20,564	<i>Increased number of sessions and events</i>
Equipment Rental: Computers, A-V, Poster and Exhibit Booths	\$43,843	\$68,554	<i>Increased number of sessions and quantities and types of equipment</i>
Contracted Labor: Projectionists, Union Labor	\$59,718	\$87,136	<i>Increased number of sessions, more equipment, and higher service rates</i>
Credit Card Fees	\$0	\$18,053	<i>Charges to GSA by credit card companies</i>
Printing	\$25,366	\$57,818	<i>GSA Today, program, various printed materials</i>
Direct Postage	\$3,314	\$9,327	<i>Nonpublications mailings, including speaker kits, fliers, programs</i>
Shuttle	\$3,783	\$29,709	<i>City specific</i>
Facilities	\$11,633	\$28,450	<i>Convention center rental</i>
Meetings Headquarters, Direct and Indirect Costs	\$278,808	\$615,083	<i>Direct operations and labor plus indirect costs</i>

is responsible for negotiating room contracts five to six years prior to the meeting and has usually succeeded in getting a 30% or better group-rate reduction below the "standard" hotel rate. Even so, the GSA weighted average room rate (room rate and number of rooms at that rate) has risen from \$72/night to \$107/night (48% increase) over the past 10 years. Such increases are typical for major North American venues.

It is interesting that hotel profits slumped from 1979 to 1991, when room supply generally exceeded demand by 3%–5%. Hotels stopped building, and room inventory leveled. However, since 1991 demand has exceeded supply so hotel rates have risen, owing especially to an increased corporate market. This means that (1) the private sector market is more lucrative than ever, and (2) the association market looking for deep discounts is not as attractive to hotels. In the popular months, rooms are offered at the highest rates, and associations no longer benefit from previously customary discounts.

GSA has handicapped itself by holding its Annual Meeting during a peak period for the hotel industry (October). Some key hotels will no longer book educational groups during such peak seasons unless the membership is willing to pay comparable rates. Hotels now insist on contracts that bind groups to producing specific revenues, and severe penalties await groups that promise a particular level of hotel-room occupancy but do not deliver. Penalties for cancellation or shortfall can cost GSA amounts in six figures, a significant risk—and one borne unilaterally by GSA. This has resulted in ever more complex hotel negotiations as GSA tries to meet the needs of its attendees for both room rates and dates, while working within a totally changed hotel

negotiating environment. The Annual Meeting scheduled for Boston in 2001 nearly fell through over hotel contract issues. Two other venues *did* fall through (Nashville and Phoenix).

Hotels are now implementing extra charges for early departure and for changes to meeting room setups—charges that may affect GSA members or associated societies and divisions, and not just at GSA gatherings! Have you already been dismayed by a \$0.75 charge to make a local phone call from your room or a \$2 surcharge for delivery of a cup of coffee?

Another issue is why GSA cannot reserve student housing. This idea, while noble in concept, is currently nearly impossible to implement. GSA makes a major effort to provide a spectrum of lodging opportunities at the most reasonable rates we can negotiate in each host city. Some of the best rates are at properties miles from the convention center, making shuttle costs prohibitive and private or public transportation necessary. In addition, there is currently no way we can control the "first-come" reservation queue for low-cost accommodations. We have offered camping and room-share services, only to find out that students would rather share closer-in accommodations with faculty members or friends. Also, because we meet when educational institutions are in session, campus housing is not available.

Airfare

Good news here: for many locations, airline markets have been highly competitive. Low fares via Saturday night stay-overs and travel on other favored days, advance purchase, pennywise routing, and use of small airlines are more available than ever. In fact, one can travel for the

same dollar amount today as in 1986 (less, if inflation is considered). Of course, last-minute reservations and noncompetitive routes are significantly more expensive.

The Ultimate Question

A major question must be addressed by GSA and its Annual Meeting attendees alike: **Does the GSA Annual Meeting provide you with sufficient personal and professional benefits to make it worth your time and money to attend?** This is not only a question of cost, but also a matter of perceived value. Numerous professional groups are bidding for your annual meeting interest and dollars (AGU, AAPG, AEG, Soils Science Society, and NGWA, among others). Thus, even though GSA has a strong following among its members and attendees, the Society can never take this for granted. Not only must GSA provide a cost-responsive event, but we must also find the best possible ways to deliver a user-friendly environment for scientific exchange that is of value to you, the consumer. When you ask yourself, "Is the GSA Annual Meeting worth it?," the answer must definitely be "Yes."

Where Do We Go From Here?

GSA shares the primary concern of over 87% of the various 700 member organizations polled by the American Society of Association Executives—*keeping meeting costs affordable for attendees*. The GSA Meetings Department strives to meet its obligation of keeping the Annual Meeting affordable while simultaneously responding to the expectations of its well-educated membership. On the question of perceived value and vitality of the scientific program, the newly formed Annual Program Committee, chaired by Sharon Mosher (University of Texas, Austin), considered this matter in depth in a meeting on March 1 and 2, 1997. This committee will recommend some substantial changes that they believe will make the GSA Annual Meeting even more valuable to the scientific community. Some of the changes will take effect as early as the Salt Lake City meeting. Others are charted for 1998. You will be hearing more about these changes in future issues of *GSA Today*. Stay tuned.

In the meantime, feel free to write, call, or E-mail us:

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Buzzwords and Debate About the Human Future

Arthur H. Lachenbruch, U.S. Geological Survey (Emeritus), Menlo Park, California

Increasing concerns over the future of people on Earth have sparked scholarly research in the social and natural sciences, a heightening of political debate, and an increased need for concerned lay people and specialists of many kinds to talk to one another to decide how to address these concerns. In such discussions we inevitably abstract words or phrases that allow us to convey recurring themes simply and conveniently, without elaborating arcane details or invoking vocabulary that is not shared by the broad range of participants. The resulting buzzwords—e.g., “environmental change,” “ozone hole,” “global change,” or “sustainability”—play an indispensable role in developing the public awareness needed for action on global issues. But the convenience of these buzzwords comes at a price. They are usually uprooted from a reasonably well defined technical context, and as their usage broadens or shifts, they can become ambiguous, and poorly understood, or

tinged with marginal meanings and emotional content. Once buzzwords become established, they can influence the questions we ask and alter the nature of the debate itself. Here we consider the important role of buzzwords and the types of messages they are called upon to convey in the debate about our future.

Effective action to deal with perceived threats to the human future can depend on whether the peoples of Earth believe that the threats are real. But survival in a poorly understood world has taught people to test threatening predictions with two questions: “Why should I believe that?” (or “who says?”) and “What does it mean for me?” (or “who cares?”). If, as is often the case, the threat involves a predicted change in the physical, chemical, or biological environment for life, the two parts of the test of the threatening message are: (1) the “who-says?” part, involving the credibility of a predicted change in the (physical) environment for life, and

(2) the “who-cares?” part, involving the importance of the predicted change to things people value.

In some respects, this “who says? – who cares?” division separates the concepts to be communicated—whether by buzzword or more extensive discourse—in a rather natural general way. The first critical question finds most of its answers in the natural sciences, and the second ultimately involves the social sciences. Each question addresses a different aspect of human involvement (the first as an agent of change, the second as a victim or beneficiary of it—the two human roles are interactive, but logically distinct).

An example of a widely used buzzword that often deals with the “who-says?” question (i.e., with prediction of environmental change and its scientific justification) is “global change.” The term generally conveys a useful and only recently appreciated perspective that the environment for life on Earth is controlled by an ever-changing, interacting Earth system of enormous complexity, in principle describable by a continuum of virtually all of the natural sciences (U.S. Committee for an International Geosphere-Biosphere Program, 1986). “Global change” encompasses prediction of both natural and anthropogenic changes in the Earth system, a proper subject for empirical science

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as long as the physical inputs or "forcing" are understood. The principal ambiguity in the "global change" buzzword lies in the scales of time and space implied by "global," and in the relative roles of physical and social sciences (with growing emphasis on the latter) in defining its subject matter (Stern et al., 1991; National Science and Technology Council, 1995).

An example of a widely used buzzword associated largely with the "who-cares?" question (that regarding the impact of predicted change on things people value) is "sustainability." If we want to sustain something, we generally value it, and what we value we want to sustain. In the present anthropocentric context, "sustainability" often deals with the extent to which people can continue to meet their needs from a particular beneficial service, resource, product, or amenity, as the environment that provides that benefit undergoes "global change." In this sense "sustainability" deals largely with the viability of people and their institutions under the anticipated impact of changing conditions. The principal ambiguity in this useful term comes from the need to specify what we propose to sustain and for how long—one or both are often left unspecified. The problem is compounded in related buzzwords like "sustainable growth" or "sustainable development" (discussed below). To the extent that the added noun carries the connotation of physical growth, it contributes a measure of self-contradiction to the existing ambiguity.

When establishing research priorities and programs to deal with global change, the "who-cares?" question can provide a simple pragmatic test of whether any such activity is likely to receive the needed political support. But political support for research, whether concerning environmental predictions or their societal significance, will depend, among other things, on an informed public; people won't "care" if they don't know (they may or may not care if they do). For reasons discussed earlier, informing the public is likely to involve communication by buzzword, and in this sense buzzwords become vital links in the debate about our future. If their technical meaning becomes unclear and ambiguous, they can seriously encumber the communication.

To illustrate some of these points, we consider the example of "sustainable development," a widely used buzzword mentioned above in connection with "sustainability." Although influential political and scientific panels and boards, international conferences, and countless symposia bear its name, there is considerable lack of agreement over just what "sustain-

CALL FOR ABSTRACTS



IEE is sponsoring or cosponsoring the following theme sessions at the 1997 GSA Annual Meeting in Salt Lake City. Each of these provocative, interdisciplinary sessions seeks to integrate geoenvironmental insights into broader scientific and societal contexts. For information on submitting abstracts, see the April or forthcoming June *GSA Today* or visit the GSA website at www.geosociety.org.

Concepts in Geocology and Ecosystem Management: Applying New Knowledge from the Interface of the Life and Earth Sciences.

Successful restoration and protection of ecosystems requires development and application of geocological principles. This session will explore how the feedback between geologic and biological processes influences ecosystem dynamics, with an emphasis on work that defines the physical parameters of ecosystem function and structure. Convened by Cathleen L. May, USDA Forest Service; Kenneth Kolm, Colorado School of Mines. (Theme Session T6)

Conservation Geology: Restoring and Maintaining Earth's Ecosystems.

Geologists are now often faced with the task of conservation rather than exploration and extraction of natural resources. This includes restoring or maintaining the structure and function of geologic systems and processes for humans and other species. Topics will include conservation and restoration of riparian areas and wetlands, restoration of surface- and ground-water quality and quantity, and landscape restoration. Convened by Abraham Springer, Northern Arizona University. (T7)

The Geosciences in Context: Values, Sustainability, Culture, and Curricula.

The earth sciences today find their work inescapably linked to a larger cultural context. How are we to integrate science and values? What values are implicit within the scientific enterprise itself? What implications does an earth science perspective have for ethics, politics, sustainability, economics, and other aspects of our culture? Convened by Paul H. Reitan, SUNY, College at Buffalo; Robert Frodeman, Fort Lewis College; Trileigh Stroh, Seattle University. (T39)

The Sustainability Challenge: A Problem in Geoscience Communication.

The challenge of attaining global sustainability is often misunderstood by the public and policy makers, because these communities lack knowledge about fundamental geoscientific concepts. This session explores how successful communication of such concepts through dialogue with nonscientists can catalyze public understanding about sustainability and help to stimulate effective social action. Cosponsored by the GSA Ad Hoc Committee on Critical Issues. Convened by Allison R. Palmer, Institute for Cambrian Studies, Boulder, Colorado. (T40)

Natural Background Chemistry and Environmental Decision-making.

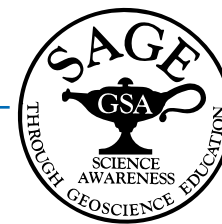
The characterization of natural background chemistry affects decision-making in such areas as regulatory affairs, agriculture, epidemiology, risk assessment, water supply, and geochemical exploration. Regulatory and environmental decisions that fail to consider natural background chemistry run the risk of being seriously flawed. This session will bring together people from disciplines and sectors that have a stake in characterizing natural background chemistry. Cosponsored by the International Association of Geochemistry and Cosmochemistry. Convened by Donald D. Runnells and Georgia A. Doyle, Shepherd Miller, Inc., Ft. Collins, Colorado. (T41)

Environmental Impacts on Western Rivers.

Human activities in the western United States have impacted rivers since beaver trapping in the early 1800s. Activities within the watershed (lumbering, agriculture) and within the channel (placer mining, flow diversion) alter the movement of water and sediment, causing adjustments in channel morphology. This session addresses the regional cumulative impacts of human activities. Cosponsored by the Quaternary Geology and Geomorphology Division. Convened by Ellen Wohl, Colorado State University. (T45)

Influence of Geomorphic Processes on Biological Communities.

Recent collaborative research indicates the importance of geologic processes to biological communities. This research is important for ecosystem management. Examples of these interactions include the effects of river flow regimes on benthic and fish communities, associations among wetland species and hydrological conditions, and the relationships among hillslope processes and forest ecosystems. This theme session will highlight these and many other collaborative research projects. Cosponsored by the Quaternary Geology and Geomorphology Division. Convened by Karen L. Prestegard, University of Maryland. (T47)



How Do Our Students Compare?: A Look at the Third International Mathematics and Science Study

Many of us are interested in how students in the United States of America compare in science and mathematics achievement with students from other countries. Are our students in the top group of achievers? Are we making progress toward our goal of being first in the world in mathematics and science by the year 2000, or are our students falling behind the rest of the world? While these are interesting questions, we should keep in mind that standardized achievement

test data alone cannot help us know what we are doing well or how we can improve our children's education.

To bring *GSA Today* readers up to date on the latest international comparisons, I have selected excerpts from the executive summary of the *Third International Mathematics and Science Study (TIMSS): Science Achievement in the Middle School Years*, and U.S. National Research Center, Report No. 7 (Dec. 1996) to share with you. Most of these excerpts are direct

quotes from the reports. I have done some minor editing and rearranging of TIMSS observations, but the interpretations and comments are primarily those of the TIMSS authors. If you would like information on how to order a copy of the TIMSS Science Achievement report or other TIMSS documents, please call (617) 552-4521, the TIMSS International Study Center, Chestnut Hill, Massachusetts.

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able development" means. With value-laden uncertainty over whether it represents a "means" or an "end," popular interpretation of it has ranged from "sustaining development" to "developing sustainability." A likely reason for its widespread acceptance is that ambiguity in the definition of "development" (Daly, 1991) permits the view that "sustainable development" offers the seemingly contradictory goals of "sustainability" for the environmentalist, and of endless "development" for the economic community. At one extreme, "sustainable development" (like another timely if more understandable buzzword: "safe sex") promises a coveted end without feared side effects. In our quest for "sustainable development" it is possible to lose sight of the fundamental human problems we are trying to solve with it. Observations on the contemporary state of global society, like those of Kaplan (1994), suggest that there are two rather distinct problems with different goals and time scales: (1) achieving an equitable (politically sustainable) society, largely in a few generations; and (2) sustaining that society, presumably for tens or hundreds of generations. Here again the "sustainable development" rubric can be misleading because the "development" urgently mandated by the shorter term equity problem is not likely to be "sustainable" or appropriate in the context of the long-range problem.

In defense of broadly ambiguous, if not self-contradictory, buzzwords like "sustainable development," it might be

argued that they have the political advantage of enlisting widespread support among people with widely divergent or even opposing interpretations of the term, but they do so at the risk of obscuring the technical issue that must be debated in the public interest. Not all buzzwords in the debate about our future have as many problems as the foregoing example, which combines words whose popular meanings may be contradictory on some time scales. The potential for misunderstanding can be reduced by choosing more easily understood substitutes. If the report that popularized "sustainable development" (World Commission on Environment and Development, 1987) had, instead, called for the broadly related but less self-contradictory goal of a "sustainable society," with its necessary conditions such as a "sustainable economy," "sustainable resource use," and perhaps "equitable development," many but not all of the semantic problems would have been avoided. As discussed above, even without conflicting word combinations confusion can, of course, remain, unless buzzwords are used with a consistent context that provides guidance on where in the broad range of subject matter and scales of time and space these words are being applied.

It is customary for scientists to downplay questions over word usage—e.g., should "development" imply no increase of scale in the use of physical resources? (see Daly, 1991)—because they can be disposed of by agreement without affecting substantive debate in a rational technical forum. It is important to remember, however, that much of the communication

that reaches the lay public does not occur in such a forum—it comes in "sound-bites" containing buzzwords whose connotation carries the message. It is likely that these buzzwords will continue to play an important role in developing the public awareness needed for action on global issues. In the interest of productive discussion, we should choose buzzwords and use them with care, mindful of their potential for obfuscating the message we wish them to communicate, whether it concerns a prediction of physical change or the importance of the change to people.

ACKNOWLEDGMENTS

I thank the large number of thoughtful friends and colleagues who made helpful comments on a draft. Needless to say, they did not all agree.

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“Some Commonly Held Myths Addressed

“When discussing why U.S. education in general and science education in particular is not as good as in other countries, several common misconceptions exist. For example, it has been suggested that U.S. student performance would improve if they would watch less TV or do more homework. Others have suggested that U.S. schools should be in session for longer periods of time or that U.S. teachers should have more education, or that diversity and discipline problems are greater in the U.S. Findings from the TIMSS report suggest that these factors, while of some influence, may not be as important as most people believe. TIMSS found the following:

- “Heavy television watching is as common among Japanese eighth graders, who do better than U.S. students, as it is among American eighth graders.
- “U.S. teachers assign more homework and spend more class time discussing it than teachers in Japan.
- “U.S. students are required to spend more time in mathematics and science classes than either German or Japanese students.
- “U.S. students report about the same amount of out-of-school math and science study as their Japanese and German counterparts.
- “U.S. teachers of math and science have more college education than their colleagues almost anywhere in the world.
- “Working with students of different academic abilities is just as much of a challenge to Japanese and German teachers as it is to U.S. teachers.”

“What is TIMSS and what can we learn from it?

“Since its inception in 1959, the International Association for the Evaluation of Educational Achievement (IEA) has conducted a series of international comparative studies designed to provide policy makers, educators, researchers, and practitioners with information about education achievement and learning contexts. The Third International Mathematics and Science Study (TIMSS) is the largest and most ambitious of these studies ever undertaken.

“Conducted between 1991 and 1995, TIMSS assessed more than 500,000 students, at ages 9, 13, and 18 in more than 40 countries. To learn about curriculum, more than 1600 curriculum frameworks and textbooks were analyzed. Teachers were surveyed about what they teach, how they teach, and why. In three countries, classrooms were videotaped, and case studies of educational context were conducted.... Because the home, school, and

national contexts within which education takes place can play important roles in how students learn science, TIMSS collected extensive information about such background factors.

“Five content dimensions were covered in the TIMSS science tests given to middle-school students: earth science, life science, physics, chemistry and environmental issues, and the nature of science. Approximately 75% of the science items were multiple choice. About one-fourth of the questions were in free-response format requiring students to generate and write their answers. These types of questions, some of which required extended responses, were allotted approximately one-third of the testing time. The results provided in this report describe student’s science achievement at both the seventh and eighth grades.

“Student Science Achievement: Major Findings

- “Singapore was the top-performing country at both the eighth and seventh grades. The Czech Republic, Japan, and Korea also performed very well at both grades. Lower-performing countries included Colombia, Kuwait, and South Africa.
- “Perhaps the most striking finding was the large difference in average science achievement between the top-performing and bottom-performing countries.

“[This] study ... found that current U.S. curricular standards [for science and math] are ... a mile wide and an inch deep.”

For example, at both grades, average achievement in top-performing countries was comparable to or even exceeded performance for 95% of the students in the lowest performing countries.

- “In most countries and internationally, boys had significantly higher mean science achievement than girls at both the seventh and eighth grades. This is attributable mainly to significantly higher performance by boys in earth science, physics, and chemistry. In few countries were significant gender differences found in life science or environmental issues and the nature of science, although in life science one such difference favored girls in one country at the eighth grade.

“Students’ Attitudes Towards Science

- “Even though the majority of eighth-graders in nearly every county indicated they like science to some degree, clearly

not all students feel positive about this subject area.

- “In all except three of the countries, the majority of students agreed or strongly agreed that they did well in science or science subject areas—a perception that did not always coincide with the comparisons in achievement across countries in the TIMSS test.
- “In the majority of countries, for eighth-grade students, pleasing their parents and getting into their preferred university or secondary school were both stronger motivators for doing well in sciences than was getting their desired job.

“Home Environment

- “In every country, eighth-grade students who reported having more educational resources in the home had higher achievement than those who reported little access to such resources. Strong positive relationships were found between science achievement and having study aids in the home, including a dictionary, a computer, and a study desk/table for the student’s own use.
- “The number of books in the home can be an indicator of a home environment that values and provides general academic support. In most TIMSS countries, the more books students reported in the home, the higher the achievement.

- “In every country, the pattern was for the eighth-grade students whose parents had more education to also have higher achievement in science.

- “Beyond the one to two hours of daily television viewing reported by close to the majority of eighth graders in all participating countries, the amount of television students watched was negatively associated with science achievement.
- “In most countries, eighth-graders reported spending as much out-of-school time each day in non-academic activities as they did in academic activities.

“Instructional Contexts and Practices

- “The qualifications required for teaching certification were relatively uniform across countries. Most countries require teachers to have four years of post-secondary education.

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- “There was no clear pattern across countries between the number of in-class instructional hours and science achievement.
- “Working together as a class with the teacher teaching the whole class, and having students work individually with assistance from the teacher were the most frequently used instructional practices.
- “Teachers reported using a textbook in teaching science for 95% or more of the students, but reasoning tasks were reported to be very common activities in science classes.
- “Demonstrations of experiments by the teacher were common in almost all countries where science is taught as an integrated subject, as well as in physics and chemistry. In integrated subject classes, a high percentage of students reported doing experiments or practical investigations in class. In countries where science is taught as separate subjects, according to students, teachers performed demonstrations more frequently than students themselves did practical, hands-on work.
- “Most eighth grade students were assigned science homework at least once a week.

“How well did U.S. Students do on the TIMSS tests?”

“The average score of U.S. eighth grade students was somewhat below the international average in mathematics and somewhat above the international average in science. There were no significant differences between the performance of U.S. eighth-grade boys and girls in either mathematics or science. In countries such as Germany, Sweden, Ireland, Canada, and the Russian Federation students performed at a comparable level to the U.S. while students in Singapore, the Czech Republic, Japan, Korea, and other countries performed at a significantly higher level than the U.S. students. It should be noted, however, that many U.S. states have larger populations than some TIMSS countries, and in previous international comparisons, the scores of some states were similar to the highest-scoring nations, while those of other states were about the same as the lowest-scoring nations.

“U.S. Eighth Grade Achievement in Context

“As a nation, the U.S. does not have a single coherent vision of what students should learn through mathematics and science education. The U.S. is atypical among the TIMSS countries in its lack of a nationally—or regionally—defined curriculum. TIMSS’ study of curricula found that current U.S. curricular standards are unfocused and aimed at the lowest common denominator. They are, in other

words, a mile wide and an inch deep. The TIMSS analysis found that, before high school, states in the U.S., on average, intend students to cover more topics in mathematics and science than most of the other countries studied.

“TIMSS data also show that this lack of clear focus is evident in what is taught. Teachers skip among many topics and attempt to cover far more than their German or Japanese counterparts. Topics and concepts are presented in a fragmented and disjointed manner in which the underlying themes or principles are either not identified or simply stated but not developed. In other countries, math and science are presented with greater logical coherence—more as a story line that is developed both within each lesson and across a series of lessons. While a more focused curriculum would probably help to improve the achievement of U.S. students, it should be noted that not all countries that are performing better than the U.S. have a highly focused curriculum.

A Few Personal Observations About the TIMSS Report

The TIMSS report is a powerful document that offers us a glimpse of how we teach science in the United States. To some it will be interpreted as a stinging indictment of what and how we teach science. To others it will offer insights into how we might improve science education for U.S. students by debunking many of the current myths about why we don’t perform as well as other countries in science. What TIMSS tells me is that the problem is not television, nor the amount

of homework assigned to students, nor is it that our science teachers are poorly qualified. Our teachers are, for the most part, well-educated and dedicated professionals who are making a valiant effort to teach what we have asked them to teach. Unfortunately, what we have asked them to teach is everything we know about science. Our science teachers teach more classes and cover more science topics than in most other countries. On average, U.S. teachers teach 30 hours per week, while in Japan teachers teach an average of 20 hours per week. Not surprisingly, U.S. teachers also have less time to discuss teaching-related issues than do teachers in many other countries.

When I sift through the TIMSS data and look for ways to improve U.S. science education, four ideas readily come to mind:

- Encourage all school districts to develop more coherent and focused curricula that are based on the National Science Education Standards.
- Teach fewer science topics in any given year.
- Encourage all students to learn science by doing science.
- Provide additional resources so that science teachers have the time, support, and materials they need to continually improve their teaching and curricula.

While none of these ideas is new, the TIMSS report strongly suggests that unless we find ways to implement them, U.S. student achievement in mathematics and science will not improve to any significant degree. ■

Special Volume on Exhumation Processes: Normal Faulting, Ductile Flow, and Erosion

Editors Uwe Ring (University of Mainz), Mark Brandon (Yale University), Gordon Lister (Monash University), and Sean Willett (Pennsylvania State University) are soliciting papers for a special publication on exhumation processes. The intent is to provide a broad review of frontier research on all processes that contribute to exhumation of deeply seated rocks in ancient and modern orogens. They want papers that (1) review and synthesize knowledge about normal faulting, ductile flow, and erosion in exhumation processes; (2) provide primary data about the relative contributions of these different processes, using information from metamorphic petrology, isotopic thermochronology, structural and kinematic analysis, synorogenic stratigraphy, geomorphology, or paleoelevation analysis; or (3) utilize geodynamic models to examine the interaction between surface processes and tectonic deformation or the role of crustal and mantle instabilities on the growth and collapse of mountainous topography.

The volume will be published as a Special Publication of the Geological Society of London (GSL). Instructions to authors can be found at the following Web site: <http://love.geology.yale.edu/~brandon/exhume.html>. Interested authors should submit proposed titles by June 15, 1997. Manuscripts are due on September 1, 1997. Authors should submit four copies plus a list of suggested referees. GSL has promised to have the finished volume completed by November 1, 1998. Color figures and flyout pages are possible, but the extra expense will have to be covered by the author. All correspondence should be directed to Uwe Ring, Institut für Geowissenschaften, Johannes Gutenberg-Universität, Postfach 3980, 55099 Mainz, Germany; phone 49-6131-392164; fax 49-6131-394769; E-mail: ring@mail.uni-mainz.de.

Exhumation Processes: Normal Faulting, Ductile Flow, and Erosion

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Over the past 25 years, there has been a growing appreciation of the role that tectonic processes play in exhuming metamorphic rocks. This trend began with the discovery of highly attenuated crustal sections in the Basin and Range province and the recognition that attenuation was caused by regional-scale horizontal extension, as manifested by normal faulting. This discovery caused many geoscientists to rethink the role that horizontal extension or, as it is more commonly called, tectonic extension, might play in other orogenic settings. Of particular interest is emerging evidence that tectonic extension might be responsible for exhuming metamorphic rocks within convergent orogens, such as onland thrust belts (e.g., Himalayas, European Alps, Betic Cordillera of southern Spain, Brooks Range of Alaska) and subduction-related convergent margins (e.g., Franciscan of California, Sanbagawa of Japan, Hellenic-Aegean convergent margin of Greece, Hikurangi accretionary wedge of northeastern New Zealand).

We use the term “exhumation” to refer, in a generic way, to all processes that contribute to the unroofing of deeply seated rocks and their rise to the Earth’s surface. There are several exhumation processes. Normal faulting and extensional ductile flow operate within the Earth and are a direct manifestation of tectonic deformation, whereas erosion operates at the Earth’s surface but can be indirectly influenced by tectonically driven changes in topography.

One of the most difficult questions to answer in most orogenic belts, especially the older ones, concerns the relative contributions of these different exhumation processes. Even so, the tectonics community has moved toward a casual consensus that normal faulting is the primary mechanism for exhumation of deeply seated rocks. The most commonly cited evidence is the presence of “younger-over-older” relationships, where large faults, with low to moderate dips, have placed younger rocks on older rocks or lower grade rocks on higher grade rocks and, in the process, have cut out significant thicknesses of stratigraphic or metamorphic section. But recent papers have shown that this type of evidence, by itself, is not diagnostic. Contractional faults can also cut out section if the section was tilted back toward the hinterland prior to faulting. A typical contractional fault would climb upward toward the foreland but would appear to cut downward through the tilted section. Top-to-the-foreland motion would produce the appearance of normal offset where the fault cut through the tilted section. An additional problem is that the total offset and original dip of most crustal-scale normal faults, especially those involving deep crustal rocks, are typically poorly resolved. All of these factors make it difficult to quantify the relative contribution of normal faulting in exhuming deeply seated rocks.

Despite the current preference for exhumation by normal faulting, it is clear that ductile flow and erosion must play

some role. Penetrative deformational fabrics are present in most exhumed mountain belts and provide clear evidence that ductile flow is an important process that can either increase or decrease the rate of exhumation, depending upon whether the flow causes thinning or thickening in the vertical direction. Erosion is also an important exhumational process, as indicated by the large volumes of sediment found adjacent to most contractional orogens.

Within this context, we organized a Penrose Conference to examine all processes that contribute to exhumation of deep-seated rocks in ancient and modern orogens. We started with three broad objectives: (1) to review and synthesize our knowledge about normal faulting, ductile flow, and erosion as exhumation processes; (2) to examine the geologic evidence needed to quantify the relative contributions of these different processes, using information from metamorphic petrology, isotopic thermochronology, structural and kinematic analysis, synorogenic stratigraphy, geomorphology, and paleoelevation analysis; and (3) to examine relevant geodynamic models and their predictions for conditions that might trigger gravitational collapse.

THE CONFERENCE

The conference was held October 9–13, 1996, at the Orthodox Academy of Greece, located near the town of Chania on the island of Crete in southern Greece. It included three days of presentations and two days of field trips. There were 94 participants, 42 from the United States, 15 from England, 13 from Germany, five from Australia, four each from Greece and Canada, three from Switzerland, and one each from France, Israel, Japan, The Netherlands, New Zealand, Norway, Poland, South Africa, and Spain. The participants included 16 Ph.D. students. The conference had a relatively large number of women participants, 13 professionals and 9 students, marking a positive trend

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Doug Burbank	Marnie Forster	Carl Jacobson	John P. Platt	Colin Stark	Donna L. Whitney
B. Clark Burchfiel	David Foster	Rebecca A. Jamieson	Raymond A. Price	Bernhard Stöckhert	Sean D. Willett
Erin Campbell	Wolfgang Franke	Barbara E. John	Meinert K. Rahn	John Tarney	Paul F. Williams
Christian Chopin	Wolfgang Frisch	Christopher Johnson	Tim Rawling	Micheal P. Terry	Brian Windley
Peter Copeland	Dieter Gebauer	Sue Keay	Steve Reddy	Christian Teyssier	
Meg Coleman	Allen F. Glazner	Adiamantis Kilias	Stephen J. Reynolds		

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in the reduction of the gender gap, at least in the area of exhumation research.

Presentations were divided into six half-day sessions. Each session had about two hours of oral presentations, about one hour of poster presentations, and about one hour for a panel discussion. This report highlights the oral presentations and panel discussions. Those who are interested in further details will find a complete listing of the conference program, including the titles of all presentations, at the following Web site: <http://love.geology.yale.edu/~brandon/exhume.html>.

FIELD TRIPS

The field trips were led by Bernard Stöckhert (Ruhr-Universität Bochum, Germany) and Eberhard Seidel (Universität zu Köln, Germany), and focused on geologic evidence for Miocene exhumation in a convergent-margin setting. The island of Crete is a forearc high that formed above the south-facing Hellenic subduction zone. The island has spectacular exposures of high-pressure–low-temperature (HP) metamorphic rocks that formed at depths of ~35 km and were exhumed rapidly, starting in the Miocene. Geodetic data and the presence of young normal faults indicate that the surface of the island is being extended in a strike-normal direction, presumably due to southward rollback of the subducting slab. Extensional deformation on Crete is commonly viewed as a southern manifestation of the active extensional province that underlies the Aegean Sea to the north. But an important distinction is that Crete lies in the forearc above the Hellenic slab, whereas the Aegean metamorphic core complexes have formed in the arc and back-arc regions.

At present, Crete has very rugged topography, with local relief >2 km (highest point is Psiloritis at 2456 m). The rugged landscape suggests rapid erosion rates, but the relative contribution of erosion to total exhumation remains poorly resolved. This problem was a common theme throughout the conference.

SESSION 1: LOCAL EXPRESSION OF TECTONIC EXHUMATION: STRUCTURE, METAMORPHISM, AND THERMOCHRONOLOGY

Mark Brandon opened the conference with a short introduction. He made the point that exhumation rates alone are not diagnostic of process. A common assumption is that tectonic exhumation is fast and erosion is slow. But erosion has been clocked at rates up to ~15 mm/yr¹ (e.g., Southern Alps of New Zealand). Conversely, there are settings, such as long-lived continental rifts, where tectonic

exhumation probably operates at very slow rates. Other evidence is needed to distinguish between tectonic and erosional exhumation.

John Platt followed with a keynote presentation on synexhumation deformation in mountain belts. He reviewed geologic evidence for detecting tectonic exhumation, the main clues being the excision of metamorphic gradients, the shape of pressure-temperature-time (P-T-t) paths, and the kinematics of ductile shear zones and brittle faults.

Jane Selverstone challenged the use of P-T-t paths to distinguish exhumational processes. The shape of a P-T-t path is typically difficult to resolve, and the youngest part of the path, which is most diagnostic of process, is the most difficult to constrain. She emphasized her point by showing two sets of published P-T-t paths, one set attributed to erosion and the other to tectonic exhumation. There was no obvious difference between the sets. The inference is that steep decompression curves should not be considered diagnostic of extensional exhumation.

Clark Burchfiel reviewed the development of the South Tibetan detachment system, a north-dipping system of faults and ductile shear zones with top-north offsets that crop out for more than 700 km along the southern flank of the Himalayan crest. The detachment system has probably been active since 22 Ma and appears to have evolved diachronously along its length. There is local evidence in the Mount Everest area that the detachment system caused rapid exhumation, but at present it is not known if this is a general feature of the entire system.

Steve Reddy reviewed the pitfalls in recognizing extensional faults. He showed an example from the Pennine zone of the Swiss Alps where metamorphic section was thinned by a doubly vergent system of extensional faults that moved top-northwest and top-southeast.

The panel, chaired by Ray Price, focused on the correct use of kinematic indicators and on the distinctions between strain and displacement and between crystallization ages and cooling ages. There was also some discussion about the difficulties in using time-temperature data to estimate a time-depth path. One panelist noted that the present northward dip of the South Tibetan detachment system could be caused by isostatic uplift associated with deep erosion of the high Himalayas. This possibility highlighted the general difficulties in resolving the original dip of exhumational structures.

SESSION 2: FORMATION AND EXHUMATION OF UHP METAMORPHIC ROCKS

The most intriguing examples of deeply exhumed rocks are the ultra-high-pressure (UHP) metamorphic rocks, first

found in the Alps and the Norwegian Caledonides, and now known from numerous places around the world. UHP metamorphic rocks are continental or oceanic crustal rocks that were metamorphosed within the coesite-eclogite or diamond-eclogite facies. P-T-t data for these rocks demonstrate that both oceanic and continental crust can be subducted to depths >100 km and then returned to the surface.

The keynote presentation by Christian Chopin provided a general review of the UHP problem. Simon Wallis described some UHP rocks from China and then explored the role that buoyancy might play in returning these rocks to the surface. Paddy O'Brien discussed attempts to determine the P-T-t path for HP metamorphic rocks in the Bohemian massif of Germany.

Dieter Gebauer reviewed his application of SHRIMP U-Pb dating to determine ages of igneous and metamorphic growth of zircons from HP and UHP metamorphic rocks of the Alps. His work indicates an Eocene age for metamorphism which would require exhumation rates of ~10 to 30 mm/yr for some of the Pennine nappe. A major problem, however, is that, as of yet, there is no direct tie between Gebauer's zircon ages and the formation ages of the diagnostic HP and UHP metamorphic assemblages.

The panel, chaired by Gary Ernst, emphasized that UHP rocks are typically found as large, internally coherent slices at least several kilometers wide. The preservation of UHP assemblages suggests dry metamorphic conditions during exhumation. Tectonic extrusion was reviewed as one way to account for the exhumation of these unusual rocks.

General comments from the floor highlighted several additional issues. Are UHP rocks metamorphosed above the Moho within a very thick crustal root or below the Moho as slices subducted into the mantle? The paucity of mantle rocks in association with UHP rocks favors the crustal-root option. But the mantle option is favored by the observation that crustal rocks are not strong enough to support the exceptional high topography that should form above a region underlain by very thick (>100 km) continental crust. A thick crustal root would be further inhibited by the higher radiogenic heat production typical of continental rocks, which should lead to thermally induced softening and/or melting. For the modern Earth, continental crust is thought to be no thicker than about 60 to 70 km. But what defines the Moho in areas where the crust has been metamorphosed to UHP assemblages? A study of the seismic-velocity properties of UHP rocks is needed to understand the relationship of the seismically determined Moho to the petrologically defined base of the crust.

What is the role of buoyancy in returning metamorphosed crustal rocks to the surface? Chopin indicated that the UHP granitoid rocks found in the Pennine nappes of the Alps have densities of 2840 to 3080 kg/m³. These rocks would be buoyant with respect to the mantle but not with respect to average continental crust. The buoyancy argument is further challenged by the discovery of ultramafic rocks with UHP assemblages (e.g., metamorphic diamonds in the Beni Bousera and Ronda peridotites of Morocco and southern Spain; >120 km assemblages from the Alpe Arami garnet peridotites in the Alps).

SESSION 3: RATES AND PATTERNS OF LONG-TERM EROSIONAL EXHUMATION

Most currently cited erosion rates are estimated from short-term (10–50 yr) studies of sediment yield from modern river drainages. A nagging question is whether or not these rates are representative of long-term erosion rates. This problem is particularly important for the Quaternary because global climate has been fluctuating on a period of ~100,000 yr due to the glacial cycle. In this context, long-term erosion rates can be usefully defined as the average rate of erosion for a period of time >~0.1 m.y., to ensure that the effects of the glacial cycle are averaged out.

In his keynote presentation, Doug Burbank reviewed various methods for estimating long-term erosion rates, such as the reconstruction of eroded geologic features, isopach measurements of synorogenic sediments, thermochronologic dating of exhumed bedrock or detrital grains in synorogenic sediments, or an inventory of erosional processes operating within a modern drainage. Burbank cited geologic evidence indicating that the Salt Range of Pakistan was eroded at long-term rates of 5 to 10 mm/yr.

Peter Copeland discussed the interpretation of cooling ages for detrital grains derived from the Himalayas. The large volume of sediment in the Himalayan foreland and in the offshore Bengal and Indus fans provides an important record of erosional exhumation for the Himalayas. Paul Fitzgerald reviewed fission-track data that indicate long-term erosion rates of ~2 mm/yr for Denali (Mount McKinley) in southern Alaska.

David Rowley described the exhumation history of UHP rocks in Dabie Shan, China, where exhumation rates are estimated to have been 3 to 11 mm/yr. He presented a variant of the tectonic extrusion model, where UHP rocks moved upward as a large tabular body, with the relative motion resolved along a lower thrust fault and an overlying normal fault. The front of the extruded body is eroded back at a rate close to the extrusion rate.

This type of model emphasizes the fact that exhumation is not necessarily restricted to vertical motions and may also involve the interaction between erosional and tectonic processes.

The panel, chaired by Karen Kleinspehn, highlighted several additional issues. To what degree are erosion rates controlled by climate? When using thermochronometry, how can one account for the effects of topography on isotherms and the rotation of isochronal surfaces after isotopic closure? How much of the exhumation history of a UHP terrane is preserved in its present structural and stratigraphic setting? Do shallow-level structures bear any relations to the processes associated with the early phases of exhumation when the rocks were still at great depths?

SESSION 4: PROCESSES AND CONTROLS OF LONG-TERM EROSIONAL EXHUMATION

Geomorphology continues to provide fundamental information about erosional processes, but much of this research remains at an early stage of development. In particular, there are many unanswered questions about how short-term local-scale erosional processes relate to the long-term erosional behavior of a whole mountain range. Nonetheless, this research is essential for resolving the interplay between tectonics, topography, global climate change, and regional-scale erosion.

Bernard Hallet gave a keynote presentation in which he compared modern rates of erosion in glaciated and nonglaciated active mountain belts. He noted that nonglaciated mountainous drainages in Asia and New Zealand have modern erosion rates of about 1.5 to 8 mm/yr, which overlaps with exhumation rates estimated for UHP rocks. He then went on to show that warm-based alpine glaciers in southern Alaska had erosion rates of 5 to 80 mm/yr. This observation suggests that increases in alpine glaciation, which could be caused by global cooling, increased precipitation, and/or growth of mountainous topography, could play a major role in exhumation of metamorphic rocks and in limiting the maximum height of mountains.

Sean Willett reviewed the results of numerical models of orogenesis that account for both deformation and erosion. He emphasized that deformation and erosion are strongly coupled, so that their relative effects on the orogenic system may be difficult to separate.

Niels Hovius presented the results of a regional-scale inventory of landslides in the Southern Alps of New Zealand as observed over the past several decades. He estimated that erosion due to landslides was occurring at rates ranging from 5 to 18 mm/yr. Earthquakes seem to be

the primary factor in triggering the landslides; climate has played a subsidiary role.

The panel, chaired by Paul Hoffman, considered a range of topics. What factors are most important for determining when a tectonically active landscape reaches steady state? In this context, steady state means that the rates of rock uplift are balanced by equal rates of erosion. Is the time to steady state typically short (<1–2 m.y.)? In that case, the geomorphic system would closely track tectonic uplift. Or is the time to steady state typically long (>10 to 20 m.y.)? If so, the geomorphic system would be constantly out of phase with tectonic uplift. This question is critical for resolving the cause of the increased flux of terrigenous sediment to the world's oceans during the Quaternary, whether due to climate change or to increased rates of tectonic convergence.

One panelist presented a comparison of the exhumation history of the Tauern window, which is the most deeply exhumed part of the eastern Alps, with the record of erosional exhumation preserved in the Alpine foreland and offshore basins beneath the Mediterranean and the North Sea. An integrated sediment budget showed that orogenic sedimentation rates were low when the Tauern window was being exhumed. The inference was that tectonic processes probably dominated during deep exhumation of this part of the Alps.

Another panelist showed that fast erosion can have a profound influence on the shape of metamorphic isograds and, in some cases, can result in inverted isograds.

SESSION 5: THE ULTIMATE CAUSE FOR TECTONIC EXHUMATION: ACTIVE RIFTING VS. PASSIVE GRAVITATIONAL COLLAPSE

Tectonic exhumation has been recognized as a common factor in continental orogenesis, but the cause remains poorly understood. Is it a result of far-field displacements, as postulated for the back-arc stretching that formed the Aegean metamorphic core complexes, or is it due to collapse of overthickened crust, as has been suggested for the Himalayan-Tibetan orogen?

In his keynote presentation, Gordon Lister stressed the importance of far-field displacements. For the Aegean, he argued that back-arc stretching was caused by rollback of the subducting slab. He also emphasized the transient nature of metamorphism in extensional settings.

Leigh Royden showed how convective flow in thickened crust might account for deformation of the Tibetan plateau. She argued that the style of deformation in a convergent orogen is controlled by the average strength of the crust, parti-

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tioning of strain, and the degree of coupling between the crust and mantle.

John Dewey presented evidence that UHP rocks of the Western Gneiss region in the Norwegian Caledonides were exhumed tectonically during oblique continent/continent collision. Exhumation rates were estimated to have been ~10 mm/yr. He discounted erosion exhumation because basinal strata that overlie the Western Gneiss contain no HP or UHP detritus. Dewey also noted that the Western Gneiss was subjected to extreme vertical shortening, locally as much as -75%, which indicates that ductile thinning was probably an important factor in exhuming these rocks.

The panel discussion, chaired by George Davis, started with the comment that the Kapuskasing uplift of Canada, which exposes deep-seated Precambrian crust, may provide a particularly well studied example of gravitational collapse. The panel then considered some more speculative questions. Would the exhumational phenomena be better understood by dividing the tectonic setting on the basis of the "absolute" motion of the upper plate? For instance, did the upper plate retreat (Aegean), advance (Alps), or surrender (lithospheric delamination in the Himalaya)? Is fault dip related to tectonic process, with gravitational collapse producing gently dipping normal faults and rifting resulting in moderately dipping normal faults?

SESSION 6: INFLUENCE OF DEEP-SEATED PHENOMENA ON THE GEODYNAMIC EVOLUTION OF MOUNTAIN BELTS

Deep-seated processes have also been proposed as important factors controlling exhumation in mountain belts. In particular, there has been much emphasis on thermal softening of an orogenic root and delamination of a thickened mantle root. Thermal softening would reduce the strength of the crust, and mantle delamination would increase the average topography of the orogen. Both phenomena could lead to gravitational collapse.

The theme of Peter Molnar's keynote presentation was that normal faulting is typically initiated by some major change in the geodynamic system, such as a change in boundary conditions (e.g., plate motions), a change in the constitutive behavior of the crust (e.g., thermal softening), or a change in the position of rocks relative to a heterogeneous stress field. He then reviewed the current understanding of Rayleigh-Taylor instabilities in thickened lithosphere, which might explain the conditions needed for mantle delamination. This type of instability has been investigated using analog models, but the characteristic time and length scales of

the instability in the real mantle remain poorly understood. Molnar finished with an overview of a current project that combines paleobotany with meteorology to estimate paleoelevation, with the objective to resolve the uplift history of the Colorado Plateau and other high-elevation areas.

Alan Glazner and John Tarney reviewed how magmatism might influence extensional deformation. Glazner focused on buoyancy of magmas and their level of emplacement in the crust. Tarney discussed how magmatism might trigger crustal extension.

The panel, chaired by Neil Mancktelow, started with a discussion about the concept of gravitational potential energy for understanding conditions leading to gravitational collapse. This was followed by two questions. How does magmatism affect deformation and heat transfer during extension? What is the relationship of UHP metamorphism to magmatism?

SUMMING UP

The meeting ended with summaries from the panel chairs. The general consensus was that the conference succeeded in providing a broad overview of the exhumation problem. In particular, it is clear that in most active mountain belts, erosion and tectonism are dynamically coupled to the point where it may be difficult to separate cause and effect. It appears that erosion can operate at very fast rates, perhaps as high as 15 mm/yr, given sufficient precipitation, steep terrain, and/or extensive alpine glaciation. These rates could be sustained for long periods of time, as long as uplift rates continued to match erosion rates and climate conditions remained favorable for fast erosion. Alpine glaciation appears to be the most aggressive agent of erosion, one that is particularly sensitive to global climate. In this regard, the relatively high sediment production rate of the Quaternary may be the result of a cooler climate and more extensive alpine glaciation. A problem, however, is that much of our current understanding of erosion rates is based on relatively short records. There is a serious need for better long-term estimates using the sediment inventories or thermochronometry.

Buoyancy remains an often-cited factor for return of HP and UHP rocks to the surface, but there are an increasing number of examples where relatively dense rocks have been exhumed. Geologists have generally accepted the possibility that subduction is able to carry continental crustal rocks to depths >100 km, perhaps because the driving force involves the negative buoyancy of subducting oceanic lithosphere. What remains conceptually difficult is how tectonic forces can return rocks to the surface, especially relatively dense eclogite-facies rocks and

mantle peridotites. The presence of these rocks at the Earth's surface suggests that accretionary wedges must have sufficient upward flow to overcome the negative buoyancy. This inference implies that buoyancy is not a significant rate-limiting factor in the exhumation of metamorphic rocks.

The conference highlighted some major challenges in understanding the origin of UHP rocks. One important issue concerns the relationship of the petrologic Moho to the seismic Moho in areas with anomalously thick continental crust. Another concerns the tectonic setting in which UHP metamorphic rocks are formed. For instance, where would one expect to find these rocks forming today? If UHP metamorphism occurs while crustal slices are in the mantle, then this phenomenon may be unrelated to tectonic processes that thickened the crust.

IN MEMORIAM

Just prior to the conference, one of the student participants, Steve Thornley, was killed in an accident in the Himalayas. Steve had been invited to give a presentation at the conference. He had just finished a Ph.D. under Dick Walcott at Victoria University, Wellington, where he studied extensional deformation operating at the surface of the Hikurangi accretionary wedge, New Zealand. We were saddened by the death of this promising young scientist.

ACKNOWLEDGMENTS

We are thankful to Alexandros Papaderos, general director of the Orthodox Academy of Crete, and Evangelos Kastrinakis, manager of the academy, along with their staff, for making our stay comfortable and our scientific proceeding efficient and productive. Conference coordinator Lois Elms did an excellent job of handling the arrangements and logistics, especially given the complexities associated with an overseas venue. We are grateful to Bernard Stöckhert and Eberhard Seidel for suggesting the academy as a conference site and for leading the conference field trips. We thank Gordon Lister and Marnie Forster for organizing and leading an informal week-long post-conference trip to the Aegean metamorphic core complexes. They put together an excellent field guide, "Inside the Aegean Metamorphic Core Complexes." Copies are available from Lister (gordon@artemis.earth.monash.edu.au). We also thank Suzanne Baldwin, Meg Coleman, Darrel Cowan, Carol Evenchick, John Garver, and Susan Monsen for their comments on a preliminary draft of this report. The conference was supported in part by National Science Foundation grant EAR-9628304 and the Geological Society of America. ■

WASHINGTON REPORT

Bruce F. Molnia

Washington Report provides the GSA membership with a window on the activities of the federal agencies, Congress and the legislative process, and international interactions that could impact the geoscience community. In future issues, Washington Report will present summaries of agency and interagency programs, track legislation, and present insights into Washington, D.C., geopolitics as they pertain to the geosciences.

What Is Freshwater Worth?

Water is essential for all life.... In addition to being critical for the health of both humans and ecological systems, water is an important element in many of our recreational and economic activities. It is used in virtually everything we make and do. Water is the most widely used resource by industry; it is used both directly and indirectly to produce energy; it provides the basis for much of our outdoor recreation; it is an important part of our transportation network; it serves as a vehicle for disposing of wastes; and it provides important cultural and amenity values.... Economic and recreational opportunities and the overall quality of life depend in part on how water is allocated among these competing values.

— Economic Values of Freshwater in the United States, p. 1.

Resources for the Future (RFF) is a Washington, D.C. – based, independent, nonprofit research organization that aims to help people make better decisions about the conservation and use of their natural resources and the environment. One of their newly released reports, “Economic Values of Freshwater in the United States” (EVFUS), Discussion Paper 97-03, by Kenneth D. Frederick, Tim Vandenberg, and Jean Hanson, prepared for the Electric Power Research Institute, is fully in keeping with this goal. EVFUS addresses the questions, What is freshwater worth? and What is its value?

To provide an answer, EVFUS presents 493 water value estimates for eight different uses of water, four involving water withdrawal from streams and four involving in-stream uses. The 493 water values are compiled from 41 different published and unpublished literature sources. For uniform comparisons, all water value estimates are converted to 1994 dollars, using a methodology presented in the “1995 Economic Report of the President” (Appendix A). The standard unit for the water value estimates presented is “dollar value per acre-foot of water” (\$/AF). The highest water values described in the EVFUS study reach 2,642 \$/AF, for water

used for recreational purposes in the Lower Colorado River Basin. For other uses, and in other basins, reported values are as low as zero.

The report consists of five sections totaling 37 pages, three appendices totaling 45 pages, and a listing of the 41 references. The report examines each of the eight water use categories in 21 Water Resources Regions (WRR) of the United States (numbers in parentheses indicate number of water value estimates for each WRR presented in the report): New England (7), Mid-Atlantic (10), South Atlantic-Gulf (17), Great Lakes (10), Ohio (17), Tennessee (16), Upper Mississippi (17), Lower Mississippi (10), Souris-Red-Rainy (2), Missouri (49), Arkansas-White River (24), Texas Gulf (26), Rio Grande (21), Upper Colorado (29), Lower Colorado (70), Great Basin (14), Pacific Northwest (66), California (71), Alaska (0), Hawaii (0), and Caribbean (0). Another 19 water values estimates, which cut across WRR boundaries, are also presented.

EVFUS’s Introduction presents important caveats for interpreting the data and for determining the relevance of water values for achieving efficient use of the resource. Included are definitions of the eight water use activities evaluated. These water use categories are (numbers in parentheses are number of water value estimates for each type of use):

- Domestic use (6)—includes water used for household purposes such as drinking, bathing, washing clothes and dishes, toilets, food preparation,

and outdoor uses such as lawns and washing cars.

- Irrigation use (176)—includes water artificially applied to agricultural crops; estimates are presented for 22 different crops or crop types.
- Industrial processing (7)—includes water used in the processing of chemicals, paper, minerals, cotton, vegetables, and meat.
- Thermoelectric power generation (6)—includes water used in the generation of electrical power with fossil fuel, nuclear energy, and geothermal energy.
- Hydroelectric power generation (57)—includes water used to generate electricity at plants where turbines are driven by falling water.
- Recreation and fish and wildlife habitat activities (211)—includes use of streams and reservoirs for activities such as fishing, boating, rafting, swimming, picnicking, and hiking. Five separate categories of recreational activity are included in the evaluation. Two categories, fishing and wildlife refuges, account for more than 95% of all recreation value estimates.
- Navigation on inland waters (7)—includes water used for transportation of cargo. This depends on the depth of navigable rivers and lakes; these parameters are a function of water quantity.
- Waste disposal (23)—is the ability of a stream to assimilate wastes without exceeding water-quality standards. This depends on quantity of flow, nature of the waste, and other conditions; the value of water that is released for this purpose is calculated on the basis of downstream damage avoided or waste-treatment costs that are saved.

The second section of the report, “Presentation of the Data,” discusses the methodology for presenting the economic values information and water-use data. For instance, there are many more estimates of water value from arid regions than elsewhere. This is partially true because these arid regions are focal points for long-standing conflicts about water use. Also noted is that three of the 21 water study regions have no value estimates of any kind.

The third section presents data by geographic region to illustrate how the values within a region vary among uses and how values for the same use vary across regions. More than 20 tables and graphs are used to summarize data and help to interpret the water value evaluations. For example, the national averages of water values for each category (expressed as \$/AF) are: domestic use—\$97; irrigation use—\$75; industrial processing—\$282; thermoelectric power generation—\$34; hydroelectric power generation—\$25; recreation and fish and wildlife habitat activities—\$48; navigation

CORRECTION

The Department of Education (not Energy) released the report discussed in the March Washington Report.

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on inland waters—\$146, and waste disposal—\$3.

Values vary from one part of the country to another. Eastern water values are significantly lower than those in the west. Eastern in-stream values (89) range from \$0 to \$483, and average \$16, while western water values (203) range from \$0 to \$2,642, and average \$56. Eastern withdrawal values (17) range from \$0 to \$198, and average \$29, while western withdrawal values (167) range from \$0 to \$1,227, and average \$80.

Average and maximum water values in each WRR are also presented. They are (in \$/AF): New England (\$4 and \$12), Mid-Atlantic (\$25 and \$198), South Atlantic-Gulf (\$12 and \$57), Great Lakes (\$7 and \$42), Ohio (\$31 and \$483), Tennessee (\$14 and \$91), Upper Mississippi (\$30 and \$420), Lower Mississippi (\$8 and \$50), Souris-Red-Rainy (\$1 and \$3), Missouri (\$13 and \$95), Arkansas-White River (\$31 and \$187), Texas Gulf (\$64 and \$199), Rio Grande (\$191 and \$1615), Upper Colorado (\$32 and \$70), Lower Colorado (\$122 and \$2,642), Great Basin (\$38 and \$461), Pacific Northwest (\$55 and \$1,228), and California (\$51 and \$756).

Section 4 presents the data for individual water uses to illustrate how the values for specific uses vary within each of the 18 water resources regions that compose the conterminous United States. For instance, a comparison of the value of water for the category of "recreation and fish and wildlife habitat" shows almost a 600-fold difference in average value between the Lower Colorado Basin and the Pacific Northwest. In the Lower Mississippi, water has no recreational value. Average recreation values for each of the regions are (in \$/AF): New England (\$4), Mid-Atlantic (\$6), South Atlantic-Gulf (\$3), Great Lakes (\$9), Ohio (\$3), Tennessee (\$2), Upper Mississippi (\$4), Lower Mississippi (\$0), Souris-Red-Rainy (\$3), Missouri (\$14), Arkansas-White River (\$21), Texas Gulf (\$8), Rio Grande (\$313), Upper Colorado (\$51), Lower Colorado (\$597), Great Basin (\$60), Pacific Northwest (\$1), and California (\$27).

Information such as the location, year, and methodology used to derive each of the values is presented in Appendices B and C, along with each of the water value estimates. The data are organized by water resources region in Appendix B and by type of use in Appendix C.

The report is available from: Resources for the Future, 1616 P Street, NW, Washington, DC 20036, (202) 328-5000, fax 202-939-3460, <http://www.rff.org>. ■

Call For GSA Committee Service—1998

The GSA Committee on Committees wants your help. The committee is looking for potential candidates to serve on committees of the Society or as GSA representatives to other organizations. You can help by volunteering yourself or suggesting the names of others you think should be considered for any of the openings and submitting your nomination on the form on page 23. Younger members are especially encouraged to become involved in Society activities.

Listed are the number of vacancies along with a brief summary of what each committee does and what qualifications are desirable. If you volunteer or make recommendations, please give serious consideration to the special qualifications for serving on a particular committee. *Please be sure that your candidates are Members or Fellows of the Society and that they meet fully the requested qualifications.*

The GSA Council acknowledges the many member-volunteers who, over the years, have stimulated growth and change through their involvement in the affairs of the Society.

Each year GSA asks for volunteers to serve on committees, and many highly qualified candidates express their willingness to serve. Not everyone can be appointed to the limited number of vacancies; however, members are reminded that there are also opportunities to serve in the activities and initiatives of the sections and divisions. Annually, the Council asks sections and divisions to convey the names of potential candidates for committee service to the Committee on Committees.

Volunteering or Making a Recommendation

All nominations received at headquarters by **Friday, July 11, 1997**, on the official one-page form will be forwarded to the Committee on Committees. *Council requires that the form be complete.* Information requested on the form will assist the committee members with their recommendations for the 1998 committee vacancies. Please use one form per candidate (additional forms may be copied). The committee will present at least two nominations for each open position to the Council at its October 21, 1997, meeting in Salt Lake City, Utah. Appointees will then be contacted and asked to serve, thus completing the process of bringing new expertise into Society affairs.

Committee on Committees

The 1997 committee consists of the following people: Chair **Stephen H. Stow**, FEDC Building, 104 Union Valley Road, Oak Ridge, TN 37831-8218, (423) 576-7802; **Derald G. Smith**, Department of Geography, University of Calgary, Calgary, Alberta T2N 1N4, Canada, (403) 220-6191; **Russell S. Harmon**, Engineering and Environmental Science Division, U.S. Army Research Office, P.O. Box 12211, Research Triangle Park, NC 27709, (919) 549-4326; **Ellen E. Wohl**, Department of Earth Resources, Colorado State University, Fort Collins, CO 80523, (970) 491-5298; **Ted A. Maxwell**, Center for Earth and Planetary Studies, MRC-315, Smithsonian Institution, Washington, DC 20560, (202) 357-1424; **Jean M. Bahr**, Department of Geology and Geophysics, University of Wisconsin, 1215 W. Dayton Street, Madison, WI 53706-1692, (608) 262-5513. ■

COMMITTEE VACANCIES

Annual Program

(2 vacancies)

Develops a plan for increasing the quality of the annual meeting in terms of service, education, and outreach. Evaluates the technical and scientific programs of the annual meeting.

Committee members should have previous program experience or experience at organizing an annual meeting, or be actively involved in applying geology knowledge to benefit society and awareness of critical issues.

Continuing Education

(2 vacancies)

Directs, advises, and monitors the Society's continuing education program, reviews and approves proposals, recommends and implements guideline changes, and monitors the scientific quality of courses offered.

Committee members should be familiar with continuing education programs or have adult education teaching experience.

Day Medal

(3 vacancies)

Selects candidates for the Arthur L. Day Medal. Committee members should have knowledge of those who have made "distinct contributions to geologic knowledge

Committee Service continued on p. 24

NOMINATION FOR GSA COMMITTEES FOR 1998

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Eldridge Moores's Call for Action (*GSA Today*, January 1997, p. 7–10) gives us some welcome thoughts about the role of geology in society. This topic is very much on our minds as we see support for science dwindle and our graduate students struggling to find jobs where they can put their knowledge and skills to good use. Like most of us, Moores sees the problem in terms of making the general public

more knowledgeable about geology and appreciative of our financial needs. I am beginning to wonder, however, whether our difficulties may not be partly of our own making.

Christopher Lasch (*The Revolt of the Elites and the Betrayal of Democracy*, 1995) laid the problem out very well when he pointed to the increasing intellectual isolation of scientists and to our deteriorating

rapport with the rest of society. He suggested that the reason we are having trouble getting the general public to understand and support us is that we do not understand or support the general public.

When C. P. Snow defined *The Two Cultures* back in 1959, his attitude was that the future of western civilization lies in the hands of morally superior scientists and that the rest of society, particularly

Committee Service continued from p. 22

through the application of physics and chemistry to the solution of geologic problems."

Education (2 vacancies—1 high school teacher; 1 middle school teacher)

Stimulates interest in the importance and acquisition of basic knowledge in the earth sciences at all levels of education.

Committee members work with other interested scientific organizations and science teachers' groups to develop precollege earth-science education objectives and initiatives. The committee also promotes the importance of earth-science education to the general public.

Geology and Public Policy (3 vacancies)

Translates knowledge of the earth sciences into forms most useful for public discussion and decision making.

Committee members should have experience in public-policy issues involving the science of geology. They should also be able to develop, disseminate, and translate information from the geologic sciences into useful forms for the general public and for the Society membership; they should be familiar with appropriate techniques for the dissemination of information.

Honorary Fellows (2 vacancies)

Selects candidates for Honorary Fellows, usually non-North Americans.

Committee members should have knowledge of geologists throughout the world who have distinguished themselves through their contributions to the science.

Membership (2 vacancies)

Evaluates membership benefits and develops recommendations that address the changing needs of the membership and attracts new members.

Committee members must be able to attend one meeting a year. Previous experience in benefit, recruitment, and retention programs is desired.

Minorities and Women in the Geosciences (3 vacancies)

Stimulates recruitment and promotes positive career development of minorities and women in the geoscience professions.

Committee members should be familiar with minority and female education and employment issues and have expertise and leadership experience in such areas as human resources and education. Membership shall include representation of minorities and women and representatives from government, industry, and academia.

Nominations (6 vacancies; one to be a member from Canada or Mexico)

Recommends to the Council nominees for the positions of GSA officers and councilors.

Committee members should be familiar with a broad range of well-known and highly respected geological scientists.

Penrose Conferences (2 vacancies)

Reviews and approves Penrose Conference proposals, recommends and implements guidelines for the success of the conferences.

Committee members must either be past conveners or have attended two or more Penrose Conferences.

Penrose Medal (3 vacancies)

Selects candidates for the Penrose Medal.

Committee members should be familiar with outstanding achievements in the geological community that are worthy of consideration for the honor. Emphasis is placed on "eminent research in pure geology, which marks a major advance in the science of geology."

Publications (1 vacancy)

Makes recommendations to the Council concerning Society publications.

Committee members should be familiar with a wide range of scientific publications and especially GSA publications. Should also have some knowledge of publication processes and costs and should have concern for the quality of content and presentation of GSA publications.

Research Grants (3 vacancies)

Evaluates research grant applications and selects grant recipients.

Committee members must be able to attend the spring meeting and should have experience in directing research projects and in evaluating research grant applications.

Young Scientist Award (Donath Medal) (2 vacancies)

Selects candidates for the Donath Medal.

Committee to have members covering a broad range of disciplines, i.e., geophysics, economic geology, stratigraphy. Committee members should have knowledge of young scientists with "outstanding achievement(s) in contributing to geologic knowledge through original research which marks a major advance in the earth sciences."

GSA Representative to the North American Commission on Stratigraphic Nomenclature (1 vacancy)

Must be familiar with and have expertise in stratigraphic nomenclature. ■

intellectuals and humanists, must adopt more scientific ways of thinking. I wonder what he would say today. A generation later, it is we, the scientists, that are on the defensive. Having become superb experts on increasingly abstruse topics, we have withdrawn into a narrow corner of the cultural world and take little or no part in public affairs.

Instead of deploring the scientific illiteracy of the public, perhaps we should be concerned about the cultural literacy of scientists. We have become hopelessly isolated, even within the universities. When did you last see a geologist at a lecture in another department, say political science or modern literature? How many of us participate in the affairs of our community or have close friends outside our professional circle? Can you imagine a geologist on the local school board or joining a civic or fraternal organization? It can hardly be otherwise, when so much of our time is taken up, not so much with research itself, but with writing or reviewing papers and research proposals, managing a lab, organizing and attending meetings, and the countless other chores that research entails.

Let's be honest. For the last 40 years or so, we have enjoyed generous, almost unquestioning support for science. The average citizen accepted on faith our claims that our work contributes to the nation's prosperity. Science has indeed brought untold benefits and has given us a far better understanding of the planet on which we live. In recent years, however, we have overdrawn our account. At a time when research is becoming more specialized and difficult to explain to the public, funding is increasingly viewed as an entitlement, and campaigns for support are looking more and more like lobbying of yet another special-interest group. No, I can offer no easy solution to the financial problem, but it seems to me that there was a clear message, not just to physicists but to all of us, when funding for the supercollider was finally canceled. From now on, it will be harder to convince tax payers that my research on the holmium-thulium ratios of kuselites should be high on the list of national priorities.

It is often said that in every crisis there is an opportunity, if one can only grasp it. Today's crisis offers the opportunity to reexamine some of the basic tenets of modern science. Foremost among these is the assumption that we can continue to work on more and more specialized topics and never reach a point of diminishing returns. John Horgan, in *The End of Science* (1996), argues that we have, by our approach to research, imposed limits on the scope left open to us in the future.

Research is, of course, a vital part of science, but in focusing our efforts so narrowly we lose our ability to adapt to changing needs. This may be less so in the natural sciences than it is in physics and chemistry, but it is still a concern.

We might do well to ask ourselves a few simple questions. Does it make sense, for example, to give our students the impression that total dedication to arcane research is the only reputable function of a geologist? Does it serve our interest to perpetuate the myth that the most effective teachers are always those engaged in intensive research? Is it possible that we might make a greater contribution to society if we took a broader, more scholarly approach to geology? And, most important, might we not make our careers more rewarding if we came out of our hole and took part in the cultural world around us?

Alexander R. McBirney
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In her column in the March 1997 issue (p. 37) of *GSA Today*, Tamara Nameroff expressed her concern with an apparent trend in Congress of distrusting the scientific community and the scientific process on high-profile environmental issues. She referred to "fringe" scientists who were often funded by political think tanks as promoting a particular, biased agenda that was not well accepted by the traditional (i.e., academic) scientific community. While Ms. Nameroff raised some very good points about the potential influence of Congress on science-based policy making, she also ignored the potential for the opposite bias to occur.

All scientists have opinions on topics in their field of specialty, whether that subject is the cause of mass extinctions in the geologic past or the risk dioxin poses to human health. The source of these opinions may include past experience in conducting similar investigations, the influence of an admired mentor or colleague, or personal connections to the subject matter unrelated to scientific data. Such personal connections may be based upon political opinions, social agendas, or the nature of one's employment.

In an ideal world, these opinions are set aside, or are at least included as one of several potential hypotheses, and an objective investigation follows. In reality, these opinions may play a greater role in a scientist's assessment of data than the scientist may want to admit. A well-publicized example of personal connections interfering with the scientific process is the tobacco industry ignoring data on the health risks of cigarettes.

Ms. Nameroff implied that unlike the "hired guns" of think tanks or corporations, academia or government does not have problems with objectivity. It is my experience that this condition is not always true. Many academic or government scientists in the environmental field hold strong personal convictions about their research. In some cases, these scientists are ardent environmentalists whose opinions are influenced by personal, subjective, and emotional feelings about the subject. Yet when these scientists publish their work or speak out on a subject, they are viewed as unbiased and objective. As Ms. Nameroff noted, the scientific method rarely results in an unequivocal answer. Yet at the same time, scientific opinions that publicize the dangers of various environmental threats are almost unequivocally accepted, while those that indicate that such threats may have been overstated are dismissed as subjective.

Although the public is probably unaware of it, some of the best research in the U.S. on the potential threat of various chemicals to the environment is conducted by the large oil companies. For example, recent research is showing that the best approach to remediating soil and ground water contaminated by petroleum hydrocarbons may be to do nothing at all. This conclusion is based upon voluminous amounts of data that show that such contamination often represents a minimal or nonexistent threat to humans and the environment. The public's response would likely be that this research is self-serving and certainly couldn't be accurate. Ironically, the U.S. EPA and many State regulatory agencies have embraced this work.

Our responsibility as scientists should be to teach the public, including Congress and the media, that nothing should be taken at face value. Research from think tanks, universities, or government agencies all suffer potential limitations. But one source of scientific information is not necessarily better than another. Conclusions regarding environmental threats or any other scientific issue of contention should be based upon a variety of sources after lengthy public discussion. I agree wholeheartedly with Ms. Nameroff's conclusion that peer review remains the best means of ensuring scientific quality and objectivity. But this review must include all sources of research, not just those that are assumed to be objective because of their source.

Keith R. Taylor
Hallowell, Maine 04347 ■

All the Fuss About Clean Air: A Look at EPA's Proposals

Tamara Nameroff, 1996–1997 GSA Congressional Science Fellow



I confess that I didn't think about air quality very often until I arrived in Washington to start my Congressional Fellowship. Even before I came to this Shining City in the Swamp, I knew that ozone levels in Washington can be a health hazard on some summer days. But I didn't worry about it much. I didn't think at all about any of the other pollutants in the air such as particulate matter, sulfur dioxide, and carbon monoxide. I was sure that somebody had a plan to deal with the problem. Little did I suspect that I was to become one of those faceless, nameless people who had to grapple with this issue.

Air quality became a more personal experience when, at the outset of my GSA Congressional Fellowship, the Environmental Protection Agency proposed to tighten the current air-quality standard for ozone and add a new standard to regulate emissions of fine particulate materials (PM). Ground-level ozone is the prime ingredient of smog

and is formed by photochemical reaction between nitrogen oxides and volatile organic compounds. PM is the term used for a mixture of solid particles

and liquid droplets found in the air. While individual particles cannot be seen with the naked eye, collectively they appear as soot, dust, clouds, or haze. My task is to help my boss, Sen. Joe Lieberman (D-CT), understand the intricacies of the science, and give him the information he needs to decide whether to support the standards.

Almost overnight after EPA unveiled its proposals, new radio advertisements suggested that fireworks, lawnmowers, and barbecues would be banned if these new standards took effect. Proponents proclaimed that the new standards would prevent thousands of premature deaths every year and would reduce respiratory disease and hospital admissions due to air pollution. I thought a presentation of the issue would be useful to GSA members since the proposals are controversial and far-reaching. I also think that the issue illustrates a fundamental rule about public policy: it is made by reference to values, not science.

LEGISLATIVE CONTEXT

The Clean Air Act requires EPA to set air-quality standards at a level to protect public health with an adequate margin of safety. The legal interpretation of this

language is that the standards don't have to protect against all health effects, only those that are judged to be "adverse." EPA has consistently recognized that it must make a reasonable judgment—informed by science—about what constitutes physiologically adverse health effects, and what level of the standard would provide acceptable protection from these effects. This is an important distinction for both ozone and PM, because physiological responses probably occur in extremely sensitive individuals at very low levels—even background concentrations. Court decisions have upheld EPA's intent to set the standards to protect the most sensitive populations, such as asthmatics, the elderly, and children, rather than the most sensitive individuals.

The act, its legislative history, and cases interpreting it make clear that costs and feasibility should not be taken into account when setting the standards. Costs

are considered when states develop plans to attain the standards. For example, communities with severe air-quality problems are given more

time to comply than communities where air-quality problems are moderate. Cost-effective strategies are designed by state and local governments that address specific control requirements for industry and small business.

SCIENCE AND PHILOSOPHY

The debate on EPA's proposals focuses on two broad fronts. The science used to justify the level and form of the standards has been scrutinized extensively. A more philosophical discourse has also emerged about whether the fundamental structure of the Clean Air Act is the right approach to reducing air pollution.

First the science. In order to make the best possible policy judgment, EPA performed an extensive review of the peer-reviewed scientific literature. EPA's work also was reviewed carefully by an independent expert panel that included representatives from industry, academia, state government, and the medical profession. For both ozone and PM, the reviewers concluded that EPA produced an adequate assessment of available scientific data and relevant studies and that EPA's interpretation of the science provided an adequate scientific basis for making regulatory decisions.

Interest groups are arguing about how much scientific uncertainty can remain before action on public health issues is justified.

I found it very interesting to see how science is used in the debate. Predictably, the agency's proposals were attacked as going too far. Industries that are likely to face new requirements if the standards are enacted have engaged in a huge lobbying effort to overturn EPA's proposals, suggesting that the uncertainty in the science precludes setting tighter standards. On the other hand, the environmental groups defend EPA's work and believe that the science shows that serious adverse health effects result from exposure to these pollutants.

In the broadest sense, it appears that the interest groups are arguing about how much scientific uncertainty can remain before action on public health issues is justified. For example, in the case of PM, epidemiological studies suggest that exposure to this pollutant—even at levels below the current standard—may cause premature death and aggravation of existing respiratory and cardiovascular disease. Industry groups suggest that because the mechanism by which PM damages the lung is not established, the proposed standard may lead to expensive controls that target the wrong problem. The environmental groups counter that a consistent and coherent body of evidence documents correlation between particulate matter and premature death and illness; the mechanism doesn't need to be demonstrated clearly when a cause (exposure to PM) and effects (death and illness) are documented.

The debate in Congress over the air quality standards reflects the disparate views of how much science is enough to justify a standard. However, the heart of the political argument isn't about what the science supports. It seems to be whether EPA should continue to set air-quality standards to protect public health without regard to costs. In Senate Environment and Public Works Committee hearings on this issue, this underlying political context drove most of the questions asked about the science. I saw both sides use the science to advance these views. Proponents of the standards used the evidence of serious adverse health effects to defend setting health-based standards. They argued that, should the standard-setting

EPA's Proposals *continued on p. 27*

process be revised to reflect some combination of health and cost considerations, these effects might be given less weight; people also wouldn't know if they were breathing clean air. Opponents of the standards played up to scientific uncertainty and suggested that we shouldn't spend so much money to comply with the new standards when it is not clear that large health benefits would be realized.

In the end, this issue will be decided on political grounds, not because the science has provided a compelling rationale for action or inaction. In the case of the Clean Air Act, the contributions of science to the policy-making process seem to be dominated by powerful symbols like barbecues and asthmatic children. In the end, politicians must determine what the American people value more. ■

Tamara Nameroff is the 1996-1997 GSA Congressional Science Fellow, serving on the staff of Senator Joseph Lieberman (CT). The one-year fellowship is supported by GSA and by the U.S. Geological Survey, Department of the Interior, under Assistance Award 1434-HQ-96-GR-02768. 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 or GSA. The author can be contacted via e-mail at <Tamara_Nameroff@lieberman.senate.gov>.

BOOK REVIEWS

Shocks and Rocks: Seismology in the Plate Tectonics Revolution: The Story of Earthquakes and the Great Earth Science Revolution of the 1960s. By Jack Oliver. *American Geophysical Union, 1996, 189 p., \$28 (paperback).*

Effective communication in science is a main theme of this memoir about the revolution in the earth sciences, written by one of the revolutionaries. Some aspects of communicating can be learned and honed, such as drawing illustrations that instantly convey their meaning, and writing without jargon for a readership larger than your subdiscipline. Other aspects are more subject to chance, such as getting the paper accepted quickly in a widely read journal, and most chancy of all, having your new ideas burst upon the world just when the world is eager to devour them.

Jack Oliver, a former president of the Geological Society of America, is most noted during the time of the 1960s revolution for his work with Bryan Isacks which showed that seismic waves transmit very efficiently and fast along what later became known as subduction zones. Their work indicated that slabs of cold brittle crust and mantle, which formerly lay below the seafloor, have penetrated hun-

dreds of kilometers down along the zones. He also is known for a 1968 synthesis paper with Isacks and Lynn Sykes that was especially influential in bringing the plate-tectonic revolution to the earth science community at large, from what was initially an in-group.

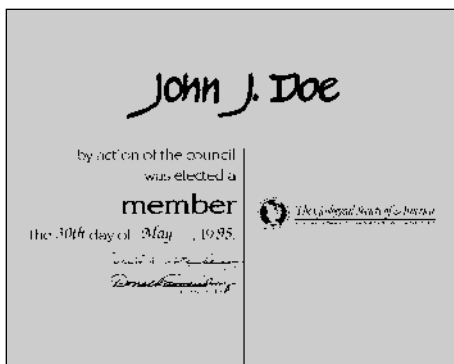
The 1968 paper "Seismology and the New Global Tectonics" is reprinted in this book as an appendix, where it serves both to add technical details to the popular writing of the main text and as a source of illustrations for referencing. The book zeros in closely on the role of seismology in the revolution.

Jack Oliver was in the first group that moved off Manhattan Island with Maurice Ewing to the Lamont Estate on the Hudson River that had been donated to Columbia University. The book emphasizes the role of Lamont Geological Observatory, which reached a critical mass of scientists and data-gathering capability just when needed by the fomenting revolution.

Several bodies of seismological information were on the scene in the years leading up to the great unifying shift in the earth sciences. Maurice Ewing and

Book Reviews *continued on p. 28*

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Book Reviews *continued from p. 27*

Frank Press had shown that the crust of Earth under the oceans is on average only one-eighth as thick as that under the continents, which refuted Eduard Seuss's then-popular idea that the oceans are floored by sunken continents. Wadati and Benioff had shown that deep-focus earthquakes line up with shallower shocks to form inclined surfaces that extend up to the seafloor at oceanic trenches. And Bruce Heezen and Marie Tharp had used the scattered earthquake epicenters then recorded in the deep oceans to help delineate their global seafloor ridge system that wraps around Earth like the stitches on a baseball.

Oliver tries to answer why many earth scientists, himself included, were slow to adopt ideas that involve a mobile Earth. Scientific brilliance alone seems to be of little help. Maurice Ewing was particularly slow to accept plate tectonics, although major breakthroughs were popping out almost monthly at his own institute. Ewing viewed the ocean basins as stable because both the thin surficial sediment in the middle of the basins and that seen by seismic reflection on the floor of the oceanic trenches showed no apparent deformation. Only later did we understand that whereas the seafloor sediment

of the basins averages about 100 million years old, that of the same thickness in the trenches is only a few hundred thousand years old, and hence has not had time yet to be obviously disturbed.

Oliver took his first college degree in physics, and during that study he did not take a course in geology. When he planned to enter graduate school in geophysics, he read the popular book *The Biography of the Earth* by physicist George Gamow. Gamow presented Alfred Wegener's concept of continental drift in a favorable light, and Oliver liked the idea. As a beginning research assistant, he was puzzled that the geologists he worked with did not accept drift, which he then thought might help them to solve some of their research problems. Soon he learned, however, that the margins of the continents and the adjacent seafloor would be far more deformed if drift occurred exclusively along those boundaries, and he came under the strong influence of respected professors who were fixists. For some years, and with later embarrassment, he suppressed all ideas of a mobile Earth.

Oliver believes that scientific research progresses in three styles: (1) deductive hypothesis testing, (2) what he calls inductive serendipity (a term apparently chosen to avoid the pejorative "shotgun method"), and (3) synthesis, a combina-

tion of the first two. He decries that most editors and grant-proposal reviewers demand material that aims for hypothesis testing, because the serendipity method provides material for many scientists beyond the initial investigators. He says the peer-review system does indeed eliminate substandard work, but unfortunately it also filters out the truly great advances. At a jubilee for plate tectonics in 1992, five out of eight people who had been at the center of the revolution said that peer review had either greatly delayed or entirely derailed concepts that later became the core of the new geology. Oliver thinks that a special journal for short papers too far out to be accepted by the regular journals would be both a service to the science and popular with readers.

This book contains no gossip. The only hint that fallible humans worked at Camelot-by-the-Hudson is his report that he was puzzled that some colleagues griped that Ewing overedited and delayed their papers, whereas he himself had no such experience. I'm not surprised that Oliver's serendipity methods would have meshed very well with Ewing's. Someone like Bruce Heezen, on the other hand, always throwing out newfangled ideas,

Book Reviews *continued on p. 29*

GEOSTATISTICS, GEODESY AND A NATURAL DISASTER



C.E. BROWN, Reston, Virginia

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I'm sure was frequently a burr under Doc Ewing's saddle. After all, Heezen even embraced the expanding-Earth concept for a time, during that brief interval when seafloor spreading was already in the can, and subduction was still filming.

This is a lively book. It's especially recommended for those who lived through the revolution, and for students wishing to position themselves for success in the at least minirevolutions of the future.

George W. Moore
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Corvallis, OR 97331

**Stress and Deformation:
A Handbook on Tensors in Geology.**
By Gerhard Oertel, Oxford University Press,
New York and Oxford, 1996, \$65.

This book is the outgrowth of a graduate course taught at UCLA by Gerhard Oertel, based on a course previously taught by Ron Shreve. The purpose of the book is to teach an advanced student to use matrix and tensor notation and to understand the concepts of continuum mechanics. The book proceeds from vectors to tensors to stress and strain. Unlike many recent texts that have tried to simplify these concepts by writing for students with little math background and by relying heavily on the use of Mohr circles, this book assumes that the reader has a good math background and still has access to math textbooks. Fairly brief explanatory material is interspersed with problems. Over half of the volume is devoted to detailed answers to the problems at the end. The errata take care of the typographical errors.

This book will be most useful as a text for rigorous courses in continuum mechanics that have previously used texts such as Nye's *Physical Properties of Crystals* (Prentice-Hall) or Fung's *Foundations of Solid Mechanics* (Clarendon Press). Generally, the material is beyond the abilities and background of most geology graduate students. The most positive aspect of this volume is the extensive set of problems and answers that allows readers to work through the problems on their own. The text is excellent for someone with a good math background who wishes to learn continuum mechanics in a rigorous manner or for someone who needs a refresher course. I, like the author, do not advise skipping any sections or problems, as the concepts and notation build on previous material throughout the book. The text is clearly written and concisely reviews matrices and tensors.

Sharon Mosher
University of Texas
Austin, TX 78712

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PHANEROZOIC FAUNAL & FLORAL REALMS OF THE EARTH: THE INTERCALARY RELATIONS OF THE MALVINOKAFFRIC AND GONDWANA FAUNAL REALMS WITH THE TETHYAN FAUNAL REALM
by A. A. Meyerhoff and others, 1996
MWR189, 78 p., hardbound, indexed, ISBN 0-8137-1189-4, \$40.00; GSA Members \$32.00

ORDOVICIAN K-BENTONITES OF EASTERN NORTH AMERICA
edited by D. R. Kolata, W. D. Huff, S. M. Bergström, 1996
The volume presents the most comprehensive set of data currently available on the occurrence and characteristics of Ordovician K-bentonites in eastern North America. The authors (1) summarize the mineralogies and chemical compositions that help distinguish individual beds and provide information regarding the tectonomagmatic setting of the source volcanoes; (2) document the geographic and stratigraphic distribution of the 60 or more Ordovician K-bentonites in eastern North America; (3) determine the relative positions of K-bentonites within an established biostratigraphic framework; and (4) determine which beds or bed complexes have potential event-stratigraphic significance.
SPE313, 90 p., 8 plates on 2 sheets, ISBN 0-8137-2313-2, \$46.00; GSA Members \$36.80

CENTRAL AND SOUTHERN APPALACHIAN SUTURES: RESULTS OF THE EDGE PROJECT AND RELATED STUDIES
edited by L. Glover III, A. E. Gates, 1997
In 1962 Harry Hess's *History of Ocean Basins* gave a mechanism and a measure of credibility to the ancient hypothesis of continental drift. The new model has been successful in explaining Mesozoic and Cenozoic tectonics; therefore, it is remarkable that today there exists no general agreement on the number, age, and location of older Appalachian sutures. This volume contributes to understanding these sutures. Topics include: the nature of metavolcanic Carolina-Avalon terrane and its problematic western boundary in the Piedmont of central Georgia; the Cambrian(?) emplacement of Carolinian rocks against Laurentia in southern Virginia; and reactivation of the southern Virginia suture as a major zone of crustal weakness that moved during every subsequent tectonic event.
SPE314, 142 p., ISBN 0-8137-2314-0, \$50.00; GSA Members \$40.00

THE THIRD HUTTON SYMPOSIUM ON THE ORIGIN OF GRANITES AND RELATED ROCKS
M. Brown, P. A. Candela, D. L. Peck, W. E. Stephens, R. J. Walker, E-an Zen, 1996
The invited papers in this volume, from the Third Hutton Symposium on the Origin of Granites and Related Rocks, summarize the latest ideas concerning crustal anatexis, melt segregation, magma transfer, and granite emplacement into lower-grade upper-crustal rocks.
SPE315, 225 p., indexed, ISBN 0-8137-2315-9, \$78.00, GSA Members \$62.40

Principles of Precambrian Geology.
By Alan M. Goodwin. Academic Press,
San Diego, 1996, 327 p., \$35.

This volume is an abridgment of Alan Goodwin's 1991 comprehensive and authoritative text *Precambrian Geology: The Dynamic Evolution of the Continental Crust*. It is extensively revised and updated from the original version, and now that it is available in paperback (reducing the price from \$230 to \$35), it should be considered for adoption as an introductory text for courses in Precambrian geology. Goodwin does a superb job of presenting the basic geologic, geochronologic, and correlative

PERMIAN STRATIGRAPHY AND FUSULINIDA OF AFGHANISTAN WITH THEIR PALEO GEOGRAPHIC AND PALEOTECTONIC IMPLICATIONS
edited by E. Ja. Leven, C. H. Stevens, D. L. Baars, 1997
An excellent overall study of the Permian Stratigraphy and fusulinid faunas of Afghanistan. All of the major stratigraphic sequences there are correlated with those of the adjacent Pamirs and are described, as are one new genus and 41 new species and subspecies of Permian fusulinid. These data are used to postulate that Afghanistan and the Pamirs consist of fragments of numerous diverse depositional basins that were crushed together during collision of the Indostanian and Laurasian plates.
SPE316, 138 p., ISBN 0-8137-2316-7, \$45.00; GSA Members \$36.00

AN 800,000-YEAR PALEOCLIMATIC RECORD FROM CORE OL-92, OWENS LAKE, SOUTHEAST CALIFORNIA
edited by G. I. Smith, J. L. Bischoff, 1997
A need for more lacustrine records that document late Quaternary climates in the now-arid western North America led to a U.S. Geological Survey-funded core-drilling project on Owens Lake, southeast California. The resulting 323-m-long core records lake fluctuations since 800 ka. This volume describes how they are revealed by variations in the CO₂ and organic-C percentages, pore-water isotopic content, composition of clay-sized materials, magnetic susceptibility, and fossils (diatoms, ostracodes, mollusks, fish, and pollen). Sediment ages are based on ¹⁴C data, measured mass-accumulation rates, and paleomagnetic variations. The recorded wet and dry climatic cycles are about 100 ka long. Although their distribution in time is similar to those of deep-sea and other records that largely reflect paleotemperatures, the maxima and minima of the wet and dry cycles differ in age from correlative inflections in paleotemperature records by an average of 15 ka.
SPE317, 172 p., indexed, ISBN 0-8137-2317-5, \$60.00; GSA Members \$48.00

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data for each geologic province, yet in many cases the book does not refer to modern plate-tectonic interpretations of specific provinces, basins, or cratons. Although this should not be a problem for those wishing to adopt the text for classes, or to use it as a desk reference for the general geology of the world's Precambrian terrains, it should be balanced by modern uniformitarian texts (such as B. F. Windley's *The Evolving Continents*, third edition, 1995, John Wiley) or journal articles on Precambrian tectonics.

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Goodwin begins with a summary of methods commonly employed by Precambrian geologists and a review of the geology of the major Precambrian cratons. The book then proceeds with detailed descriptions of each Precambrian province, beginning with Archean crust, then Early, Middle, and Late Proterozoic crust. Goodwin

has used a lithostratigraphic approach, providing many maps, stratigraphic sections, and correlation charts throughout these chapters. Concepts are generally well explained and well illustrated. Particular attention was paid to include the latest U-Pb geochronologic interpretations for each province, and the references were updated to include recent work on most of these terrains, with a few exceptions. Despite this, several references in the text are not cited in the bibliography. The book concludes with a short (20-page) segment containing Goodwin's preferred model for the evolution of the continental crust, neatly divided into sections on endogenous and exogenous processes.

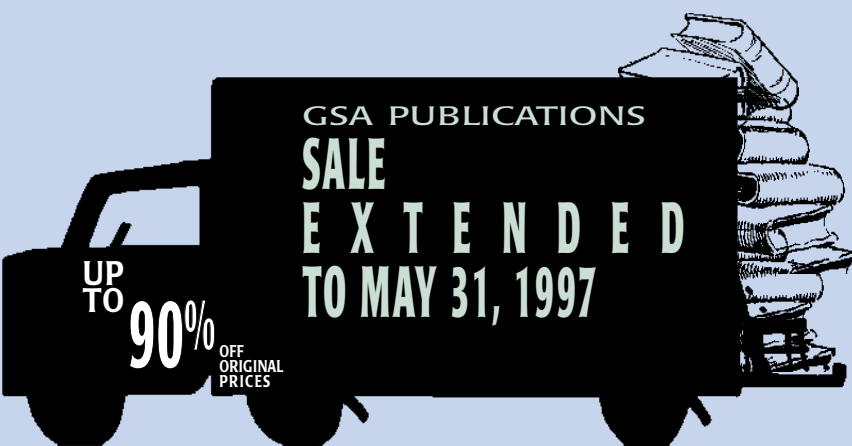
The biggest pitfall of *Principles of Precambrian Geology* is that it does not pay adequate attention to structural aspects of Precambrian terranes; cross sections are almost totally absent, and structural nomenclature is obscure, in some cases (e.g., synéclise and antéclise) dating back to old Russian literature. Folds in gneiss terranes are described as "flattish" (p. 53), and Archean greenstone belts are portrayed as 7–17-km-thick multicyclic volcanic piles, thus largely ignoring much of the structural work, done on greenstone belts in the past 10 years, that documents numerous repeated stratigraphic sections (e.g., see M. de Wit and L. Ashwal, *Greenstone Belts*, 1996, Oxford University Press.). Komatiites, which are stated to have eruption temperatures of 1600 °C (at the high end of current thinking) present an unusual problem, in that they occur next to crust that shows low paleogeothermal gradients. This apparent defiance of the

laws of heat conduction would be resolved if arguments for melting in the presence of water yielding lower eruption temperatures were supplied, and if the many documented tectonic contacts of komatiites with the surrounding gneiss terranes were described in the book.

In the last chapter, on the evolution of Precambrian crust, great emphasis is placed on a couple of ideas that are not widely accepted models of Earth evolution. For instance, in an attempt to discount the possible presence of ophiolitic fragments in Archean greenstone belts, Goodwin cites a recent theoretical model for an "expected" Archean ophiolite (thick, entirely komatiitic crust), and then states that no oceanic crust exists in these belts because they consist not of this "expected" komatiitic crust, but largely of tholeiitic basalts underlain by gabbros, resembling modern dismembered ophiolites! The possibility that Archean ophiolites didn't look as different from modern ophiolites as the theoretical model predicts is not discussed. Surely, if these rocks were in Phanerozoic mountain belts they would be classified as ophiolites, and workers would then debate their origin as arc, back arc, fore arc, oceanic crust, etc. Later in the same chapter, Goodwin moves on to summarize how tholeiitic basalt altered on the sea floor is the most likely source for the production of Archean Na tonalites.

In the summary section on crustal development by stage, relative partitioning between plume- and planiform-domi-

Book Reviews continued on p. 34



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nated mantle convection and higher geotherms is discussed in terms of global heat loss, with the suggestion that plumes may have been more important in earlier times. Goodwin suggests that modern-style plate tectonics could not have operated in the early lithosphere sitting over this vigorously cooling mantle, but presents instead ad hoc mechanisms of lithospheric tectonics. Most uniformitarianists think it highly probable that convective heat transfer mechanisms (with associated plate tectonics in the lithosphere) controlled the heat loss from early Earth, as they do today. For instance, rigorous quantitative studies show that the most efficient mechanism of planetary heat loss (convection) becomes even more efficient with higher heat production, as Rayleigh numbers are higher, and mantle temperatures are effectively buffered by changes in viscosity, rate of overturning, and cell size. Most actualistic models of early Earth suggest that it was probably dominated by numerous rapidly convecting cells, driving plate tectonics in the surface boundary conduction layer, resting over a mantle not very much hotter than that of today. Goodwin implies that workers who apply plate-tectonic models ("complacent application of a popular paradigm," p. 279) to old rocks are guilty of "unwarranted speculation based on invalid models" (p. 279), yet the concluding chapter of his book supports application of ad hoc paradigms with no actualistic foundation. While I agree with Goodwin about the dangers of model-driven science, I believe that the modern peer-reviewed journal literature provides an effective filter for such practice.

Principles of Precambrian Geology does a good job of meeting its goal of providing a detailed inventory of Precambrian geologic provinces and problems. In most sections of the book, interpretations and speculations are avoided, yet in places where interpretations are made, they reflect an anachronistic non-plate-tectonic approach. These sections of the text need to be balanced with more modern views of early Earth, but overall, *Principles of Precambrian Geology* will probably be a standard reference for many years.

Timothy M. Kusky
Boston University
Boston, MA 02215

Field Geologists' Manual. Compiled by D. A. Berkman. Australian Institute of Mining and Metallurgy, Victoria, 1995.

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in or with interests in the minerals industry. The wealth of information available, generally presented in a very user-friendly fashion, ranges from a Code of Ethics for the Australasian Institute of Mining and Metallurgy, to charts for the identification and classification (IUGS-based) of rocks and minerals, to compilations of virtually every mapping symbol imaginable, to succinct overviews of methods and interpretation of geophysical surveys. Admittedly, many aspects of this compilation are clearly devoted to the minerals exploration in the Australasian region (e.g., Australasian codes for reporting ore reserves, Australian standard color scheme and stratigraphic symbols, and Australasian magnetic declination charts). However, over 90% of the book is of universal use and interest. The 62-page-long section on standard mapping symbols and patterns, although perhaps not universally accepted, is excellent in its detail and form of presentation. Some parts of the book are less up-to-date than desired. For example, the geologic time scale, organized to highlight different stage classifications, places the Cretaceous-Tertiary boundary at 66 Ma and the Vendian-Cambrian boundary at 580 Ma.

The compiler and numerous contributors had no intention of having *Field Geologists' Manual* considered as a "text" for an undergraduate or graduate field geology course. Despite this, I can strongly recommend this book to instructors in field geology as an excellent reference, and to geoscientists in the minerals industry requiring, in a single volume, a quick, detailed summary of a great deal of useful

information needed in regular aspects of their work.

John Wm. Geissman
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Stepping Stones—The Reminiscences of a Woman Geologist in The Twentieth Century. By Katharine Fowler-Billings. Connecticut Academy of Arts and Sciences, New Haven, 222 p., 1996.

This autobiographical memoir records the life and career of one of the pioneering women geologists in the United States. It is an engaging tale of an adventurous and eventful life told as a chronological series of vignettes in an easy conversational style. Fowler-Billings starts with growing up in a well-off Massachusetts family and spending summers in the outdoors collecting shells, rocks, and plants. She then chronicles her mountaineering adventures as a student, tells of her geological travels and projects in the United States, in Africa, and across Russia, and describes her career as wife, mother, and finally educator and conservationist. The outdoors and a curiosity about nature were key parts of Fowler-Billings's life. Many of her exploits also reveal an independent and stubborn streak. For example, she reports that during her undergraduate time at Bryn Mawr College, her professor, Florence Bascom, did her best to discourage Fowler-Billings and other students from becoming geologists. So, without consulting Miss Bascom, Fowler-

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Abstracts due: July 8

General Chair: M. Lee Allison, Utah Geological Survey

Technical Program Chairs:

John Bartley, Erich Petersen, University of Utah

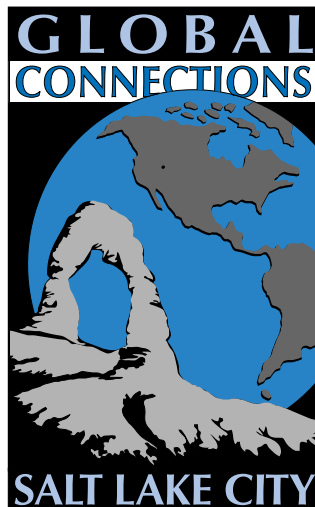
Field Trip Chairs:

Bart Kowallis, Brigham Young University

Paul Link, Idaho State University

Both technical program and field trip deadlines have passed.

Call for Papers and First Announcement in the April issue of GSA Today. Registration and Housing information will be in the June issue.



1998

Toronto, Ontario, Canada, October 26–29
Metro Toronto Convention Centre • Sheraton Toronto Centre Hotel and Towers

General Chair:

Jeffrey J. Fawcett, University of Toronto

Technical Program Chairs:

Denis M. Shaw, McMaster University

Andrew Miall, University of Toronto

Due date for symposia and theme proposals: January 2, 1998

Call for Field Trip Proposals:

We are interested in proposals for single-day and multi-day field trips beginning or ending in Toronto, and dealing with all aspects of the geosciences. Please contact the Field Trip Chairs listed below.

Pierre Robin, University of Toronto,
Dept. of Geology, 22 Russell Street,
Toronto, Ontario M5S 3B1, Canada,
(416) 978-3022, fax 416-978-3938

Henry Halls, Erindale College,
Mississauga, Ontario L5L 1C6, Canada,
(905) 828-5363, fax 905-828-3717,
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CALL FOR

Continuing Education Course Proposals

Due December 1, 1997

The GSA Committee on Continuing Education invites those interested in proposing a GSA-sponsored or cosponsored course or workshop to contact GSA headquarters for proposal guidelines. Continuing Education courses may be conducted in conjunction with all GSA annual or section meetings. We are particularly interested in receiving proposals for the 1998 Toronto Annual Meeting or the 1999 Denver Annual Meeting.

Proposals must be received by December 1, 1997. Selection of courses for 1998 will be made by February 1, 1998. For those planning ahead, we will also consider courses for 1999 at that time.

For proposal guidelines or information, contact:

Edna Collis
Continuing Education Coordinator,
GSA headquarters
1-800-472-1988, ext. 134.
E-mail: ecollis@geosociety.org

FOR INFORMATION ON ANY GSA MEETING CALL THE GSA MEETINGS DEPARTMENT

1-800-472-1988 or (303) 447-2020, ext. 133 E-mail: meetings@geosociety.org WWW: http://www.geosociety.org

Book Reviews *continued from p. 34*

Billings applied and was accepted to the geology graduate program at Wisconsin. She made the most of chances to widen her experience whenever a chance presented itself. The summer before going to Wisconsin she signed up for two field courses in the West. Between the two she climbed Mount Rainier, visited Crater Lake, and fit in a side trip to the Grand Canyon! This was the start of a life in which she took every advantage of opportunities to explore the world and to do good science.

Through her narrative, we appreciate her love of science, her fascination with meeting people of all kinds, her determination, and her ability to make the best of many different circumstances. Her discussion of her geological work is descriptive rather than technical. This has the advantage of making her exploits interesting to a wide audience curious about the life of a female scientist of her era. However, it also leaves us with no feeling for her intellectual development nor of the specific scientific challenges she faced. It is a curiosity of this book that Fowler-Billings does not mention mentoring she may have received from individuals other than her family nor any significant scientific interaction with peers. Yet she herself went out of her way to share her excitement and scientific acumen with others. Possibly this self-sufficiency is a manifestation of the independence she acknowledges when she describes traveling to a meeting in Africa by an earlier ship to avoid being with her Ph.D. thesis advisor: "I did not want him feeling responsible for me ... He ... never understood why I hadn't told him I was going."

Fowler-Billings records that she was asked by Miss Winsor, headmistress of the school she attended for eight years, "What did I teach you ... that made you do the things you have done?" After reading this autobiography, I concluded that Fowler-Billings gives us the same answer she gave Miss Winsor: "I had no ready explanation...." But from the lively portrait she has painted, we can make our own surmises and come to appreciate the style of one 20th-century female geoscientist.

*Maria Luisa Crawford
Bryn Mawr College
Bryn Mawr, PA 19010*

The Tectonic Evolution of Asia.


*Edited by An Yin and T. Mark Harrison,
Cambridge University Press, Cambridge, UK,
1996, 666 p. \$200.*

This volume is timely. It is 74 years since Argand's synthesis and 22 since Molnar and Tapponnier successfully analyzed India's collision with Asia. Here is an opportunity to assess progress since the


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appearance of those critical works. It has become clear that Asia, with its European appendage, is distinct among continents because it has been assembled within the past 400 m.y. Laurentia and the Gondwana continents, because they were largely put together during the Precambrian, cannot be quite such good places to study continental evolution. Finally, political and economic changes in Asia have revolutionized access. Oil, gas, and mineral explorations are expanding, international collaborative research has mushroomed, and much previously inaccessible

information about the continent has become available.

Understanding tectonics, "the large-scale evolution of planetary lithospheres," requires the integrated use of an astonishingly broad range of approaches. That range is wonderfully illustrated in this book. It starts with reviews of two models of the Asian collision: one a viscous sheet model with lithospheric thinning, the other a thin-shell finite-element model embodying faults. These contrasting papers set the scene by focusing on the mechani-

Book Reviews *continued on p. 37*

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address the Indian-Asian collision, providing a well-documented review of current research and new important results.

The remaining nine papers address the earlier assembly of Asia. First comes a field and laboratory study of a Cretaceous core complex near Beijing. Few places in Asia have as yet been characterized so well. Next is a review of the Songpan-Ganzi, a region where a million or more cubic kilometers of continent-derived sediment accumulated on ocean floor among colliding continental fragments during Triassic time. Two papers report field and laboratory data from the diamond-bearing rocks of the Dabie Shan which were formed during one of those Triassic collisions and were somehow exposed by Cretaceous time. The Dabie Shan is becoming a mecca for students of how deep rocks go in mountain building.

The last five papers treat regional Asian assembly, emphasizing different areas and different times. An interpretation of northwestern Turkey has existed for 15 years; field studies reported here, complemented by age determinations and petrology, improve that model and show that radically different alternatives do not work. In a landmark paper, the global power of fossil floras in indicating paleolatitude is demonstrated, compared with paleomagnetic results, and applied to Mesozoic Asia. The disposition of various fragments now within Asia during late Paleozoic and Mesozoic time comes up in several papers. Similarity in interpretation is emerging, and it is becoming clear where the problems remain. A tectonic history of China uses a variety of kinds of information to show how assembly has built China over 400 m.y., a distinctive feature being an attempt to restore now-deformed block boundaries to their original shapes. A final authoritative chapter, "Fragments of a synthesis of the paleotectonics of Asia," extends published studies of Altaid assembly to the Mongolides and Nipponides, contrasting the evolution of those giant accretionary complexes with belts like the Himalaya in which the collision of continental fragments has dominated. An emphasis is on the importance of strike-slip motion throughout continental evolution.

The Tectonic Evolution of Asia has large pages, good paper, and well-reproduced figures. This book is essential for all interested in Asian tectonics and is a worthy update to the books by Argand and by Molnar and Tapponnier. If you are new to the great continent, it will provide a fine introduction, and if you know the continent well, you will find new research reported that will improve your understanding and stimulate you to ask new questions.

Kevin Burke
University of Houston
Houston, TX 77204-5503 ■

Book Reviews continued from p. 36

cal behavior of the continental lithosphere. Two papers illustrate how earthquake mechanisms are used in tectonic research, and a short paper reviews tomography and anisotropy. Evolution of the Himalaya is covered in a masterly review and in two papers that use age and metamorphic data to explain assembly, burial, and elevation of the great range. Sediments derived from the erosion of rising mountains provide vital tectonic information. A comprehensive paper on the Himalayan foreland basin shows how much is known

about the Neogene of Pakistan and how much remains to be learned about other areas and older times. Three papers treat aspects of the Indo-Asian collision: (1) Tad-jik basin history is synthesized using a variety of techniques; (2) the diachronous onset of transtension in the Red River fault system is addressed by integrating structural and isotopic observations with sea-floor data on the opening of the South China Sea; and (3) what has happened in an area of Tibet and Yunnan just to the east of the Himalayan syntaxis is tackled using structural and paleomagnetic methods. The first twelve papers in the book

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Positions Open

GEOLGY / HYDROGEOLOGY

Lock Haven University of Pennsylvania invites applications for a full-time, temporary position in the Department of Geology and Physics for the 1997-98 academic year. Responsibilities include teaching hydrogeology and oceanography and general education courses in geology and earth science. Preference will be given to candidates with a completed Ph.D. Rank, instructor or assistant professor, is dependent upon qualifications. Review of applications will begin May 1, 1997, and continue until the position is filled. Candidates should submit a letter of application, resume, transcripts, and the names, addresses, and telephone numbers of three references to: Dr. Carl R. Carnein, Chair, Search Committee, Department of Geology and Physics, LHU, Lock Haven, PA 17745. Lock Haven University of Pennsylvania is an equal opportunity/affirmative action employer and encourages applications from minorities, women, veterans, and persons with disabilities. LHU is a member of Pennsylvania's State System of Higher Education.

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

The Department of Geology at the University of Illinois seeks to fill two possible positions of Visiting Assistant Professor or Visiting Lecturer. The successful candidates are expected to teach the following: 1) Mineralogy at the undergraduate and graduate level, introductory planetary geology, and physical geology; 2) Geomorphology, introductory physical geology and introductory environmental geology. Experience in these or closely related branches of geology is highly desirable. Candidates with a Ph.D. or equivalent in geoscience are preferred, but applications from candidates who have not yet finished the dissertation will be considered. Applicants should be able to demonstrate promise of being excellent instructors with superior interpersonal skills.

The term of appointment will be for one year, with the possibility of renewal for additional years. This is a non-tenure track position. The starting date will be August 21, 1997.

Applicants should send a curriculum vitae, list of publications, statements of teaching and research interests, and have three letters of reference sent to: Professor R. James Kirkpatrick, Department of Geology, University of Illinois, 1301 W. Green St., Urbana, IL 61801; (217) 333-7414; Fax: 217-244-4996. Preference will be given to applications received before June 1, 1997.

The University of Illinois is an equal opportunity/affirmative action employer. Women and minorities are encouraged to apply.

GEOLOGIST

ILLINOIS STATE GEOLOGICAL SURVEY (ISGS)

ISGS is a division of the Illinois Department of Natural Resources. An affiliated agency of the University of Illinois, the Survey is located on the 700-acre campus in Urbana-Champaign. This central Illinois location is just 130 miles south of Chicago. Some 200 scientists and technical support staff conduct basic and applied research in geology, compile geologic maps, and gather and manage the state's geological data to provide information to industry, governmental agencies, and the public about the geology and mineral resources of Illinois. We are seeking a full time geologist (Assistant Supportive Scientist) to conduct and/or support original research in glacial geology, glacial/fluvial sedimentology, and geologic mapping; work with a team of geoscientists in mapping 1:24,000-scale quadrangles; conduct topical research in Quaternary geology, and surface and subsurface mapping of Quaternary sediments in Illinois. Requires substantial travel in Illinois for field mapping. Requires M.S. and two years professional experience in Quaternary geology and geologic mapping. Prefer M.S. and four years experience, or recent Ph.D. and field experience with mapping 3-dimensional Quaternary deposits in the subsurface. Computer applications background helpful. Valid driver's license required. Some lifting may be required. Salary range \$29,000-31,000. For an application, please send resume or contact Human Resources listed below. To receive full consideration applications must be returned by May 15, 1997.

Human Resources, Illinois State Geological Survey, 129 Natural Resources Building, 615 E. Peabody Dr., Champaign, IL 61820.

ISGS is an AA/EEO/ADA Employer.

Phone 217-244-2401; Fax 217-244-7004; e-mail walston@geoserv.isgs.uiuc.edu; ISGS home page located at <http://www.isgs.uiuc.edu/isgshome.html>

FACULTY POSITION GEOLOGICAL ENGINEER SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY

The Department of Geology and Geological Engineering is seeking to fill a tenure-track position at the Assistant or Associate Professor level in geological engineering. The successful candidate will be required to teach undergraduate and graduate classes in geological engineering. The candidate is expected to develop a funded research program in support of the M.S. and Ph.D. degree programs. The Ph.D. is required, and it is preferable that the candidate has practical experience and is registered as a Professional Engineer or Engineer-in-Training. Salary will be commensurate with qualifications and experience.

Send vitae, letter of application, and three letters of reference to: Dr. Colin J. Paterson, Chairman, Dept. of Geology and Geological Engineering, South Dakota School of Mines & Technology, Rapid City, SD 57701. Information on the university and department, located in the beautiful Black Hills, is at the following web address: <http://www.sdsmt.edu/campus/mineral/geology/geolhp.htm> Address inquiries to paterson@silver.sdsmt.edu, phone (605) 394-2461, fax (605) 394-6703. Applications will be reviewed beginning April 20, 1997, and will continue until a suitable candidate is hired. SDSMT is an AA/EEO/ADA employer and provider.

TEXAS A&M UNIVERSITY DEAN, COLLEGE OF GEOSCIENCES AND MARITIME STUDIES

<http://www-ocean.tamu.edu/Geoscience/>

Texas A&M University invites nominations and applications for the position of Dean, College of Geosciences and Maritime Studies, Texas A&M University. The holder of this position is the Chief Executive Officer of the college, which is comprised of 130 faculty members and approximately 400 undergraduate students and 350 graduate students. The College of Geosciences and Maritime Studies seeks to provide an understanding of our changing planet—the solid earth, the ocean, the atmosphere, and their complex human and biological systems. The College includes the Departments of Geology and Geophysics, Geography, Meteorology, and Oceanography and a variety of research units such as the Ocean Drilling Program, Sea Grant Program and Geochemical and Environmental Research Group.

The major responsibilities of the position are: Supervise college planning and budgets; oversee teaching, research and administrative functions within the college; oversee faculty recruiting and development, including pro-

motion and tenure; coordinate search for and recommend appointment of department heads and research directors; represent the college's interests to its various constituencies; seek requisite funding from the University and external sources for the teaching, research, and service missions of the college.

The major qualifications for the position are: A strong record of academic accomplishment; proven administrative and leadership capabilities and experience; commitment to higher education in the form of teaching, scholarship, research, and faculty development; commitment to cultural, ethnic, and gender diversity; ability to work effectively with all departments in the college; ability to represent the college externally, on and off campus.

Texas A&M University affirms diversity as essential to its mission, is an equal opportunity, affirmative action employer/educator, and encourages applications and nominations of women and minorities. The Search Committee began screening candidates on April 30, 1997, and will continue until a suitable candidate is found. Nominations and applications, including names of references, are encouraged prior to that date. Further information is available upon request. Nominations and applications should be sent to: Dr. Edward Hiler, Chair, Search Advisory Committee for the Dean of the College of Geosciences and Maritime Studies; Texas A&M University; Room 113 Administration Building, College Station, Texas 77843-2142; phone (409) 862-4384; Fax 409-862-1637; e-mail: e-hiler@tamu.edu.

Please be advised that under Texas law, names and other information concerning applicants or nominees may be subject to disclosure upon request.

POSTDOCTORAL RESEARCH ASSOCIATE (2-YR)

The U.S. DEPARTMENT OF AGRICULTURE (USDA), AGRICULTURAL RESEARCH SERVICE (ARS), Land Management and Water Conservation Unit, Pullman, WA, invites applications for a Research Conservation Engineer position. Research objectives are to define the processes and relationships governing wind erosion and dust emissions over a significant range of soils and field conditions to provide accurate predictions and potential controls as a function of soil characteristics, surface properties, and aerodynamics. A standardized method for measuring particulate emissions from non-dispersed dry soil will be developed utilizing a particulate generator and aerodynamic particle sizer to simulate soil dependent, self-abrasion emission processes. Correlation and validation between laboratory and field measurements will be made with simultaneous wind erosion dust emissions, and meteorological measurements supplemented with data from a 1.0x1.2x15.0-m portable wind tunnel. Ph.D. in Agriculture/Civil/Environmental/Geological Engineering required, with knowledge and interest in agriculture, soils, aerodynamics and environmental impacts preferred. Salary for the GS-11/12 position (\$40,558-\$58,442) will be based on qualification and experience. For more information, contact Dr. Keith Saxton, USDA/ARS, Smith Hall-WSU, Pullman, WA 99164-6120 (509-335-2724; fax 509-335-7786; e-mail: ksaxton@wsu.edu). A resume or curriculum vitae, with references, is acceptable for application and should be mailed to Dr. Saxton. The position will remain open until filled. Candidates will be considered as applications are received. ARS is an Equal Opportunity Employer.

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LEATHER FIELD CASES. Free brochure, SHERER CUST SADDLES, INC., P.O. Box 385, Dept. GN, Franktown, CO 80116.

FREE complete set of *Economic Geology* beginning January 1970 (Vol. 65, No. 1) through January/February 1986 (Vol. 81, No. 1). This collection is in good condition and will be shipped to you at no cost. If you are interested, please respond to: Albert L. Lamarre, 3903 Rockingham Drive, Pleasanton, CA 94588 or call (510) 462-7581.

Opportunities for Students

Visiting Fellows and Students/Institute for Rock Magnetism. Applications are invited for visiting fellowships (regular and student) lasting for up to 10 days during the period from September 1, 1997 through February 28, 1998.

Topics for research are open, although fellows are encouraged to take advantage of the chosen focus for cooperative research in a given year. During 1997-8, the focus for research will be twofold: very high resolution recordings of geomagnetic field fluctuations, and magnetic proxies of environmental and climate changes.

Short proposals (two pages, single-spaced text plus two forms and necessary figures and tables) are due by June 21, 1997, for consideration by the Institute's Review and Advisory Committee (John King, Chair).

Successful applicants will be notified in early August, 1997.

A limited number of travel grants of \$500 are available to researchers who can demonstrate no existing financial resources. No funds are available for per diem expenses.

The Institute Staff manager (Mike Jackson) will be happy to provide application forms and information necessary for proposal preparation, or you can obtain them from the IRM home page on the World Wide Web (<http://www.geo.umn.edu/orgs/irm/irm.html>).

Deadline for submission is June 21, 1997, at the following address: Facilities Manager, Institute for Rock Magnetism, University of Minnesota, 291 Shephard Laboratories, 100 Union St. SE, Minneapolis, MN 55455-0128, (612) 624-5274; fax: 612-625-7502.

Correction

CORDILLERAN SECTION MEETING

The cost of Cordilleran Field Trip 3—**Petrology and Volcanology of Maui**, to be led by Sinton and Rowland, has been increased from \$150 to \$400. This includes, in addition to all previously stated information, air fare from Honolulu to Maui and from Maui to Kailua Kona. It does not include transportation from the Kona airport to the hotel.

CALENDAR

Only new or changed information is published in *GSA Today*. A complete listing can be found in the **Calendar** section on the Internet: <http://www.geosociety.org>.

1997 Penrose Conferences

September

September 10–15, **Faults and Subsurface Fluid Flow: Fundamentals and Applications to Hydrogeology and Petroleum Geology**, Albuquerque and Taos, New Mexico. Information: William C. Haneberg, New Mexico Bureau of Mines and Mineral Resources, New Mexico Institute of Mining and Technology, 2808 Central Ave. SE, Albuquerque, NM 87106, (505) 262-2774, fax 505-255-5253, haneberg@nmt.edu. For more information, see <http://www.nmt.edu/~haneberg/Fluids.html>.

September 23–28, **Tectonics of Continental Interiors**, Cedar City, Utah. Information: Michael Hamburger, Department of Geological Sciences, Indiana University, Bloomington, IN 47405, (812) 855-2934, fax 812-855-7899, hamburger@indiana.edu.

1997 Meetings

September

September 7–10, **AAPG International Conference**, Vienna, Austria. Information: AAPG Convention Dept., P.O. Box 979, Tulsa, OK 74101-0979, (918) 560-2617, fax 918-560-2684.

September 19–21, **Fall Mineralogy Symposium: Lead, Zinc, and Iron Minerals**, State College, Pennsylvania. Information: Mineralogy Symposium, c/o Penn State Mineral Museum, 122 Steidle Bldg., University Park, PA 16802, (814) 865-6427, fax 814-863-7708.

September 27–29, **Canadian Paleontology Conference** and field trip, Saskatoon, Saskatchewan. Information: Brian R. Pratt, Dept. of Geological Sciences, University of Saskatchewan, 114 Science Pl., Saskatoon, SK S7N 5E2, Canada, (306) 966-5725, fax 306-966-8593, brian.pratt@usask.ca.

September 30–October 4, **Association of Engineering Geologists 40th Annual Meeting**, Portland, Oregon. Information: Gary Peterson, (503) 635-4419, garyp@squire.com, <http://geoweb.tamu.edu/aeg/>. (Abstract deadline: May 15, 1997.)

October

October 5–8, **Seismological Society of America Eastern Section Annual Meeting**, Ottawa, Ontario. Information: Gail Atkinson, Dept. of Earth Sciences, Carleton University, Ottawa, Ontario K1S 5B6, Canada, (613) 520-2600, ext. 1399, fax 613-788-4490, esssa@ccs.carleton.ca, <http://www.seismo.nrcan.gc.ca/esssa97>.

1998 Meetings

May

May 3–7, **Canadian Institute of Mining, Metallurgy and Petroleum—Council of Mining and Metallurgical Institutions**, Montreal, Quebec. Information: Chantal Murphy, Canadian Institute of Mining, Metallurgy and Petroleum, 3400 de Maisonneuve Blvd. West, Suite 1210, Montreal, Quebec H3Z 3B8, Canada, (514) 939-2710, ext. 304, fax 514-939-2714, cmcim@login.net


May 17–22, **American Society for Surface Mining and Reclamation 15th National Meeting**, St. Louis, Missouri. Information: Dianne Throgmors-

ton, Coal Research Center, Southern Illinois University, Carbondale, IL 62901-4623, (618) 536-5521, fax 618-453-7346, diannet@siu.edu.

May 18–21, **Remediation of Chlorinated and Recalcitrant Compounds First International Conference**, Monterey, California. Information: Chlorinated Conference Registrar, Conference Group, 1989 West Fifth Ave., Suite 5, Columbus, OH 43212-1912, (614) 424-5461, fax 614-488-5747, 102632.3100@compuserve.com. (Abstract deadline: July 31, 1997.)

November 4–7, **Global Mining Opportunities**, Vancouver, British Columbia. Information: Randol International Ltd., 21578 Mountsfield Dr., Golden, CO 80401, (303) 526-1626, fax 303-526-1650. (Abstract deadline: June 1, 1997.)

Send notices of meetings of general interest, in format above, to Editor, *GSA Today*, P.O. Box 9140, Boulder, CO 80301, E-mail: editing@geosociety.org.


 **1997 Short Course Program**
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Colorado School of Mines

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June 2-6	Applied Contaminant Transport Modeling and Remediation Assessment Using MODFLOW and MT3D
June 16-20	Principles and Applications of Chemical Reaction Modeling in Ground Water
June 30-July 1	Analytical Modeling of Contamination
July 14-18	Parameter Identification for MODFLOW

For more information contact:
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1997

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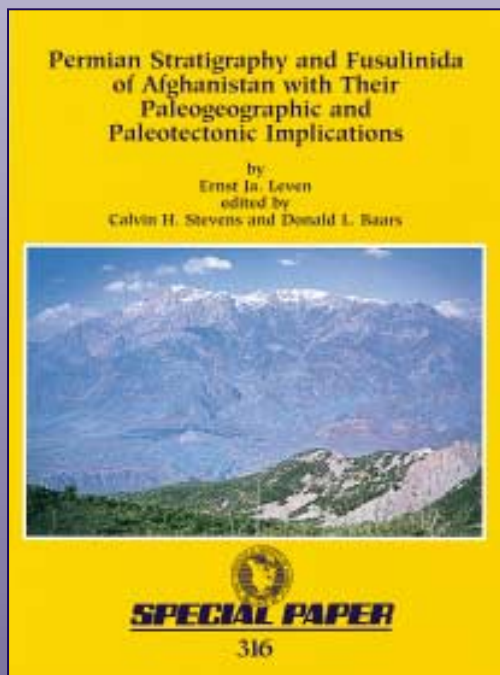
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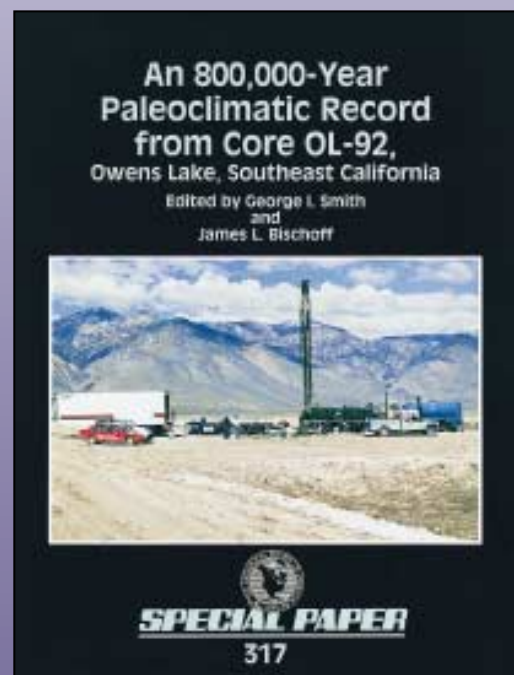
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SPE316, 138 p., ISBN 0-8137-2316-7,
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