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INSIDE

Impact Events and Their Effect on the Origin, Evolution, and Distribution of Life

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ABSTRACT

Impact cratering has affected the geologic and biologic evolution of Earth, from the earliest stages of accretion to the present. The environmental consequences of impact cratering and their biologic repercussions are illustrated by the Chicxulub impact event and its link to the Cretaceous-Tertiary (K-T) mass extinction event. While smaller impact events are more common, there were probably four to five additional impact events of this size during the Phanerozoic. These types of large impact events, and even larger ones, occurred more frequently earlier in Earth history. A particularly intense period of bombardment appears to have occurred ~3.8–3.9 Ga, corresponding to the earliest isotopic traces of life on Earth. These impact events may have made it difficult for preexisting life to survive or may have provided the necessary environmental crucibles for prebiotic chemistry and its evolution into life.

Figure 1. Earthrise over Smythii impact basin with Schubert impact crater on horizon. Views like this during Apollo missions made it clear that Earth is part of a planetary system rather than an isolated sphere, subject to the same bombardment that battered the surface of the Moon. (Apollo 11 AS11-44-6551)

INTRODUCTION

It has become increasingly clear that impact cratering has affected both the geologic and biologic evolution of our planet. Although this view has its roots in the Apollo era (Fig. 1; McLaren, 1970), it was not widely recognized until studies linked the mass extinction that defines the end of the Mesozoic Era with the Chicxulub impact event (L.W. Alvarez et al., 1980; Hildebrand et al., 1991). That particular event also illustrates how a process that destroys some organisms can create opportunities for other organisms—in this case leading to distinctly different ecosystems during the Cenozoic Era. This dual pattern of disaster and opportunity has existed with impact events throughout Earth history, even during the earliest development of life.

The biologic consequences of impact cratering depend on many factors, including the energy of the impact event, the type of target materials, the type of projectile, and the ambient conditions on Earth at the time of impact. Consequences can range from the death of individual organisms to the complete extinction of species. While the former can be the direct result of an impact event (e.g., shock wave–induced hemorrhaging and edema in an animal's lungs [Kring, 1997]), the more important biological effect, including extinction, will be through impact-generated environmental changes. To be an effective extinction mechanism, the environmental changes need to extend throughout a habitat range and exceed an organism's ability to adapt (Newell, 1962). When the environmental effect is largely regional, the changes must overwhelm the migratory capacity of a species or last longer than its dormant capacity. When the effect transcends geographical boundaries and becomes global, the change must be rapid relative to the time scale of evolutionary adaptation or, again, last longer than the dormant capacity of a species. The minimum types of impact events needed to exceed these extinction thresh-

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Impact Events *continued from p. 1*

olds are not yet known. However, many of the environmental effects that could lead to extinction, particularly in the case of the Chicxulub impact event at the K-T boundary, have been identified.

THE CHICXULUB IMPACT EVENT

Regional Effects

The Chicxulub impact occurred on a shallow carbonate shelf that is now part of the Yucatán Peninsula (Hildebrand et al., 1991). In the immediate vicinity of the crater, the shock wave, air blast, and heat produced by the impact explosion killed many plants and animals. The air blast, for example, flattened any forests within a 1000–2000 km diameter region (Emiliani et al., 1981), which would have included the highlands of Chiapas, central Mexico, and the gulf states of the United States. Tsunamis also radiated across the Gulf of Mexico basin, producing reworked or unusually high energy sediments along the latest Cretaceous coastline (e.g., Smit and Romein, 1985; Bourgeois et al., 1988; Smit et al., 1992). Tsunamis were 100–300 m high as they crashed onto the gulf coast (Bourgeois et al., 1988; Matsui et al., 1999) and ripped up seafloor sediments down to depths of 500 m (Smit, 1999). The backwash of these waves was tremendous, depositing forest debris in 400–500 m of water (Smit et al., 1992). The abyssal portion of the Gulf of Mexico basin (W. Alvarez et al., 1992), the neighboring proto-Caribbean (Hildebrand and Boynton, 1990), and Atlantic Ocean (Klaus

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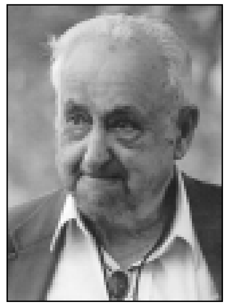

"In the 1960 reorganization of the USGS Geologic Division, Linc became chief of the New England Branch. He and [wife] Esther moved to Melvin Village, New Hampshire, and weeknights Linc lived in his 'Penthouse' in the Back Bay in Boston. Randolph "Bill" Bromery was fascinated by and learned much from Linc in many discussions of the complex uranium-rich carbonates of the Cu-rich Shaba region of Zaire, including 'survival skills—using cognac for brushing our teeth, a unique and pleasant experience. Linc had very special humanity, and my life and career greatly benefited because our paths crossed.'"

—Excerpted from Lincoln Ridler "Linc"Page (1910–1996), by James W. Skehan, *Memorials,* v. 30

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Notice of Council Meeting

Meetings of the GSA Council are open to Fellows, Members, and Associates of the Society, who may attend as observers, except during executive sessions. Only councilors, officers, and section representatives may speak to agenda items, except by invitation of the chair. Because of space and seating limitations, notification of attendance must be received by the Chief Executive Officer prior to the meeting.

The next meeting of the Council will be at 1 p.m., Monday, November 13, at the GSA Annual Meeting in Reno, Nevada.

CORRECTION: The fax numbers for registering for the 2000 GSA Annual Meeting in Reno are 303-443-1510 or 303-447-0648. An incorrect number was published on page 50 of the June issue of *GSA Today.*

GEOTRIP CANCELLATION: "Giant Steps Through Time," scheduled for September 16–October 1, 2000, has been cancelled.

et al., 2000) were also affected by the splashdown of impact ejecta, density currents, and seismically induced slumping of coastal margins (e.g., Smit et al., 1992) following magnitude 10 earthquakes (Kring, 1993). Within a few hundred kilometers of the Chicxulub crater, the thick blanket of ejecta was sufficient to exterminate life.

Global Effects

While these effects devastated organisms in the Gulf of Mexico region, the most significant environmental perturbations were the direct and indirect result of ejected debris that rained through the atmosphere, as first postulated by L.W. Alvarez et al. (1980). This material was carried in a vapor-rich plume that rose through the atmosphere into space. Once above the atmosphere, it expanded on ballistic trajectories, enveloping the whole Earth as it fell back into the atmosphere. The impact ejecta was distributed globally in a pattern much different from that of volcanic plumes, which simply rise into the stratosphere and then spread into latitudinal bands. Calculations indicate that most of this material reaccreted to the top of the atmosphere over a three-day period (Durda et al., 1997), where it then settled to the ground over a longer period of time, depending on grain size. If a substantial portion of this dust was submicron in size, model calculations suggest the dust may have made it too dark to see for one to six months and too dark for photosynthesis for two months to one year, seriously disrupting marine and continental food chains and decreasing continental surface temperatures (Toon et al., 1982; Covey et al., 1990).

In addition to the dust in the vapor-rich plume of ejecta, several important gas species were entrained. The Yucatán Peninsula, near the Chicxulub impact site, consists of carbonate and anhydrite deposits that overlie a crystalline silicate basement, so the impact produced several climatically active gas components, including aerosol-producing SO_2 and SO_3, greenhouse-warming CO_2 and H_2O, and ozone-depleting Cl and Br (e.g., Brett, 1992; Pope et al., 1997; Pierazzo et al., 1998; Yang and Ahrens, 1998; Kring, 1999). The worst appears to have been the S species, which enhanced stratospheric S

Impact Events *continued on p. 4*

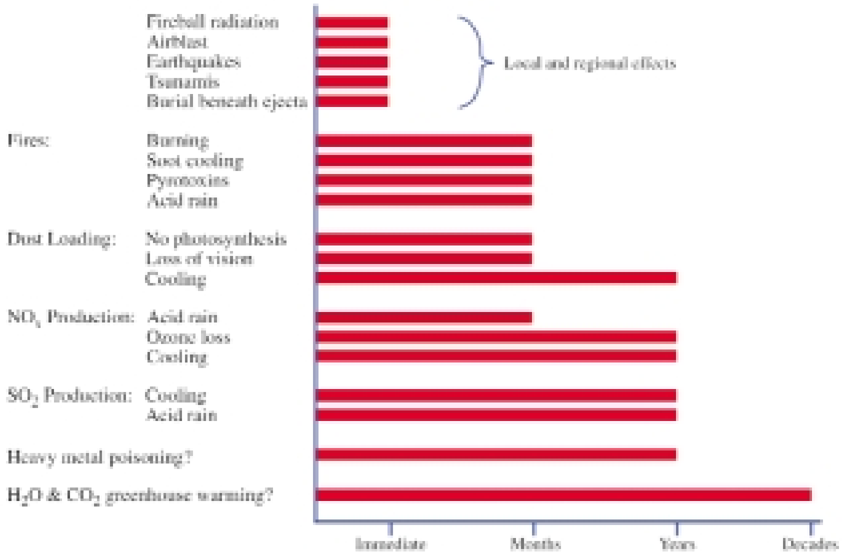

Figure 2. Relative time scales of several environmental perturbations caused by Chicxulub impact event.

Impact Events *continued from p. 3*

on the order of 10^5–10^6 times relative to modern abundances.

Sulfate aerosols were converted to sulfuric acid rain, whose effects compounded those produced by nitric acid rain. Nitric acid rain was produced from nitrous oxides that were created when the atmosphere was shock-heated by the impact event (Lewis et al., 1982; Prinn and Fegley, 1987; Zahnle, 1990). Acid rain could have defoliated continental vegetation and even aquatic plants in shallow, inadequately buffered lakes or seas whose entire water columns became acidic. Asphyxiation of animals by nitrous oxides and toxic poisoning by metals acid-leached from the ground have also been suggested (Prinn and Fegley, 1987), possibly compounding the toxic effects of metals from the projectile (Erickson and Dickson, 1987). The amount of sulfuric acid was not, however, large enough to acidify oceans (D'Hondt et al., 1994; Pierazzo et al., 1998). The nitric acid production may have produced a pH of 3–4 in the upper 100 m, if maximum estimates are correct, but this also seems unlikely (D'Hondt et al., 1994).

Sulfate aerosols significantly reduced the amount of sunlight reaching Earth's surface and would have, thus, enhanced the effects of ejected dust particles and soot produced by fires (discussed later). Darkness and cooler temperatures produced by these particles were relatively short-term, lasting only a few years. On the other hand, there may have been a longer-term increase in temperatures because a large quantity of greenhouse gases were produced from vaporizing sediments (CO_2 and H_2O), the projectile (CO_2 and H_2O, depending on the type of asteroid or comet), shock heating of the atmosphere (N_2O), carbonates dissolved by acidic waters (CO_2), and wildfires (CO_2 and N_2O; discussed later). However, the magnitude of greenhouse warming is still uncertain.

In addition, ozone-depleting Cl and Br were produced from the projectile, target water, target sedimentary rocks, target basement rocks, and postimpact wildfires. The amount of Cl injected into the stratosphere is believed to be five orders of magnitude greater than that needed to destroy the modern ozone layer (Kring, 1999). However, this issue illustrates the current uncertainty of postimpact atmospheric conditions. While ozone may have been consumed by reactions with Cl, Br, and NO, reactions with dust and smoke particles, and heating by reentering debris and accompanying thermal radiation and increased solar absorption, the effects may also have been mitigated by ice, which briefly enhances planetary albedo, dust and smoke, which absorb solar radiation, NO_2, which strongly absorbs part of the ultraviolet spectrum, and sulfate aerosols, which scatter solar radiation. At the moment, there is a good list of the perturbing elements injected into the atmosphere, but the complex microphysical and chemical reactions that occurred have not been modeled.

On the ground, however, it is clear there were postimpact fires. Charcoal and soot, which are produced when vegetation or fossil carbon are burned, have been found in K-T boundary sediments around the world (e.g., Tschudy et al., 1984; Wolbach et al., 1990). Theoretical calculations suggest these fires were ignited by intense thermal radiation produced by ejecta reentering the atmosphere on ballistic trajectories (Melosh et al., 1990). Fires consumed large quantities of latest Cretaceous vegetation, burned many animals, and robbed herbivores of their food. Fires would have produced several secondary effects too, absorbing sunlight, possibly inhibiting photosynthesis, lowering atmospheric temperatures, and producing organic pyrotoxins (Wolbach et al., 1990).

As this brief review illustrates, several impact-caused perturbations on the ground and in the atmosphere could have contributed to the K-T boundary extinctions (Figs. 2 and 3). However, it was likely the combination of primary and secondary effects that was so deleterious. Different parts of the global environment would have been perturbed over diverse time scales (e.g., days for reentering impact ejecta, months for dust in the stratosphere, and years for sulfate acid aerosols). The initial effects would be added to and amplified by secondary effects and the ensuing collateral damage. The biological consequence of the Chicxulub impact was the collapse of entire ecosystems; cascading effects destroyed the infrastructure of the biosphere (e.g., collapse of food chains, loss of habitat), compounding the initial direct environmental effects. Thus, while the physical effects of the impact event may have been relatively short-lived, the time needed to reestablish chemical gradients,

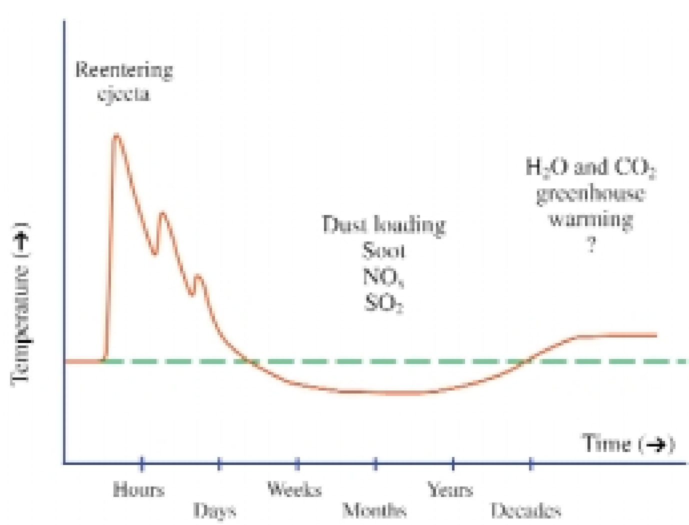

Figure 3. Thermal excursions produced by Chicxulub impact event as a function of time. Preimpact ambient temperature is marked with a dashed line.

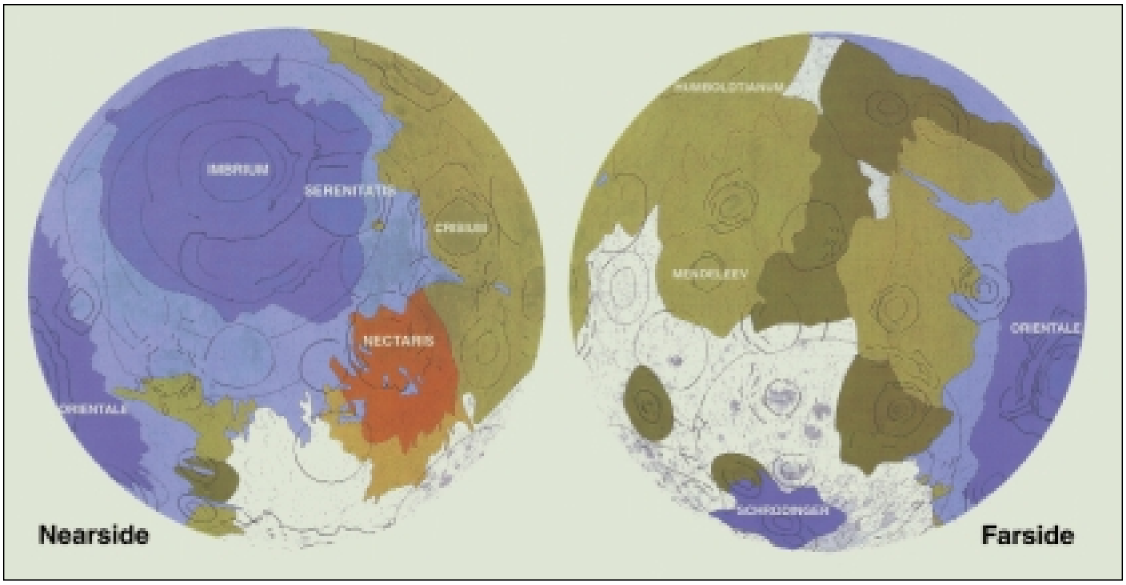

Figure 4. Maps showing regions of the Moon that were resurfaced during Nectarian Period (brown) and Imbrian Period (blue), and outlines of larger basins. Also shown are pre-Nectarian units (darkest brown) and areas of unclear stratigraphic relationships (gray) (Wilhelms, 1987).

repair food chains, and rebuild integrated ecosystems was much greater.

The details of the biologic crisis and its recovery are difficult to tease from the geologic record, but some progress is being made. Impact cratering theory suggests the crisis was global and, indeed, marine bivalve extinction intensities are global without any latitudinal or geographic variations (Raup and Jablonski, 1993). In both marine and continental settings, organisms with dormant or resting states faired better through the crisis. For example, planktonic diatoms that produce resting spores specialized to persist in benthic or deep-pelagic environments of low- to no-light conditions, and, during periods of stress, had a high survival rate (Kitchell et al., 1986). It has also been suggested that the loss of primary productivity and the subsequent collapse of food chains had much less an effect on organisms that were detritus feeders or starvation resistant (Sheehan et al., 1996). The recovery of these survival species, however, did not represent the full recovery of the ecosystem with robust food chains and attendant biochemical gradients. For example, it appears that while marine production may have recovered relatively quickly (albeit with a completely different population of organisms), the flux of organics to the deep sea took approximately three million years to recover (D'Hondt et al., 1998).

Among plants in the western interior of North America, the record of survival and recovery is marked by a dramatic increase in the ratio of fern spore to angiosperm pollen (Orth et al., 1981; Tschudy et al., 1984). The pioneering behavior of the ferns after the impact-generated wildfires is similar to their behavior after forest fires today. In Canada, both ferns and angiosperm taxa behaved in an opportunistic fashion depending on the preimpact plant community, suggesting the vegetation recovered from local seeds and spore, rather than being repopulated from distant communities (Sweet and Braman, 1992). Gymnosperms were generally lost at the boundary, suggesting the swamp forest canopy was destroyed for several years (Sweet and Lerbekmo, 1999), even at sites ~4000 km from the impact.

LIFE'S ORIGINS

The Chicxulub event is an example of how impact cratering can affect life and is likely to be only one of five to six such events during the Phanerozoic (Kring, 1995). Impact cratering also had an important effect much earlier in Earth history when life was initially being established. A particularly intense period of bombardment appears to have occurred ~3.9 Ga, which almost completely reset the U-Pb system in lunar highland samples in the Apollo collection (Tera et al., 1974). The event also seems to have put an upper limit on the ages of surviving impact melts in the Apollo collection (Ryder, 1990; Dalrymple and Ryder, 1993). While the concept of a cataclysm has been controversial (Baldwin, 1974; Hartmann, 1975), recent analyses of impact melts in lunar meteorites (Cohen et al., 2000), which represent a much larger fraction of the Moon, have the same age limit and support a planetwide impact cataclysm.

The initial stage of intense impact cratering on the Moon is known as the Nectarian Period (3.8–~3.9 Ga), which began with Nectaris impact and ended with Imbrium impact (Wilhelms, 1987). This period is believed to have been <200 Ma long (Tera et al., 1974; Wilhelms, 1987), during which time at least 1700 craters >~20 km diameter were produced, including at least 12 impact basins far larger than Chicxulub (Fig. 4; Wilhelms, 1984, 1987). The number of impacts occurring on Earth would have been an order of magnitude larger, implying >10,000 large impact events. This was followed by the Early Imbrian Epoch, which began with the Imbrium impact and ended with the Orientale impact, again roughly 3.8–3.9 Ga, producing additional basin-size craters on the order of 1000 km diameter. These large impact events also produced swarms of secondary craters with diameters >20 km (e.g., Wilhelms, 1987), which were also large enough to cause dramatic effects. Impact events of these sizes on Earth would have been large enough to have affected the environment and most likely any life that had arisen. The largest impact events probably produced immense quantities of ejecta, temporarily charged the atmosphere with silicate vapor, and boiled away large quantities of surface water (Sleep et al., 1989; Sleep and Zahnle, 1998).

Interestingly, the earliest isotopic evidence of life on Earth comes from this same period of time (e.g., Mojzsis and Harrison, 2000). In addition, ribosomal RNA analyses of the most deeply branching organisms suggest that life is rooted among thermophilic or hyperthermophilic forms. Commonly, this is interpreted to mean that life originated (or survived the impact bombardment in) volcanic hydrothermal systems. However, during the period of bombardment, impact-generated hydrothermal systems were possibly more abundant than volcanic ones. The heat source driving these systems is the central uplift and/or pools of impact melt. In the case of a Chicxulub-size event (among the smallest ~3.9 Ga), melt pools may have driven a hydrothermal system for 10^5 yr (Kring, 1995). The

Impact Events *continued on p. 6*

Dialogue

Sara Foland, CEO

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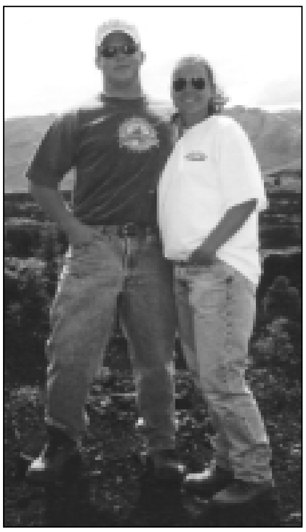
"To learn geology one must travel widely and observe carefully, for geology is learned through the soles of your shoes, not the seat of your pants! The Earth is vast, its features, varied. One must climb mountains, travel over limitless plains, watch the waves of the sea beat unendingly upon the shore, study the work of mountain torrents as they carry their load to the sea, and learn to read the character of the rock record to understand the Earth. Delve deeply into the rocks, for truth is hidden there. Take heed to observe carefully the seemingly insignificant things, as each and every phenomenon and event is an integral part of nature's process. Be untiring in your zeal to learn; and when you have accumulated facts, give careful thought to their interpretation. Let all your work be marked by ceaseless patience, tireless industry, vigilant caution, and prolonged study. Nature's deeds are not erratic. What occurs is ruled by laws. When one is trained to read the geologic record, the deeds of nature become clear, usually simple, and amenable to understanding and description. The Earth gives no higher or nobler task than to study nature, to unlock her secrets and interpret her deeds."

—Walter L. Manger et al.
University of Arkansas Sigma Gamma Epsilon Initiation Ceremony

Service at GSA: Support for Students



Jack May and Julie Williams May

Over the past several months, we've talked about GSA's values of science and stewardship. This month, we're ready to look at the third of our three Ss, which is service. One significant form of service GSA and its members perform is support for the professional growth and development of young geoscientists.

Exploring this topic with me are Jack May and Julie Williams May, both spring 2000 graduates of the University of Arkansas. Julie earned a B.A. in geology and a B.S. in earth science (cum laude); Jack received his M.S. in geology. They married in May and now live in Columbia, South Carolina, where Jack is pursuing a Ph.D. in geology and Julie a master's degree in environmental resource management at the University of South Carolina.

Sara: I started out as a student member of GSA, and I remember how valuable that experience was for me. What stands out for you about membership in GSA?

Jack: We've been student members for the last three years, and GSA has provided us with lots of opportunities to interact with geologists in industry, academia, and government research. We attended the 1999 South-Central Section meeting in Lubbock, the 1999 annual meeting in Denver, and this past spring we helped host the South-Central Section meeting in Fayetteville.

Julie: Interacting at these meetings with professional members from so many different environments has helped us get a sense of "career." It has helped with everything from making a commitment to the field of geology to developing interests in specific sub-disciplines and formulating career plans. All those exhibitors at meetings make gathering information easy, and travel grants help with the cost of getting there on a student budget.

Jack: The mentoring sessions have been particularly useful. I've talked one-on-one with people working for the U.S. Geological Survey, environmental consulting firms, and in the petroleum industry. I've asked what their jobs were like, what they'd do if they were just starting out, and whether continuing my education to the Ph.D. level is worthwhile. The sessions also covered practical matters like résumé writing.

Sara: In fact, GSA's mentoring programs are intended to give you perspective and the skills you need in addition to your geoscience expertise. In funding these programs, I think Roy Shlemon was looking for a way to help young geoscientists begin making the transition from student to professional.

Jack: Certainly another growth experience for me came from presenting some of my research on sedimentation on the California continental borderland at a poster session in Denver last year.

Sara: Many of us had our first sweaty-palm experience presenting research at a GSA meeting. Section meetings are particularly good for this because you can present to peers and faculty from outside your home institution in a relatively small and somewhat informal venue. The great thing is that everyone wants you to succeed and people are extremely supportive. A related aspect of GSA's support for students is our research grants program. Since the program began in 1933, GSA has awarded more than $7 million to 6,800 students.

Julie: Jack and I have certainly enjoyed and benefited from our participation in GSA, and we intend to be lifetime members. See you in Reno!

Impact Events *continued from p. 5*

dimensions of these systems can extend across the entire diameter of a crater and down to depths in excess of several kilometers (e.g., Komor et al., 1988; Pevzner et al., 1992). Large regions within these systems should have had appropriate temperatures for thermophilic and hyperthermophilic organisms. When the craters were subaerially exposed, the hydrothermal systems probably vented in mud pots, hot springs, and geysers, similar to those in volcanic terranes. When the craters were filled with freshwater lakes or marine incursions, the hydrothermal systems probably vented subaqueously, like those in volcanic crater lakes or deep-sea vents. In addition to providing a suitable environment for thermophilic and hyperthermophilic forms of life, it has been suggested that the impacting objects may have seeded the surface of Earth with amino acids and other important organic materials (e.g., Chyba, 1993; Pierazzo and Chyba, 1999).

CONCLUSIONS

Impact cratering is a very energetic geologic process that has the capability of disrupting or redirecting the biologic evolution of a planet. In the case of the Chicxulub impact event 65 Ma, a large number of regional and global environmental effects were generated that were likely the cause of the mass extinction that marks the K-T boundary. The potential for disrupting the environment was larger and more frequent earlier in Earth history, particularly ~3.9 Ga when life with thermophilic and hyperthermophilic characteristics evolved. This implies that life either originated in these impact-dominated conditions or possibly that these forms of life were the type best suited to survive this brief period of intense bombardment. In the latter case, life may have originated under different conditions in different environments and only found itself frustrated by impact cratering (Maher and Stevenson, 1988; Chyba, 1993) as it was by Chicxulub.

ACKNOWLEDGMENTS

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PENROSE CONFERENCE REPORT

Volcanic Rifted Margins

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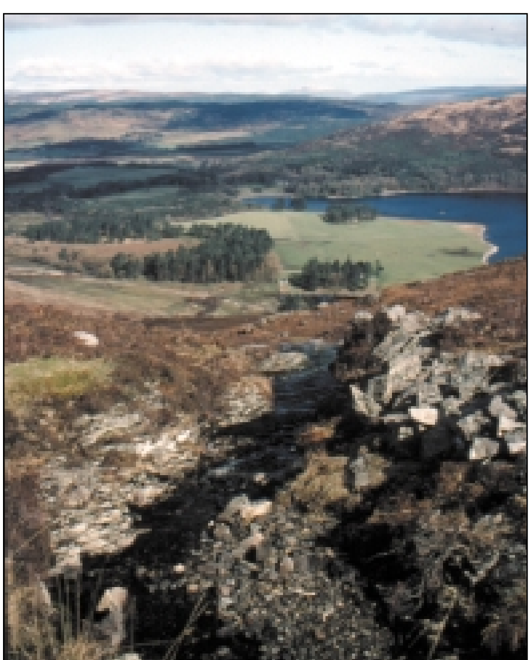
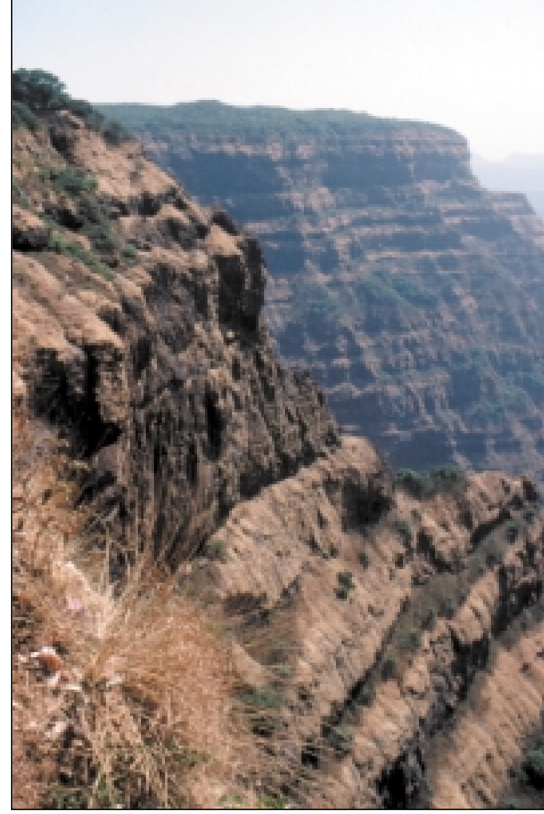
Active rifting (plume-driven) models are the traditional explanation for the formation of volcanic rifted margins with significant surface uplift occurring prior to flood volcanism and break-up extension. However, recent research on volcanic rifted margins indicates that their evolution is more complex than that defined by earlier models, and several hybrid models have been proposed. At the Penrose 2000 Volcanic Rifted Margin Conference held at Royal Holloway, University of London, discussion centered on the margins of the north, central, and south Atlantic Ocean, the western and eastern coasts of Australia, the southern Red Sea, the west coast of India and its conjugate margins in Madagascar and the Seychelles. The characteristic features of volcanic rifted margins were summarized and it was agreed that formation of a volcanic rifted margin required complete rifting of a continent to form an ocean above an upper mantle with a temperature 100–200 °C above "normal" asthenosphere. This should be contrasted with rifting without additional thermal perturbation which leads to non-volcanic rifted margins (e.g., Newfoundland, Iberia) and thermal perturbations in the absence of rifting which lead to formation of intraplate large igneous provinces in ocean basins (e.g., Ontong-Java oceanic plateau) and on continents (e.g., Siberian flood basalts).

Continental Flood Volcanism, Underplating and Seaward-Dipping Reflector Sequences

Volcanic rifted margins are characterized by subaerial volcanic rocks (~4–6 km thick) on a continental margin. Ar-Ar and K-Ar dating indicates that, in the majority of volcanic rifted margins, 70%–80% of the subaerial mafic and/or basaltic volcanism occurred over a relatively short period of time (2 m.y. in the case of the Red Sea and East Greenland plateau lavas and <0.5 m.y. in the case of the Deccan). The short phase of basaltic volcanism is followed by a lengthy period of silicic volcanism that can last for 5–10 m.y. In some volcanic rifted margins, silicic volcanic rocks erupted from multiple caldera complexes tend to dominate the upper volcano stratigraphy (Argentina-Antarctica, eastern Australia, Etendeka-Namibia, Scotland, Yemen), but in the Parana-Etendeka and Ethiopia, silicic units are interbedded with the basaltic lava flows. In the Deccan and the British Tertiary the presence of ash layers in the volcano stratigraphy indicates "silicic" volcanism between periods of basalt volcanism. The switch from basaltic to silicic volcanism reveals the importance of high-level magma chambers and crustal melting in the formation of volcanic rifted margins of magma. In Etendeka, individual silicic eruptive units have thicknesses of up to 100 m, aerial extents >8000 km^2 and volumes of 3000 km^3, indicating large-scale explosive eruptions. Eruption rates in volcanic rifted margins have not been adequately constrained by volume-time studies of individual eruptive units and, as a first approximation, thickness-time relationships reveal a marked decline in eruption rate from the mafic to the felsic eruptive stages of volcanic rifted margins. This is consistent with the requirement for longer time periods to allow basaltic magmas to pond in shallow magma chambers and to evolve toward silicic derivatives by a combination of fractionation processes and assimilation of surrounding basement and/or roof rocks. While the emplacement of thick mafic flows within volcanic rifted margins has no modern analogues, a possible explanation for the mechanism of emplacement may be found in the recently proposed "self-inflation" model for basaltic lavas (single or compound) with thicknesses ranging from 1 to 100 m (e.g., Etendeka, Deccan).



Unroofed Loch Ba center and late caldera on Mull, Scotland.



Deccan volcanic stratigraphy exposed by scarp retreat at King Arthur's Seat, Mahabaleshwar.

Underplating, or formation of an over-thickened oceanic layer 3 and adjacent stretched continental crust, is evident as distinctive high-seismic velocity (7.2–7.4 km/s) and associated gravity anomalies, but only sometimes by lower-crustal reflectivity. Because bright lower-crustal reflectivity can have other causes, surface denudation should be sought as independent verification of underplating. Magmatic underplating may involve multiple dike-sill systems, multiple igneous intrusions, or single magma bodies. In southeast Greenland, the maximum igneous crustal thickness varies from 30 to 40 km close to the thermal anomaly (i.e., track of Iceland hotspot), thinning to 18 km at 500–1000 km from the anomaly. On the northwest Australian margin, the underplated thickness is ~7 km near the ocean-continent boundary. These thicknesses have been widely used to infer the magnitude of mantle temperature anomalies, but if average Vp is also measured, and used as a proxy for composition, one may also infer the degree of mantle upwelling. Along the Iceland hotspot track, there is a clear requirement for active upwelling, defined as a mantle upwelling velocity exceeding that due purely to the plate separation rate. In contrast, 500 km off the hotspot track, upwelling appears to be passive and can be explained purely by plate velocity. On the Greenland–northwest Europe conjugate margins, crustal-generation rates as high as 2000 km^3/m.y. per km of margin occurred at breakup, declining rapidly over a few m.y. Magma production rates of volcanic rifted margins (i.e., per kilometer of active margin) seem similar to that of island arcs, but volcanic rifted margins are less effective in generating new continental crust because the total length of active arcs exceeds that of active volcanic rifted margins by a factor of 5–10.

Seaward-dipping reflector sequences, first recognized along the North Atlantic margin, are a characteristic of volcanic rifted margins and are recognized by reflectors which steepen and diverge downward to dips of over 15 degrees. These reflector packages reach up to a maximum estimated thickness of 10 km and extend for up to 200 km perpendicular to the margin and up to 4000 km along strike (e.g., Argentina-Brazil margin). Seaward-dipping reflector sequences are interpreted to be largely subaerial eruptions, and their seaward termination may typically mark the transition to submarine eruptions. The sequences may be predominantly volcanic rocks with associated sedimentary rocks. On the Namibian margin, models of seismic data, tested against magnetic data, suggest that the seaward-dipping reflector sequences package is a mixture of volcanic and sedimentary rocks, and on the Norwegian volcanic rifted margin, seismic sections have been interpreted as documenting a transition from subaerial to submarine volcanic deposits that comprise lavas and volcaniclastic sedimentary rocks. Underplating is an integral part of the architecture of volcanic rifted margins and, with the extrusive part of the sequences, is what may distinguish volcanic from nonvolcanic rifted margins. However, there are possible complications in margins like Sergipe-Alagoas, Brazil. The lack of pre- and synrift volcanics is a classic nonvolcanic margin characteristic while the thick wedges of postrift seaward-dipping reflectors are a classic volcanic margin characteristic.

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Deadline: Ballots must be submitted electronically or postmarked by September 16.

Plumes and Upwellings: Magmatism and Rifting

Melt production at volcanic rifted margins requires (1) mantle potential temperatures of 1400–1600 °C (which may or may not be expressed as geochemical or geophysical anomalies), and (2) lithospheric thinning to (or preexisting lithospheric thickness no more than) ~90 km to allow adiabatic decompression melting. Geophysical and geochemical data, backed up by theoretical modeling, support the presence of one (or more) plume(s) during the formation of the volcanic rifted margins of the Atlantic, the Red Sea, India-Seychelles, and the volcanic rifted margins in Antarctica. However, some controversy exists over the extent to which various geochemical parameters (e.g., helium-lead isotope ratios and trace-element parameters) can be used to define plumes. While magma geochemistry clearly indicates input from mantle and crustal sources, at present, geochemical and geophysical data cannot, to everyone's satisfaction, distinguish between core-mantle boundary plumes and upper-mantle upwellings related to topography at the lithosphere-asthenosphere boundary beneath continents. Overall, at the Penrose, geochemical and geophysical data were found to be far from conclusive when it came to deciphering the presence or absence of deep-mantle plume structures. What is clear is that thermal anomalies exist on Earth and that their distribution, shape, and size appear to be variable, and their duration and genesis manifest themselves to different degrees and in nonspecific order, in the uplift/subsidence, extension/volcanism, of the lithosphere.

Some models of volcanic rifted margin formation that involve input from the mantle require that rifting and magmatism were essentially synchronous, but in many volcanic rifted margins (e.g., Yemen, North Atlantic, Australia), several million years lapsed between the onset of flood volcanism and widespread rifting. In the Parana-Etendeka, it can be argued that the Etendeka magmatic province was erupted prior to onshore rifting because the main volcanic units can be traced from the Etendeka into the Parana, so there could not have been major topographic depressions ponding sequences. Alternatively, it can be argued that the transcontinental correlation of eruptive units is possible because the rift topography was quickly blanketed by sheetlike eruptive units. While "offshore valley systems" appear to be filled with lavas and have been interpreted as evidence of rifting having predated volcanism, later deformation and faulting may explain the apparent "channeling" of units. On the North Atlantic volcanic rifted margins, basaltic volcanism overflowed the conjugate margins, as it did in the Deccan, and as such must be largely synrift. In the case of the volcanism associated with the central Atlantic Ocean (200 Ma) there is geochronological evidence that volcanism postdated rifting

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by 30 m.y. in some cases, but was synchronous with basin formation in others.

Denudation = Surface Uplift–Rock Uplift

In many volcanic rifted margins, what we observe today are erosional remnants, and the degree of preservation is inextricably linked to climate, elevation, and the amount or rate of denudation. The youngest volcanic rifted margins (Ethiopia-Yemen) are characterized by incised 3-km-high uplifted flanks atop a broad plateau. Volcanic rifted margins formed at the Cretaceous-Tertiary boundary are characterized by major scarp retreat in India and an eroded mountain range in Scotland. The central Atlantic magmatic province in the eastern United States and West Africa was reduced to a feeder dike swarm during 200 m.y. of erosion. Within volcanic rifted margins, unconformities provide important temporal information about denudation and the potential supply of sediments to extensional basins. In some cases erosion postdated the main magmatic episode and was synchronous with breakup extension (e.g., Yemen), and in other volcanic rifted margins (e.g., eastern Australia) erosion and sediment input (i.e., with >1.4 million km^3) into adjacent or preexisting sedimentary basins coincided with the main magmatic episode.

Apatite fission track analyses and U-Th/He dating are used to quantify the timing and rate of denudational processes (tectonic and erosional) as measures of crustal cooling, and cosmogenic isotopes are used to date paleosurfaces (e.g., Deccan). Fission-track dating has been applied to many volcanic rifted margins and, whereas young, hot volcanic rifted margins (e.g., Yemen) have a relatively simple cooling history, older and colder volcanic rifted margins tend to have a more complex cooling history that may be difficult to unravel (e.g., United Kingdom–Greenland, India). Studies in Antarctica indicate that landscape evolution was very slow with a cessation to scarp retreat in the past 15 m.y. On the Yemen margin of the Red Sea, denudation peaked in the Miocene during breakup, with scarp retreat determining landscape evolution since that time.

Theoretical models require 500 m–2 km of uplift prior to, or concurrent with, magmatism depending on proximity to the plume head or stem and lithospheric heating. To properly understand rock and/or surface uplift, constraints must be placed on the prerift paleogeography (relative to sea level) and the denudational history. According to the prevolcanic sedimentary rock record of eastern Greenland and Scotland, the southern Red Sea, and north, west, and east Australia, the prebreakup continental masses were close to sea level. However, it is apparent that some variation existed in the North Atlantic as west Greenland is characterized by incised fluvial systems, east Greenland by a landscape close to sea level and northwest Scotland–Faeroes by a low-relief, vegetated land surface. In Yemen, a shoreline existed close to the present location of a mountain range (~3 km) but, judging from paleocurrent information and the maturity of the prevolcanic sediments in Yemen, a hinterland must have existed in the Danakil horst, Eritrea. In contrast to these volcanic rifted margins, the Drakensburg mountains (South Africa) are believed to have inherited "relief" at the time of Gondwana breakup. While the nature of the Deccan-Seychelles land surface prior to breakup (relative to sea level) is unknown, in the Parana-Etendeka it is characterized by a large aeolian erg system.

Denudation coincides with the peak of extension in Yemen and eastern Australia, while in west Greenland, major unconformities beneath the volcanic rocks are associated with fluvial peneplanation and valley incision, indicating a period of substantial prevolcanic uplift and denudation. In Antarctica, landscape development followed the onset of uplift and a change in base level. Scarp retreat, planation surfaces, and incision by fluvial systems produced a landscape that has changed little in 15 m.y. In the Deccan of India, some topographic expression must have existed, perhaps triggered by uplift, because palynological data indicate the presence of floodplain or lacustrine environments. The western Ghat escarpment is believed to have an erosional rather than a tectonic origin, and scarp retreat is believed to be the major determinant of landscape with the original continental margin ~75 km west of its present location. Thus, it appears that there may be spatial separation of plume head or stem material driving uplift and zones of melt generation (thinned lithosphere) within broad plume provinces.

Characteristics of Volcanic Rifted Margins

The Penrose Conference participants concluded that the defining characteristic of a volcanic rifted margin (that which distinguishes it from a nonvolcanic margin) is the presence of a significantly greater thickness of new intrusive and extrusive igneous crust, ≥~10 km, at a rifted margin than is formed in normal oceanic crust or nonvolcanic margins. However, as we learn more about the 3-dimensional crustal architecture of volcanic rifted margins, we should perhaps be identifying them as *magmatic* at all levels, rather than merely as *volcanic.* Nonetheless, Penrose 2000 suggests that the following observations are sufficiently common at volcanic rifted margins to be regarded as characteristic features:

(a) Subaerial volcanic rocks reached 4–6 km in thickness on the continental margin prior to denudation.
(b) Magmatic underplating, evident as high velocities (~7.4 km/s) in the lower crust interpreted as new mafic igneous crust—the intrusive counterpart of extrusive volcanic rocks on the continental margin or seaward-dipping reflector sequence in the continent-ocean transition.
(c) 70%–80% of the erupted volume was emplaced over a 1–2 m.y. period, with basaltic magmas erupted from fissure systems. Individual eruptive units can be ~100 m thick and cover several 1000 km^2.
(d) Silicic volcanic rocks, erupted from caldera-type complexes, can be a significant part of the upper (and lower) volcano stratigraphy of volcanic rifted margins (Ethiopia-Yemen, Parana-Etendeka, eastern Australia) with individual eruptive units comprising 100s to 1000s km^3.

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About People

Member John W. Gibson Jr. was named president and CEO of Landmark Graphics Corporation, a supplier of integrated exploration and production technical and economic software designed to help petroleum companies worldwide find, produce, and manage oil and gas reservoirs.

Member Robbie R. Gries has been elected president-elect of the Association of Petroleum Geologists for the 2000–2001 term. She will serve as president of the association for the 2001–2002 term.

Member Thomas L. Wright, a consultant in San Anselmo, California, received the American Association of Petroleum Geologists' (AAPG) Michel T. Halbouty Human Needs Award. Wright was honored at the 85th AAPG Annual Convention in New Orleans on April 17. The Michel T. Halbouty Human Needs Award honors an individual for the outstanding application of geology to the benefit of human needs, recognizing scientific excellence.

Birdsall-Dreiss Distinguished Lecturer for 2001 Announced

Steve Ingebritsen has been selected as the 2001 Birdsall-Dreiss Lecturer. Ingebritsen received a B.A. degree in geology from Carleton College and M.S. and Ph.D. degrees in hydrogeology from Stanford University. He has been a member of the U.S. Geological Survey (USGS) since 1980 and is currently chief of Regional Research, Water Resources Division, Western Region. He is author, along with Ward Sanford, of the textbook *Groundwater in Geologic Processes* (Cambridge University Press, 1998).

Ingebritsen will offer the two lectures detailed below. The first describes an ongoing study of crustal permeability done in collaboration with Craig Manning, a metamorphic petrologist with the University of California at Los Angeles. The second relates to a recent USGS circular on land subsidence, done in collaboration with Devin Galloway, David Jones, and many others. To request a visit to your institution during the tour, contact Steve Ingebritsen directly at (650) 329-4422, or seingebr@usgs.gov. The GSA Hydrogeology Division pays transportation expenses; the host institution is expected to provide for the lecturer's local expenses. Liberal arts colleges are particularly encouraged to participate.

LECTURE TOPICS

The Permeability of the Continental Crust

The variation in permeability with depth in the crust can be probed indirectly with (1) hydrologic models that use geothermal data as constraints, and (2) the progress of metamorphic reactions driven by fluid flow. These data indicate that, in orogenic belts, $\log k = -14 - 3.2 \log z$, where k is in meters squared and z is in km. This relation implies that typical metamorphic fluid-flux values are consistent with fluid pressures significantly above hydrostatic values; that the metamorphic carbon dioxide flux may be sufficient to affect climate; and that there is a significant capacity for diffuse degassing of Earth in tectonically active regions.

Land Subsidence in the United States

From the San Francisco Bay Delta to the Florida Everglades, and from upstate New York to Houston, illustrative case studies describe three basic mechanisms by which human manipulation of groundwater causes land subsidence: groundwater withdrawal, dewatering and oxidation of organic soils, and dissolution collapse of susceptible materials. In the United States, subsidence due to these mechanisms affects more than 40,000 square kilometers in 45 states and causes at least $125 million in annual damage. Interferometric Synthetic Aperture Radar (InSAR) is a powerful new tool for assessing and mitigating subsidence. ■

Volcanic Rifted Margins
continued from p. 10

(e) Rift flank uplifts atop broad plateaus reach up to 4 km above sea level and act as a source for clastic sediments in adjacent extensional basins. Some of this uplift is permanent as opposed to time-decaying thermal uplift. A gradual decrease in the elevation of these mountains away from the rift axis is evident in both young and/or active (i.e., Ethiopia, Yemen) and old and/or inactive (i.e., Greenland and Scotland) volcanic rifted margins.

(f) Seaward-dipping reflector sequences appear to consist of a mixture of volcanic rocks (lavas ± ignimbrites), volcaniclastic and nonvolcanic sedimentary rocks.

(g) The ocean-continent boundary is abrupt (e.g., Greenland, East Coast of the United States, Namibia).

(h) Magmatism and rifting in volcanic rifted margins are not necessarily synchronous. Magmatism may predate rifting by several million years, may be synchronous with rifting, or may postdate rifting.

(i) Prior to formation of the volcanic rifted margin, the continental land masses were close to sea level (Yemen, east Greenland, United Kingdom, Etendeka) and displayed a variety of sedimentary environments (e.g., fluvial, aeolian, etc.).

(j) Kilometer-scale uplift prior to magmatism is not demonstrable on most volcanic rifted margins, but uplifted and rapidly denuded continental margins are observed, indicating that uplift and/or base-level change is a vital part of the formation of volcanic rifted margins.

(k) Unroofing of mantle rocks is not observed in volcanic rifted margins in contrast to at least some non-volcanic margins (e.g., Iberia, northern Red Sea).

Ultimately, the degree to which we search for similarities or distinctions between different volcanic rifted margins may owe as much to our personal philosophical predilections, whether we are by nature "lumpers" or "splitters," than to the existence of an underpinning geological truth.

Acknowledgments

This report stems from a Penrose Conference held at the Department of Geology, Royal Holloway, University of London, on March 28–29, 2000.

Conference Participants

Mohamed Al-Kadasi	Ian Davison	Jake Hossack	Andrea Marzoli	Robert Smith
Abdulkarim Al-Subbary	Yildirim Dilek	Sarah James	Ken McClay	K.V. Subbarao
Don Anderson	Cecile Doubre	Claude Jaupart	Greg McHone	Michael Summerfield
Nicholas Arndt	Cindy Ebinger	Priya Javeri	Leone Melluso	Roger Swart
Laurence Audin	John Encarnacion	Alistair Jeffcoate	Martin Menzies	Christian Tegner
Dereje Ayalew	Richard England	Dougal Jerram	Daniel Miggins	Mengist Teklay
Joel Baker	Manuel Fernandez	Garry Karner	Webster Mohriak	Gary Thompson
Christian Berndt	Paul Fitzgerald	Seifu Kebede	Jean-Paul Montagner	Montserrat Torne
Wouter Bleeker	Mary Fowler	Bruno Kieffer	Clive Neal	Robert Trumbull
Scott Bryan	Frederick Frey	Simon Klemperer	Soenke Neben	Ingrid Ukstins
Jean-Paul Callot	Kerry Gallagher	Kim Knight	Andy Nyblade	Mike Watkeys
Joe Cartwright	Laurent Geoffroy	Biswaketan Kundu	Sanjaya Pattanayak	Nicky White
James Chalmers	Rhiannon George	Nick Kusznir	David Peate	Robert White
Gilles Chazot	Linda Hanley	Hans Christian Larsen	Raphaël Pik	Pierre Wiart
John Chesley	Chris Hawkesworth	Philip Leat	Teal Riley	Mike Widdowson
Branko Corner	Lara Heister	Frank Lisker	Pierre Rochette	Ellen Wolfenden
Jenny Cripps	Steve Holbrook	Isabelle Manighetti	Richard Single	

Congressional Science Fellow Rachel Sours-Page

New GSA Congressional Science Fellow to Begin Term in September

Rachel Sours-Page, of Oregon State University (OSU), is the 2000–2001 GSA–USGS Congressional Science Fellow. Sours-Page grew up in the San Francisco Bay Area and graduated from The College Preparatory School in Oakland, California. She attended Harvey Mudd College and neighboring Pomona College where she received a B.S. in geology. As an undergraduate, she served as student liaison to geology department faculty and as dormitory president. During 1994 and 1995, she participated in the Keck Undergraduate Research Program and completed her senior thesis on the petrology of the Mount McLaughlin region of southwestern Oregon.

In 1995, Sours-Page enrolled in OSU's Department of Geosciences' Ph.D. program and worked as both a teaching and research assistant. Her research focused on the use of olivine and plagioclase-hosted melt inclusions in the understanding and determination of mantle and crustal processes at mid-ocean ridges. Active in OSU's student government, Sours-Page served as both the graduate representative to the geosciences department faculty and proxy senator for the Graduate Student Senate. She also became a founding member of the Coalition of Graduate Employees, the labor union for OSU graduate employees.

Sours-Page is interested in the interface between science and public policy, with emphasis on environmental issues, including sustainable living, renewable resources, and the preservation of natural habitats. As a staff member working directly with Washington decision makers, she will be well positioned to help bridge the communication gap that often exists between scientists and their legislators, while furthering her own education in science policy and government issues. "I'm honored to receive the GSA–USGS Congressional Science Fellowship and am excited by the opportunity to represent the geology community," Sours-Page said. Look for perspective articles from Sours-Page in upcoming issues of *GSA Today*.

The Fellowship

The Congressional Science Fellowship, funded by GSA and a grant from the U.S. Geological Survey, was established in 1986. Rachel Sours-Page, named as the 2000–2001 fellow, is the 15th person to take on the challenge of applying scientific and technical expertise to a wide range of public policy issues.

Fellows can and do directly impact public awareness of earth science and related issues. For an account of one fellow's influence, see "Science and Politics: A Personal Encounter," on p. 13.

The fellowship places highly qualified scientists in the offices of individual members of Congress and committees for a 12- to 15-month appointment. While fellows explicitly do *not* represent special interests, they do play a professional role for GSA during their appointment by bringing issues and perspectives to the attention of GSA headquarters staff, our members, and staff members from the USGS. In exchange for the opportunity to acquire experience and the chance to contribute to the formulation of public policy, fellows bring to the position special knowledge, skills, and competence. Fellows report periodically to the GSA membership and to the USGS on geoscience issues facing Congress and on the positive roles available for all earth scientists in policy formulation.

To prepare for their assignments, fellows attend a two-week orientation conducted by the American Association for the Advancement of Science. Fellowship requirements include an exceptional competence in some area of the earth sciences, cognizance of a broad range of issues outside their particular areas, and a strong interest in working on a range of public policy programs.

In alignment with GSA's Strategic Plan, the Institute for Earth Science and the Environment administers the Congressional Science Fellow program and supports our members' activities and interests in public policy. For additional information on this program and other science and policy topics, see "Policy and Government Affairs" in the Public Interest section of the GSA Web site (www.geosociety.org). ■

Call for Applications!

Looking to expand your professional horizons? ◆ Believe in serving society through science? ◆ Ready for a unique challenge?

Apply for GSA's Congressional Science Fellowship 2001–2002.

Put your expertise and experience to work helping shape science and technology policy on Capitol Hill. Work directly with national and international leaders.

The Congressional Science Fellow will be selected from top competitors early in 2001. Successful candidates are GSA members who possess either a Ph.D. in the earth sciences or a related field, or a Master's degree in the earth sciences or a related field with at least five years of professional experience. If you possess this professional background, have experience in applying scientific knowledge to societal challenges, and share a passion for helping shape the future of the geoscience profession, GSA invites your application. The fellowship is open to U.S. citizens or permanent residents of the U.S. *The deadline to apply is February 2, 2001.*

To learn more about the Fellow experience, contact David Verardo, 1997–1998 GSA Congressional Science Fellow, at (703) 625-6105 or dverardo@geosociety.org.

For application information, check our Web site at www.geosociety.org/science/csf/scifello.htm or contact Karlon Blythe, Program Officer, GSA Headquarters, (303)-447-2020, ext. 136, or kblythe@geosociety.org.

Science and Politics: A Personal Encounter

Ann Boylan

How many of us are politically active? More important, how many of us are even politically aware? As a geoscientist working for an elected official, I know how underrepresented we are in the political world.

The journey that brought me out of the laboratory and into the political arena involved a series of serendipitous encounters with several geologists who turned out to be helpful mentors. It began while I was earning a bachelor's degree in geology from the Department of Geography and Earth Science of George Mason University (GMU) in Fairfax, Virginia, located near the U.S. Geological Survey (USGS) National Center in Reston, Virginia. Like many GMU geology students under the guidance of Department Chair Rick Diecchio, I took advantage of the opportunity to gain valuable experience by working as a USGS laboratory assistant. I had the good fortune of working with Bill Orem, a biogeochemist who engaged his student assistants in every part of the research process. Between my education in the classroom and my education in the workplace, I learned a great deal about what it is to be a scientist.

When I filed my intent to graduate in the spring of 1998, however, I received disappointing news. Government policies dictated that I could not keep my job with the USGS unless I was enrolled in a degree program. I was crushed! I had intended to stay with the project for another year, then move to the West Coast with my husband. I loved my work at the Survey, and I did not want to start graduate school before I was ready in order to keep my job.

After a panicked call to the registrar's office and a scan of my transcripts, I signed up to complete a second bachelor's degree in government and international politics. Since many of my general electives had been in government and the social sciences, I could apply my previous work to this program and finish it in two semesters. I could keep my job at the USGS and pursue a whole new area of study that interested me. So began my odyssey into politics.

I was ready for anything. Except, that is, the negative responses I received from my fellow scientists. Many people told me I was crazy to study politics. Other geology students demanded to know why I did not select a more "useful" degree, such as biology. Co-workers laughed and wanted to know why I did not simply earn a certificate in computer skills at a technical college. Even a favorite geology professor greeted me on campus one day with a chuckle, saying, "Funny, you don't look like a politician." Although most of this was in jest, I felt the negativity towards my choice was real. I would not go so far as to say I sensed an elitist attitude, but it was a separatist attitude. Everywhere I turned, I was reminded that geology and politics did not mix. Everywhere, that is, but in my government classes.

When I shared my story with the faculty and students of the government department, I was warmly received and felt buoyed by their enthusiasm for the fact that I was a geologist interested in political science. I delved deeper into the connections between my education, my scientific experience, and my role as a scientist in our democracy.

Then came another encounter that helped change my attitude. In 1998, Dave Verardo, the 1997–1998 GSA–USGS Congressional Science Fellow, came to GMU to celebrate the inaugural Earth Science Week by sharing his experiences in the office of U.S. Senator Ron Wyden of Oregon, the congressional sponsor of Earth Science Week. As I listened to Dave talk, I imagined myself in his position, doing the things he was doing. I was amazed by the stories of how science and policy fit together at some times and how different the perspectives were at others. I was hooked! I ran up to Dave at the end of his presentation and said, "You have the perfect job. How can I do what you do?" Dave laughed and invited me to visit the senator's office to discuss an internship. I visited and was offered an internship in Senator Wyden's Capitol Hill office. During the semester, I answered constituent mail and got a feel for the breadth of issues followed by a member of Congress in service to his constituents and the larger society. Although science and technology are in the mix of issues, they are only part of the larger fabric of important decisions facing Americans.

After graduation, my husband and I moved to Portland, Oregon, where I continue to work for Senator Wyden. During the past year in the senator's state office, I have had many opportunities to call upon my scientific background in helping constituents understand environmental issues and scientific principles. I have to admit, however, that in observing the workings of politics, what impresses me most is just how much influence people with limited scientific backgrounds have on environmental policy, and the tremendous effort they put forth to understand the science behind an issue and make informed decisions. I also now realize that science is only part of an environmental issue. Socioeconomic considerations play an important role, as does the freedom elected officials have to choose a course of action regardless of any "expert opinion." In general, I see a tremendous need for scientists to be involved with decision makers early in the formulation of policy ideas. In this way, misunderstandings of fundamental science can be minimized.

Scientists must become more active in policy. Thousands of political staff members across the country are reading and researching, trying to be a part of *our* world. We need to make an effort to be a part of *theirs* by helping them understand geoscience. We need to know more than who our representatives are. We need to know where they stand on issues that are important to us. Our role as citizens does not end on election day. We need to actively participate in our government. We need to call, write, and visit our senators and representatives—both on Capitol Hill and in their state offices. We need to do this with our state and local government representatives as well.

The professional benefit I receive in observing the interface of science and public policy firsthand is incalculable. It is an experience I urge more geoscientists to pursue and be encouraged to pursue. The office of every member of Congress is open to interns. Whether one works for a city, state, or federal elected official matters little so long as one takes the opportunity to intern. In doing so, we will begin to build better scientists, better citizens, and better policies. I am not saying that an army of undergraduate geology interns can change the face of science policy today. But an army of politically savvy geoscientists can change the future of policy tomorrow. Every day I spend working in public policy is a lesson in government that I will take with me throughout my career. It is an experience that would be beneficial for many new scientists. ■

Internships: Help Form Sound Policy Through Sound Science

GSA is launching a new program to help undergraduate geoscience students work as interns with their congressional representatives in Washington, D.C., and in their home districts. See "Science and Politics: A Personal Encounter" for a first-person account of the rewards of internship. For more information, contact Ann Boylan, a caseworker in the Portland, Oregon, office of U.S. Senator Ron Wyden (D-OR), at Ann_Boylan@wyden.senate.gov.

For information about programs in public policy at GSA, please contact Cathleen May, (303) 447-2020, ext. 195, cmay@geosociety.org, or Dave Verardo, (703) 625-6105, dverardo@geosociety.org.

A Vision for Geomorphology and Quaternary Science Beyond 2000

Report of NSF-sponsored workshop, University of Minnesota, February 2–4, 1999

Robert S. Anderson, *University of California at Santa Cruz, rsand@earthsci.ucsc.edu*
Emi Ito, *University of Minnesota, eito@umn.edu*

Humans have achieved the ability to alter the planet in significant ways and have built in the path of some of nature's most destructive processes. In most places on Earth, the regolith on which terrestrial biota depends is only a few centimeters to meters thick. This thin layer of dirt can evolve chemically, and it is mobile. These facts have squarely embedded geomorphology, the study of Earth's surface and the processes that shape it, and the Quaternary sciences, the study of the history of Earth's surface through the last two million years, within research on global change. These sciences can and must act as the link between the solid Earth, the biological system, and the climate system.

We propose two new initiatives for surficial processes research at the National Science Foundation (NSF). These will constitute bold new steps that recognize the role these sciences should play in both near-term and longer-term understanding of the Earth system. The initiatives represent an unprecedented level of interaction and commitment to integrated research within the surficial-processes community.

PREDICTIVE EARTH SURFACE DYNAMICS

We propose a community-level effort to develop and test landscape models for predicting mass fluxes and landform change at time scales ranging from individual storm events to millions of years. These general models would serve both as a fundamental framework for exploration of landscape evolution and as a practical tool for addressing pressing environmental problems. This proposal has two complementary initiatives: Whole Basin Dynamics and Sustainable Landscapes. A crucial element in common between these initiatives is the required close cooperation between the quantitative geomorphology and the Quaternary geology communities. In addition, we suggest four distinct infrastructure facilities common to and necessary for both initiatives.

Whole Basin Dynamics: A Community Initiative in Surficial Processes

Landscapes are inherently dynamic. This dynamism reflects the combination of tectonic processes that move rock with respect to base level, and a suite of physical and chemical surficial processes that alter the state of the rock and move it about on hillslopes and in rivers, glaciers and coastlines. Over long time scales, the net effect of such processes is to sculpt the landscape. While the study of surface processes is a mature field, much of the work has focused on individual elements of the landscape, with little attempt to integrate among the elements. In addition, we are only beginning to explore how geomorphic processes are affected by biota. We envision a community initiative to close some of the gaps in our current understanding and to focus on more integrated studies. The tasks will include both field studies and modeling. The key elements are:

- measurement of critical mass fluxes throughout a small set of carefully chosen transport systems (basins) over time spans long enough to include numerous transport events and hence long enough to characterize the response to the full probability distribution of events;
- quantitative approach to measuring transport processes, and casting of all processes in a quantitative formalism that connects explicitly to the meteorological forcing;
- integrated view of the geomorphic system that includes all key processes and hence involves the tectonics, physical geomorphology, low-temperature geochemistry, groundwater hydrology, and ecosystem biology;
- cooperative effort to integrate direct flux measurements with time-averaged measures of erosion and deposition in the system, as deduced from stratigraphic and geochronological studies; and
- use of the field and experimental data to constrain development of community landscape evolution models that could be used as general predictive tools.

Some general characteristics that field sites should have are:

- Manageable scale. An extremely small system would not include a sufficiently wide spectrum of processes to promote or to encourage generalization, while a continental scale system is likely to be too diverse and unwieldy.
- Active tectonics. Some field sites should be in areas with active tectonic uplift and subsidence. Such sites would allow exploration of the time scales over which mountain erosion achieves rough balance with uplift, if ever. The linkages must be forged between mountain erosion and the transportation of the eroded debris across the foreland.
- Closure with respect to fluvial sediment. Careful construction of sediment budgets constitutes one of the strongest means of organizing information about the erosional and depositional system. While perfect closure with respect to sediment in natural basins is seldom achieved, proper choice of the study site with closure in mind is preferred.
- Variation in fluvial transport mechanism. Fluvial transport is the dominant mechanism of mass transfer between the erosional and depositional parts of the geomorphic system. While we will therefore emphasize fluvial systems, the fact that the fluvial system forms the bottom boundary conditions for hillslopes explicitly links these systems.
- Land cover. The type and amount of vegetation influences not only the geomorphic processes operating in a basin, but their rates. It is critical not only to be aware of the role of vegetation in the observed process rates, but also of the vegetation history of a study site. Vegetation dynamics may well play a key role in setting the lags between climatic events and the sedimentary response of the system. We seek interactions with the biological community in developing both better empirical data sets and a theoretical understanding of these dynamics.

Community landscape evolution models should have the following characteristics:

- While they may vary with respect to time and spatial scales addressed, they should all have common conceptual elements. Effort should be made to unify varying approaches, and to encourage modular structure so that improved representations of particular processes could be readily incorporated.
- Ambitious integrated models that seek to include biological, chemical, and physical processes.
- A commitment on the part of the surface-processes community to work on standardized interfaces and programming protocols for computer modeling.
- Both field and experimental studies are required to constrain the proper physics

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Vision *continued from p. 14*

and chemistry, and to determine empirical constants relevant to the system.

Sustainable Landscapes: Landscapes at the Human Time Scale

This initiative is motivated by the need to develop the science to restore and protect landscape functions in order to sustain natural resource use and ecosystem functionality. We lack, however, both the theoretical framework and the field data to predict landscape change on human time scales. With this initiative we attempt to encourage a communitywide focus on building theoretical tools, obtaining fundamental field data, and communicating advances, in both our conceptual understanding of the system and in the technologies to monitor it, to practitioners. A strong educational component to the initiative recognizes that land use and ecosystem function issues have wide appeal to students; we will strive to provide them opportunities to participate in both the development of theory and its application to human-scale issues. The Sustainable Landscapes program has three components.

- Reference landscape. We need full, high-resolution characterization of the topographic and subsurface bedrock fields that serve as the stage for the near-term geomorphic play.
- Landscape forecasting. Event-based predictions of runoff and erosion that can lead to the prediction of the sites of initiation and the paths of landslides, and the extent of inundation by water and debris in floods.
- Landscape prediction. Decadal- to century-scale prediction of the landscape processes and functions under various land-use and global climate change scenarios.

We propose a “2050 project” to predict major landscape changes that would occur in the face of the expected changes in the greenhouse gas content of the atmosphere. This exercise requires collaboration with the general circulation model and hydrological communities, policy experts and planners, and ecosystem biologists. An added collaborative opportunity with industries such as hydroelectric power and insurance companies should be explored.

INFRASTRUCTURAL SUPPORT

Chronologies, Database, and Sample Curation

Chronology is fundamental to understanding both the rates of change and the correlation of events separated geographically.

The standard chronological tool, accelerator mass spectrometry (AMS) ^{14}C dates, needs calibration because ^{14}C ages vary by 3000 years or more from calendar dates. While correlation with dendrochronology and U-series chronology has made the calibration to calendar ages fairly reliable back to the Last Glacial Maximum (18 ka), this effort must be continued. We are not at present capable of testing synchroneity of events in terrestrial records beyond the Last Glacial Maximum. This requires that sites with dateable records be identified at geographically widespread locations. Demand for AMS dates far exceeds the capacity.

Many landscape events cannot be dated by ^{14}C. Cosmogenic isotopes such as ^{10}Be, ^{26}Al, ^{36}Cl, and ^{3}He have revolutionized our understanding of geomorphic processes and climatic timing in both high-altitude and arid landscapes. U-series dating has reenergized the study of past sea-level changes, and has provided chronological control to the study of uplift of tectonically active coastal areas. Methods such as thermal luminescence and optically stimulated luminescence are now providing ages of flood and loess deposits. Fission-track counting has proven useful in studies of long-term exhumation. However, the laboratories

Vision *continued on p. 16*

Engaging "My Neighbor" in the Issue of Sustainability Part VIII: We Are a Part of, Not Apart From, the Global Ecosystem

A.R. Palmer, *Institute for Cambrian Studies, Boulder, Colorado*

> "Humans aren't the only species on Earth; they just act like it."
>
> —Unknown

Prior to the agricultural revolution (about 10,000 years ago), humans had lived off the land for perhaps hundreds of millennia. Survival depended on knowledge of local ecosystems for hunting, food gathering, medical assistance, and shelter. The passage of time was measured by natural seasonal cycles; the rhythm of life was the rhythm of the seasons. We were an integral and integrated part of the global ecosystem.

With the invention of agriculture and accompanying technological innovations, villages and finally cities developed, artisans appeared, and social structures and communications became more elaborate. Exploitation of natural resources for enrichment of the human enterprise became a part of the more urbanized cultures. There seemed to be no limits to those resources. The creative human mind and the advent of commerce found increasingly more sophisticated ways to obtain the resources and to use them. Thus, today, although we are still integral parts of the system, we are less integrated. We are somewhat analogous to an exotic species that disrupts the ecosystems into which it is introduced.

One of the tragic and unintended consequences of the exponential increase (see Part III, *GSA Today,* v. 10, no. 3) in urbanization, particularly in the past century, has been the increasing isolation of human beings from the natural rhythms and conditions that both nurture and constrain them. This is especially true in the so-called developed world, where, aided by the ease and rapidity of transport of goods, our city markets have fresh vegetables, fruits, milk, and meat more or less continuously available. We have very little understanding of the unique combinations of soil, water, weather and climate that determine the seasons of harvest for the fruits and vegetables we enjoy directly, or of the processes which make it possible to bring meat and milk to our tables. We have even less of an understanding of the complex interaction among elements of the lithosphere, hydrosphere, and atmosphere that sustain populations of fish in our oceans and lakes.

Many of us are far removed from our heritage as peoples of the land. As a consequence, we are dependent on specialized technology, skilled artisans, global commerce, and large-scale exploitation of the commons (see Part I, *GSA Today,* v. 10, no. 1) for food, shelter, and clothing. Most of us have lost the knowledge needed to do even simple farming. That loss may come back to haunt us because large cities are the most vulnerable human

Vision *continued from p. 15*

engaged in these dating schemes are limited, and the wait for dates can be long.

The need for global databases is becoming critical in many disciplines. Databases serve a variety of functions. Beyond making data available, they provide a protocol for data collection such as the inclusion of the original lab analysis to enable, for example, chronological correlation of records dated by ^{14}C at different times. Selected samples and relevant data should be archived in a publicly accessible facility. For certain types of samples, such as sediment cores and speleothems, curation facilities similar to those for Ocean Drilling Program cores can serve this function. The first such facility is taking shape at the University of Minnesota.

High-Resolution Digital Topographic Mapping Resources

Topography is the fundamental data set that serves as the test of a theory of landscape evolution and as the template on which all surface processes occur. Within the past decade, laser altimetry has come into its own as a tool for generating high-resolution digital elevation models at 2 m resolution. It is at this scale that many geomorphic processes act, as they can be strongly controlled by local gradients and local curvature of the landscape. A recent example of the utility of laser altimetry is in the mapping of shoreline change in central California during the 1997–1998 El Niño.

We propose that the NSF support a facility for the collection of 2-m-resolution digital elevation models. At present, remote sensing is expensive in terms of hardware, software, and training. Few facilities exist with the luxury of full-time, long-lived support of personnel to aid in the training of new users and to ensure continuity of the program.

Shared or Centrally Managed Field Equipment

Maintaining large stores of equipment is expensive. Such equipment includes deep-drilling equipment, and habitats in a sustainable future. We—or our families—may have to learn again how to plant, nurture, harvest, and hunt. We may have to relearn how to live with the seasons and in balance with our surroundings.

The geological sciences have taught us that we live in a universe of change. This lesson is embodied in a beautiful paraphrase of a verse from the Qur'an (Sura 27; Aya 88): "In the presence of eternity, the mountains are as transient as the clouds." Geologic studies of the environmental record since the last deglaciation (about 13,000 years ago) show that this change includes global ecosystems (e.g., Ruddiman and Wright, 1987). Nature is quite dynamic and interactive. We need to understand that the complex of systems that makes up our present-day environment has never been steady state.

Increasingly sophisticated biological studies demonstrate that all organisms share some common elements, if only at the genetic level. Although we humans seem to feel and act as if we are distinct from all other organisms in the web of life, this is not really the case. If we look back in geologic time (see Part II, *GSA Today,* v. 10, no. 2), our self-determined uniqueness within the web blurs. This blur involves not only our biological relationships to other organisms, but also the cultural development of our human species. We are truly a fundamental part of the global ecosystem.

Once we come to terms with the imbalance we have created in the global ecosystem by failing to remember that our context is *within* that ecosystem, we can face the challenges of sustainability creatively.

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Geoscience Day Scheduled for Reno Meeting

Geoscience Day, a field trip for students from a middle school with a large proportion of minority students, will be held Wednesday, November 15, during the GSA Annual Meeting in Reno. This program, sponsored by the GSA Committee on Minorities and Women, began at the 1976 meeting in Denver, Colorado, when Lou Pakiser of the U.S. Geological Survey lead the trip. At nearly every annual meeting since, geologists, many of them from minorities, have joined students and their teachers on day-long explorations of the geology of the host city. Thousands of youngsters have learned about geology and have had the opportunity to meet and interact with minority scientists. For many students, this has been their first exposure to geology and often the first time they have met a minority scientist.

Donations to support Geoscience Day can be sent to the GSA Foundation. If you are interested in participating in the program or otherwise supporting activities of the Committee on Minorities and Women, please contact Mary Dowse, Chairman, GSA Committee on Minorities and Women, Department of Natural Sciences, Western New Mexico University, Silver City, NM 88062, dowsem@silver.wnmu.edu.

various surveying and monitoring equipment. A centralized facility, if properly managed, would assist the scientists, and be cost effective for the NSF. This arrangement is similar to the Incorporated Research Institutions for Seismology, or IRIS, program in seismology, University NAVSTAR Consortium, or UNAVCO, in Global Positioning System studies, PICO (now VECO) for polar and arctic support, or Drilling, Observation, and Sampling of Earth's Continental Crust (DOSECC), Inc., in deep continental drilling.

National Laboratories for Experimental Surface Process Dynamics

At present, only a few major experimental facilities for the study of earth surface processes exist. These labs are expensive to maintain. It is important that these facilities are maintained and are accessible to the entire community on a competitive basis. We propose a small funding program that would facilitate the kind of open door policy that St. Anthony Falls Hydraulic Laboratory has implemented. We expect many spin-off experimental studies from the proposed initiatives.

EDUCATION AND OUTREACH

Geomorphology and Quaternary sciences are among the most accessible of the geosciences. The recent spate of catastrophic events and unusual weather patterns has brought the topic of global change to the forefront of the public's consciousness. We must educate the public about the likely response to global changes, with the twin perspectives of the response to past climates, and of process-based theoretical research.

We see several levels and numerous formats for bringing geomorphology and the Quaternary sciences to the public. Effective visualizations can bring the geomorphic processes to colleges. Working with K–12 educators, these visualization efforts can be repackaged for elementary and secondary school students. Geomorphic processes can also be brought to the general public via numerous science and natural history museums.

The initiatives we propose have major implications for civil and environmental engineering. What we learn from these initiatives will be shared in a series of workshops and short courses offered at professional meetings.

ACKNOWLEDGMENTS

This workshop, funded by the National Science Foundation's Division of Earth Sciences (NSF-EAR) Geology and Paleontology Program, was held at the University of Minnesota in February 1999. The authors organized the workshop, whose participants were Allan Ashworth, Thure Cerling, Peter Clark, Bill Dietrich, Russ Graham, Eric Grimm, Vance Holliday, Jim Knox, Jack Oviatt, Chris Paola, and Liz Safran. ■

Diana Stordeur to Be GSA's First Distinguished High School Earth Science Educator in Residence

***Ann Cairns,** Director of Communications and Marketing*

Diana Stordeur

K–12 earth science teachers will soon have a new advocate at GSA. Diana Stordeur, science coordinator at Eaglecrest High School in Aurora, Colorado, has been selected as the inaugural Distinguished Earth Science Educator at GSA. Stordeur will take a leave from her position in the Cherry Creek School District, recognized for its excellence in science education, to work full time at GSA headquarters in Boulder during the 2000–2001 academic year. Subaru of America, Inc., a corporate sponsor, funds this new program.

Working with Science, Education, and Outreach staff members, GSA's Education Committee, and other members, Stordeur will help design our efforts to serve the K–12 geoscience education community, providing a much needed user perspective. Stordeur will also facilitate design of the GSA Web site for educators. It will serve as an information clearinghouse for teachers, directing them to a wide variety of resources—geoscience information, products for classroom use, and other services—on the Web.

"We have needed this kind of participation from the K–12 earth science education community for a long time," CEO Sara Foland said. "We want to make certain that GSA's efforts and resources go into activities and programs that match the priorities of earth science teachers. In order to get the program off to the best possible start, we want to work with a local educator from a school district with a national reputation for excellence in science education."

Robert Ridky, chair of GSA's Education Task Force, is pleased to have Stordeur on board. "The recent report of our task force identifies the development of teacher certification tracks within geoscience programs as a primary objective," he said. "Establishing discipline-based teacher education programs is also a national goal, one that is fully endorsed by the National Academy of Sciences and heavily supported by the National Science Foundation. Diana's background and experience makes her uniquely qualified to contribute to this important initiative."

Making a Difference

Stordeur holds a B.S. in geology from the State University of New York, Stony Brook, and an M.A. in secondary science education from Columbia University. Affiliated with Colorado's Cherry Creek School District since 1989, she has taught earth sciences, biology, advanced-placement biology, general science, and chemistry.

Stordeur is enthusiastic about bringing the classroom perspective into GSA, and sees this year as an opportunity to make a difference. "Consolidation and visibility of earth science resources for teachers are desperately needed," she said. "I'm also looking forward to acting as a bridge between such a venerable organization as GSA and earth science teachers around the country."

Looking Ahead

Upon completion of her year at GSA, Stordeur will return to her school district and share what she has learned about available earth science education resources. She will be able to mentor her peers by conducting science academies for other educators at all levels in the district. She will also work to integrate the national standards for earth science education into the district's curriculum development process in response to new State of Colorado proficiency standards.

The Earth Science Educator program is part of GSA's long-standing commitment to support of earth science education. It will be ongoing, thanks to the generous support of Subaru of America. ■

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GSA Names 2000 Medal and Award Recipients

Society awards for 2000 will be presented to the following people at the GSA Annual Meeting in Reno in November.

Penrose Medal

Robert L. Folk
University of Texas at Austin

Day Medal

Robert Stephen John Sparks
Montserrat Volcano Observatory

Donath Medal (Young Scientist Award)

Basil Tikoff
University of Wisconsin—Madison

New Honorary Fellow

Gerhard Einsele
Geologisch-Paläontologisches Institut der Universität Tübingen

GSA Distinguished Service Award

Suzanne Mahlburg Kay
Cornell University

Lee R. Kump
Pennsylvania State University

Bruce F. Molnia
U.S. Geological Survey, Reston

GSA Public Service Award

Orrin H. Pilkey
Duke University

Rip Rapp Archaeological Geology Award

Richard L. Hay
Tucson, Arizona

Gilbert H. Cady Award (Coal Geology Division)

Russell D. Dutcher
Carbondale, Illinois

E.B. Burwell, Jr., Award (Engineering Geology Division)

James P. McCalpin
GEO-HAZ Consultants

George P. Woollard Award (Geophysics Division)

Donald W. Forsyth
Brown University

History of Geology Award

Hugh S. Torrens
Keele University

O.E. Meinzer Award (Hydrogeology Division)

Francis H. Chapelle
U.S. Geological Survey, South Carolina

G.K. Gilbert Award (Planetary Geology Division)

Laurence Soderblom
U.S. Geological Survey, Flagstaff

Kirk Bryan Award (Quaternary Geology and Geomorphology Division)

Brian F. Atwater
University of Washington

Laurence L. Sloss Award for Sedimentary Geology (Sedimentary Geology Division)

George D. Klein
SED-STRAT Geoscience Consultants, Inc.

Structural Geology and Tectonics Division Career Contribution Award

S. Warren Carey
Sandy Bay, Australia

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FIELD FORUM REPORT

Glaciohydraulic Supercooling, Basal Freeze-on, Stratified Basal Ice and "Deformable Till Beds": Matanuska Glacier, Alaska

Conveners: ***Edward B. Evenson,*** *Earth and Environmental Sciences, Lehigh University, Bethlehem, PA 18015*
Daniel E. Lawson, *Cold Regions Research and Engineering Laboratory, Hanover, NH 03755*
Grahame J. Larson, *Geological Sciences, Michigan State University, East Lansing, MI 48824*
Richard B. Alley, *Geosciences, Pennsylvania State University, State College, PA 16802*

Geoscientists have long known that the best insights come at outcrops and exposures. The GSA Field Forum is a new approach that combines the traditional observations of a field trip with the targeted scientific discussions of a Penrose or Chapman Conference to advance the understanding of a particular topic across an important segment of the community. Recent debates concerning the nature and importance of deformable beds, ice-bed interactions, and glaciohydraulic supercooling and its role in debris entrainment and transport made a field forum focused on subglacial processes timely, especially with respect to the flow and dynamics of former ice sheets. Altered basal conditions can cause hundredfold or larger changes in ice-flow speed, and paleoclimatic records show that such changes have occurred in the past. Basal conditions also play a critical role in debris entrainment and transport. In particular, debris fluxes associated with Heinrich events and till transport and deposition emphasize the importance of understanding processes occurring at the glacier bed. Many important questions regarding the origin, deformation, and evolution of basal ice and subglacial sediment still remain unanswered and require a multidisciplinary approach by earth scientists with diverse backgrounds. The recent recognition that onset of glaciation can increase erosion rates by 1–2 orders of magnitude has further focused attention on glacier-bed processes because of the clear need to include glaciers in the models of mountain belts and global biogeochemical cycling. Finally, it is only by reviewing field evidence, data, and models of basal processes of modern glaciers that we can hope to understand the erosional, depositional, and landform record of former ice sheets and predict the behavior of modern glaciers and the Greenland and Antarctic ice sheets.

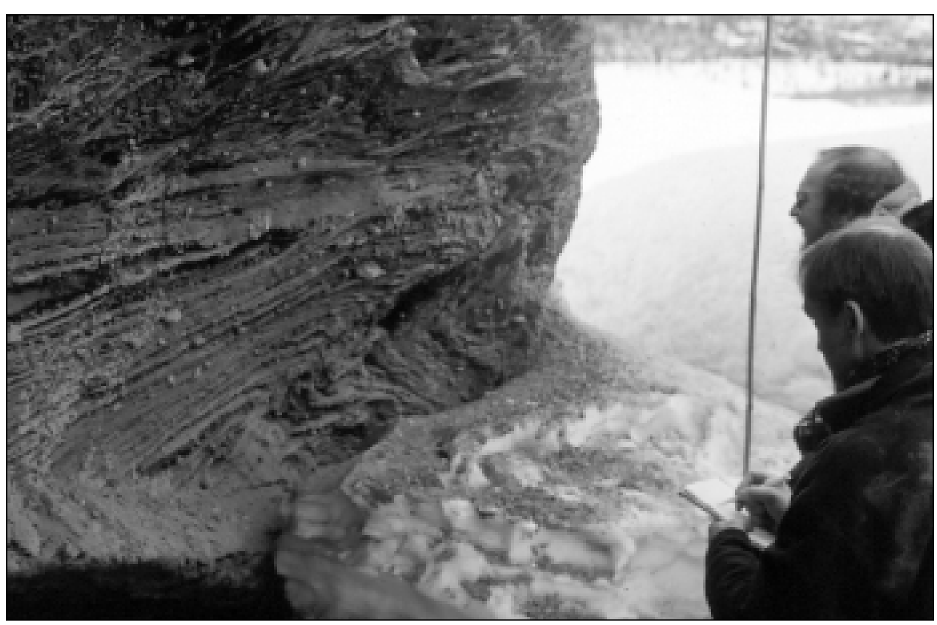
The first GSA Field Forum convened in Alaska, March 18–22, 2000. The logistics of winter field work (temperatures of –40 °F are common this time of the year at the Matanuska Glacier) and severe lodging limitations required restricting participation to 27 people, including the leaders.

Spectacular weather, combined with the excellent winter exposures produced by ice marginal uplift, sublimation, and wind etching, allowed an international group of glacial geologists, geomorphologists, sedimentologists, geophysicists, geochemists and glaciologists to simultaneously examine, discuss, photograph, and sample the basal and subglacial facies of the large, active, and well studied Matanuska Glacier.

Participants traveled to the Matanuska Glacier with six stops along the Matanuska Valley to photograph and discuss the modern Matanuska outwash system and deglacial features of the Knik-Matanuska glacial system. A hike to the glacier margin allowed participants to familiarize themselves with the ice-marginal conditions and plan appropriately for the next three days at the ice margin.

Previous work at the Matanuska Glacier has shown that during the summer melt season, pressurized subglacial waters flowing from overdeepenings supercool and grow ice on the glacier's base, trapping debris (mainly silt) and forming laminated basal-ice sections several meters thick. Ice flow during the winter is not balanced by the slow sublimation, so the ice margin upthrusts to produce superb exposures of both the laminated, basal freeze-on ice and the frozen-on subglacial deforming bed.

In three days of study, participants tested the evidence and implications of glacier growth on the bottom. A demonstration of sampling protocols involving a cement saw produced new samples. Grahame Larson has used these to confirm earlier work showing bomb-produced tritium in basal ice underlying tritium-free older glacier ice, demonstrating the recent origin of the underplated material. Associated samples have been analyzed by participant Thure Cerling for their gas (^{3}He) composition, and large anomalies from atmospheric concentrations attest to the complex processes occurring during and after ice accretion. The clear evidence of metamorphic processes in some, but not all, basal ice generated vigorous discussion on the relative importance of accretional processes and postaccretion modification in generating the observed layering. Everyone agreed that we are still confused, but at a much higher level! Staci Ensminger summarized her results showing that debris bands crosscutting the body of the glacier are basal crevasses charged by silt-laden basal waters, and several participants related consistent observations from other glaciers.



Richard Alley and Geoff Boulton examine attenuated folds in basal stratified facies.

The late-winter sun triggered debris flows from basal ice and seasonally frozen-on subglacial till, and observations of the flows illustrated the linkage between basal ice and morainal deposits. Comparison of the nascent deposits to the prominent Little Ice Age moraine and other sediment accumulations clearly showed the geomorphic importance of the active processes.

Talks by the convenors and field trip guide editors Jeff Strasser and Staci Ensminger linked the wintertime observations to summertime processes and to a wealth of other data collected over decades of work on the glacier. The talks also emphasized the physical basis for expecting that supercooling beneath overdeepened glaciers is a widespread process, with implications for glacier erosion, sedimentation, and motion. Talks contributed by Matt Roberts and Jay Fleisher then demonstrated features from Iceland and coastal Alaska quite similar to those of the Matanuska Glacier, while John Anderson showed tantalizing records from the Antarctic continental shelf at least suggesting the possibility of related processes there.

On Thursday, participants were given the morning and snowmobile transportation to visit and sample exposures of basal ice visited earlier. Many participants took advantage of the spectacular weather and the two available Super Cubs to fly up the Matanuska and into College Fjord in Prince William Sound, and several made ski landings in the Matanuska snowfields. Other participants switched to structural geology and concentrated on the beautifully exposed thrust features of the ice margin.

Acknowledgments

We thank Laura Cambiotti (Lehigh University), Tony Carter (Copper Whale Inn, Anchorage), Jodi Talcott and staff (Majestic Valley Wilderness Lodge), and Bill and Kelly Stevenson (Glacier Park). The Cold Regions Research and Engineering Laboratory cosponsored the forum. The National Science Foundation funded the participation of students and key invited participants. Jeff Strasser and Staci Ensminger wrote the guidebook and provided invaluable logistical and scientific support, and Jay Fleisher provided the photograph included in this report. ■

Forum Participants

Richard Alley
John Anderson
Greg Baker
Derek Booth
Geoff Boulton
Thure Cerling
Jim Cotter
Kurt Cuffey
Jane Dionne
Don Easterbrook
Staci Ensminger
Ed Evenson
Jay Fleisher
Dru Germanoski
John Gosse
Bernard Hallet
Ardith Hansel
Alan Knueble
Grahame Larson
Dan Lawson
Tom Lowell
Dave Mickelson
Peter Moore
Carrie Patterson
Matthew Roberts
Jeff Strasser
Slawek Tulaczyk

PENROSE CONFERENCE SCHEDULED

Longevity and Dynamics of Rhyolitic Magma Systems

June 7–12, 2001
Mammoth, California
Application due date: January 1, 2001

Conveners: ***Kurt Knesel,*** *Department of Earth Sciences, University of Queensland, St. Lucia, Brisbane, Qld 4072, Australia, 61-7-33659779, fax 61-7-33651277, k.knesel@earth.uq.edu.au*
George Bergantz, *Department of Geological Sciences, Office Box 351310, University of Washington, Seattle, WA 98195-1310, USA, (206) 685-4972, fax 206-543-3836, bergantz@u.washington.edu*
Jon Davidson, *Department of Earth and Space Sciences, University of California, Los Angeles, CA 90095-1567, (310) 206-3042, fax 310-825-2779, davidson@ess.ucla.edu*

Web site: *www.geology.washington.edu/bergantz/penrose-2001.htm*

Mammoth Mountain forms the southwest rim of the Long Valley caldera, one of three large Quaternary rhyolitic caldera centers in the United States. Long Valley, a site of recent volcanic unrest, lies at the heart of current debate over the mechanisms and time scales for the production, storage, and differentiation of rhyolite magma. Such information is critical to our understanding of fundamental geologic problems such as the formation and growth of Earth's continents and predicting volcanic hazards.

The conference aims to bring together petrologists, geochemists, volcanologists, and geophysicists actively studying the generation and evolution of silicic magmas. We hope to resolve—or at least constrain—a number of very important and currently highly topical issues pertaining to the shallow-crustal evolution of large, typically caldera-forming, silicic magma bodies. Issues include:

- What is a magma chamber—a large, long-lived fractionating liquid body or a "sleepy" crystal mush that gets kicked to life every so often, remobilizing existing material? To what degree do plutons carry forward, in some integrated way, the expression of this?
- What do crystals really represent—phenocrysts vs. xenocrysts—and what "memory" do they retain? Does crystal growth- and dissolution-zoning reflect protracted fractionation of a single magma body or remobilization and dispersal of crystal mush during injection of fresh magma into the subvolcanic system? How do crystals move in the magma system, or, are the crystals effectively static in a moving magma system?
- What is the efficacy of, and what are the driving forces for, convection and/or mixing in silicic magmas? Can crystal disequilibrium features, such as chemical and/or isotopic zoning and dissolution surfaces, serve to discriminate between thermal convection and magma mixing?
- What are the time scales needed to produce large, rhyolitic magma bodies? Recent work using $^{40}Ar/^{39}Ar$, Rb/Sr, or U-series isotope data has led to the suggestion that rhyolite magmas in the Long Valley system are stored, following differentiation, for long (10^5–10^6) time scales. This contention has been disputed principally on the basis that it would be difficult to keep a body of magma thermally viable for such long periods, even if >500 km^3 volume. Alternative physical models have been proposed, such as remobilization of juvenile plutons or cumulate materials and ion microprobe work on zircons has variously upheld or contested the claims for long magma residence times. A key focus of the meeting will be to evaluate the different types of data available that bear on ages of magmatic events, and discuss their interpretations.

Keynote talks will outline the current state of knowledge concerning the generation and evolution of large rhyolitic magma systems and will set the foundation for evaluation of existing paradigms, development of new models, and discussion of future research directions. Most of the meeting will focus on poster sessions and group discussions. Mid-meeting field trips to selected Bishop Tuff and Sierran plutonic locations will serve to raise questions concerning limits and constraints on sampling and interpreting geochemical data from pyroclastic deposits based on our knowledge of how large silicic systems erupt, links between plutonic and volcanic environments, and the importance of recharge and mixing in magma evolution.

The conference is limited to approximately 50 participants to ensure a workshop atmosphere focussed on manageable discussions. We encourage participation of graduate students working on silicic magma systems; partial student subsidies will be available. The registration fee, which will include lodging, some meals, field trips, and all other conference costs except personal incidentals, is not expected to exceed $750. Information on travel to the conference will be provided in the letter of invitation.

Application deadline: *January 1, 2000.* E-mail your application to Kurt Knesel (k.knesel@earth.uq.edu.au). Include a statement of your experience and interests as related to the themes of the conference and a proposed poster presentation title. We encourage you to include a statement of what you perceive to be the most critical questions. ■

GSA Needs Professional Representatives!

We're looking for applied geoscientists to participate as GSA Professional Representatives. This network of volunteers helps GSA improve its service to professional geoscientists and further diversify its growing membership.

As a Professional Representative, you'll act as an ambassador for GSA, spreading the word among your colleagues about the benefits of GSA membership, such as:

- national and regional meetings that give professionals a chance to network with others in their fields, meet researchers working on issues of mutual interest, and explore interests outside their specialties;
- student mentor programs, such as the Roy J. Shlemon Mentor Program in Applied Geology and the John F. Mann Mentor Program in Applied Hydrogeology, for professionals who have knowledge and experience to share; and
- our employment service, which brings job seekers and employers together year round, and provides interview opportunities and panel discussions at our Annual Meeting.

For more information, or to sign up to be a Professional Representative, contact Joanna Conley at jconley@geosociety.org, (303) 447-2020, ext. 107, or 1-800-472-1988, ext. 107.

Geoarchives and the Preservation of Archival Materials

The International Union of History and Philosophy of Science (Division of History of Science) is interested in the preservation of archives relating to 20th (and now 21st) century scientific achievements, which outnumber those of all previous centuries put together. Under the chairmanship of R.W. Home of Melbourne University, its Commission on Bibliography and Documentation is therefore undertaking a world program that aims to make the scientific community aware of the importance of preserving contemporary scientific archives.

With help from the International Commission on the History of Geological Sciences, information about the location of geology-related archives on notable geologists and of geological organizations and institutions worldwide is being collected. Other types of information being collected includes:

- locations of significant geoarchives;
- names and addresses of archivists;
- names and addresses of key organizations involved in Earth Heritage Conservation;
- techniques being used to preserve archival materials;
- details about (or plans for creating) catalogs and books listing geoarchives.

Send information to:

K.S. Murty
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2000-2003

Every year the Paleontological Society selects outstanding scientists whose works are on a wide variety of paleontological topics for The Paleontological Society Distinguished Lecturer Program. Each Distinguished Lecturer has national and international stature in paleontology, has traveled widely, and has published extensively. This program is intended to make available lecturers for inclusion in departmental speaker series or other college and university forums.

The Paleontological Society Distinguished Lecturers for the 2000-2003 academic years are included below with their e-mail contacts. Additional information, including titles, is available on The Paleontological Society homepage at **http://www.uic.edu/orgs/paleo/speakerseries.html**. If your department is interested in inviting one or more Distinguished Lecturer to your institution, please contact them directly. Although financial arrangements must be made directly with each speaker, all Distinguished Speakers have agreed to be available on an expenses-only basis. If you have any questions regarding this program, please feel free to contact William I. Ausich at **ausich.1@osu.edu**.

Roger J. Cuffey – ***Bryozoans and Reefs***
e-mail: cuffey@ems.psu.edu

Steven J. Hageman – ***Species; Carbonates***
e-mail: hagemansj@appstate.edu

David M. Harwood – ***Plankton; Antarctica***
e-mail: dharwood@unl.edu

Steven M. Holland – ***Stratigraphy; Stability***
e-mail: stratum@gly.uga.edu

Brian T. Huber – ***Cretaceous Deep-Sea Record***
e-mail: Huber. Brian@nmnh.si.edu

Claudia C. Johnson – ***Paleoenvironments***
e-mail: claudia@indiana.edu

Bruce S. Lieberman – ***Evolution; Cambrian***
e-mail: blieber@eagle.cc.ukans.edu

Charles R. Marshall – ***Innovation and Incompleteness***
e-mail: marshall@eps.harvard.edu

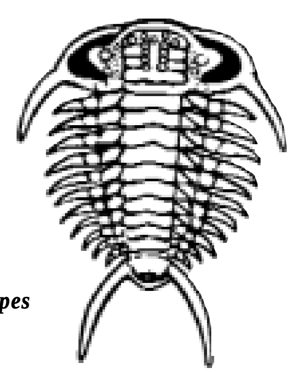
David L. Meyer – ***Crinoids and Edrioasteroids***
e-mail: david.meyer@uc.edu

Lisa E. Park – ***Ostracodes and Paleoclimate***
e-mail: lepark@uakron.edu

Judith Totman Parrish – ***Paleoclimates***
e-mail: parrish@geo.arizona.edu

Bruce Runnegar – ***Metazoan Origins: Carbonate Isotopes***
e-mail: runnegar@ucla.edu

Charles E. Savrda – ***Trace Fossils***
e-mail: savrdce@mail.auburn.edu



Planned Giving Options Give Donors the Ability to Give Generously Today and in the Future

***Julie A. Wetterholt**, Director of Development*

During the past three years, GSA Foundation was pleased to receive generous bequests from three GSA members. Clyde T. Hardy, Horace R. Blank, and Raymond Woods all held GSA dear to their hearts, and as a result, they had made the important decision to include GSA Foundation in their wills. Regrettably, because they did not notify us, we were never able to extend our appreciation to them.

While many of us do not consider ourselves to be "major benefactors," we can often create significant charitable gifts through planning. Most large gifts need to be planned by you and your advisors to ensure the best results for your financial plan and your estate plan. There are many ways to make a significant gift to GSA Foundation and maximize the impact of your gift. We urge you to let the Foundation know when you have taken this important step so that we can properly acknowledge your generosity during your lifetime. Any planned gift gives you entrance to our planned giving club, the Pardee Coterie, where we show our appreciation for your long-term investment in GSA. Here are just a few of your options and the potential tax benefits to you and your loved ones. (Be sure to consult your tax or financial advisor for information on your individual situation.)

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Cash gifts are the simplest and most effective way to give to GSA Foundation. You can receive a full tax deduction for the amount of your cash gift in the year you make your gift, subject to certain tax limits. The higher your tax bracket, the more potential for tax savings.

Gifts of stocks, bonds, mutual funds, and real estate that have appreciated in value and are owned for more than one year can result in triple tax savings. You may receive an income tax deduction on the market value, not the original price, of the securities or real estate. You bypass any capital gains tax on the gain or growth since the time of purchase. Opportunities for state capital gains tax savings may also be available.

Bequests provide a way for you to remember GSA Foundation in your will and can reduce your inheritance taxes. Your will can designate gifts of cash, securities, or other property, or a percentage of the remainder of your estate. The suggested legal wording is:

For a specific bequest: *I leave [dollar amount] to the Geological Society of America Foundation, Inc., P.O. Box 9140, Boulder, CO 80301, to be used for general purposes.*

For residual bequests: *All the rest, residue, and remainder of my estate, real and personal, I give, devise, and bequeath to the Geological Society of America Foundation, Inc., P.O. Box 9140, Boulder, CO 80301.*

Gifts of life insurance can be made in the form of a new policy or an existing policy. Premiums paid by the donor on a donated life insurance policy qualify for charitable tax deductions. If an existing policy is paid in full, your charitable contribution is generally the replacement value or the cost basis of the policy.

Gifts of retirement plan assets can be arranged through naming GSA Foundation as a beneficiary of your retirement plan or IRA (Individual Retirement Account). This option is especially effective in minimizing estate taxes. Retirement assets can also be placed in charitable trusts, maximizing your financial and estate planning benefits.

Life income gifts can be made through charitable remainder trusts, charitable lead trusts, charitable gift annuities, and pooled income funds. These arrangements offer substantial tax savings while providing an annual income to you, your family, or others. When appreciated assets or property are placed in these arrangements, the assets are reinvested and diversified and may produce a greater yield for the donor or beneficiaries.

For more information, please contact Julie Wetterholt, Director of Development, GSA Foundation.

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The Father of Modern Volcanology: Howel Williams (1898–1980)

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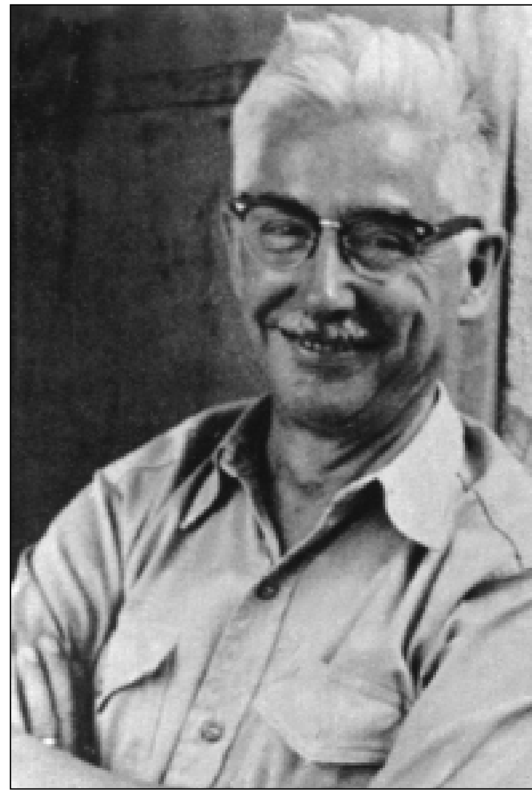


Howel Williams, 1961.

Though known to most of his friends as “Willie,” the title Howel Williams cherished most was one given to him by his students on the occasion of his retirement: The Last of the Ordovices. I think it appealed to him because it reflected his Welsh background and his role as one of the last members of a passing era.

Williams’ 50-year career spanned a period of dramatic changes in the sciences, especially geology. Through his own contributions and those of his students, he was largely responsible for the emergence of volcanology as a rigorous branch of modern science. Although his work was in a classic style that we seem to have lost, perhaps forever, few have left so pervasive an imprint on their fields. Even fewer have inspired wider admiration or deeper affection.

Born in Liverpool, England, Williams was raised along with his identical twin, David, and six other children in a modest, middle-class household. He spoke only Welsh until the age of six. His scholastic honors in secondary school won him a scholarship to the University of Liverpool where, despite an interruption for military service from 1917 until the armistice in 1918, he received his bachelor’s degree with first-class honors before the age of 20. Though his initial studies were in geography, Williams soon developed a keen interest in archaeology, which in turn, by a singular chain of events, led him to geology.

While engaged in excavations of a Roman camp site in northern Wales, Williams observed that the floor of the baths was paved with slabs of slate rich in curious fossils. Anxious to learn where the Romans had quarried the slate, he consulted P.G.H. Boswell of Liverpool’s Department of Geology. It so happened that Boswell was then studying the Silurian rocks of Denbighshire and, from the nature of the distinctive graptolites in the slate, immediately knew its source. Williams was so impressed with this instant solution to his problem that he began to sit in on lectures in geology and in 1924, after receiving his M.A. degree in geography, went on to earn an M.S. in geology.

With his geology degree came another scholarship that enabled Williams to further his studies at Imperial College. There, working chiefly under W.W. Watts, he completed a detailed study of Snowdon in North Wales. The abundant Ordovician volcanic rocks he encountered there and in the area near Capel Curig aroused his interest in volcanism and led him to the classic volcanic fields of the Eifel district of Germany and the Auvergne in central France. He returned with a firm resolve to make volcanic geology his principal work. Thanks to a fellowship from the Commonwealth Fund, Williams was able to devote the next two years to studies with A.C. Lawson at the University of California at Berkeley. Apart from a single seminar dealing with the geology of California, he took no formal courses while at Berkeley, devoting his time instead to field studies. He concentrated on the ancient volcanoes of the Sutter Buttes in the Sacramento Valley of California and on Lassen Peak, a recently active volcano in the southern part of the Cascade Range. In addition to all this, he found time to visit Hawaii and Tahiti.

In 1928,Williams returned to Britain to take his D.Sc. in geology at the University of Liverpool. He then spent two years on the staff of Imperial College before returning to America to join the faculty at Berkeley in 1930. There, he rose to the rank of full professor in only seven years. Between 1945 and 1949, he served as chairman of the Department of Geology, doing much to raise the quality of its faculty, teaching, and research. It was largely his influence during these critical years that set the course of the department and brought it into the ranks of leading American institutions. He was elected to the National Academy of Sciences in 1950.

Williams continued his studies of volcanoes in the western United States, particularly Crater Lake, where his work formed the basis for two of his most important contributions, a monograph on Crater Lake and a general treatise on the origins of calderas. The rapid succession of papers that he produced during this period included

Howel Williams, left, and Alexander McBirney use the hood of a jeep as a place to plot the geology on their map of Honduras.

several that soon became classics of volcanology. He dealt with volcanic domes, the classification of pyroclastic rocks, the Pliocene volcanic centers of the Navajo-Hopi region, and several large volcanic centers of the Cascade Range, including Newberry Caldera and The Three Sisters.

In 1943, when the volcano Paricutin was born in a Mexican cornfield, Williams joined a group of geologists recording its growth and evolution and completed a reconnaissance study of more than a hundred similar cinder cones in the surrounding region. This was the beginning of the work in Latin America that absorbed much of his energy for the remaining years of his career. He found there several opportunities to apply his geological experience to problems in archaeology. While in Mexico he used petrographic techniques to discover the source of stone used in the giant Olmec sculptures of La Venta near the Gulf of Mexico. In 1950, with the support of the Carnegie Institution of Washington, Williams went to Nicaragua to examine the extraordinary ancient human footprints in a hardened volcanic mudflow near Managua.

I was living in Nicaragua at that time. I had started a coffee farm in a remote part of the country and, while waiting for the trees to mature, took a job with a mining company. Though totally ignorant of geology, I was given the task of exploring an area near the volcanic chain to develop geothermal power for the mine. My boss asked Williams to let me accompany him in the field for a week or so in order that I might learn some rudimentary geology. During the day, we explored the geology of the area, and in the evenings Williams tutored me in volcanology and elementary petrology. His enthusiasm and lucid explanations aroused my interest and ultimately led me to study under him at Berkeley. After I obtained my degree, we worked together until his death in 1980. I was not the only student to be captivated by his enthusiasm for volcanology. In the course of his long career, Williams fostered a succession of students, many of whom went on to become leaders in their fields.

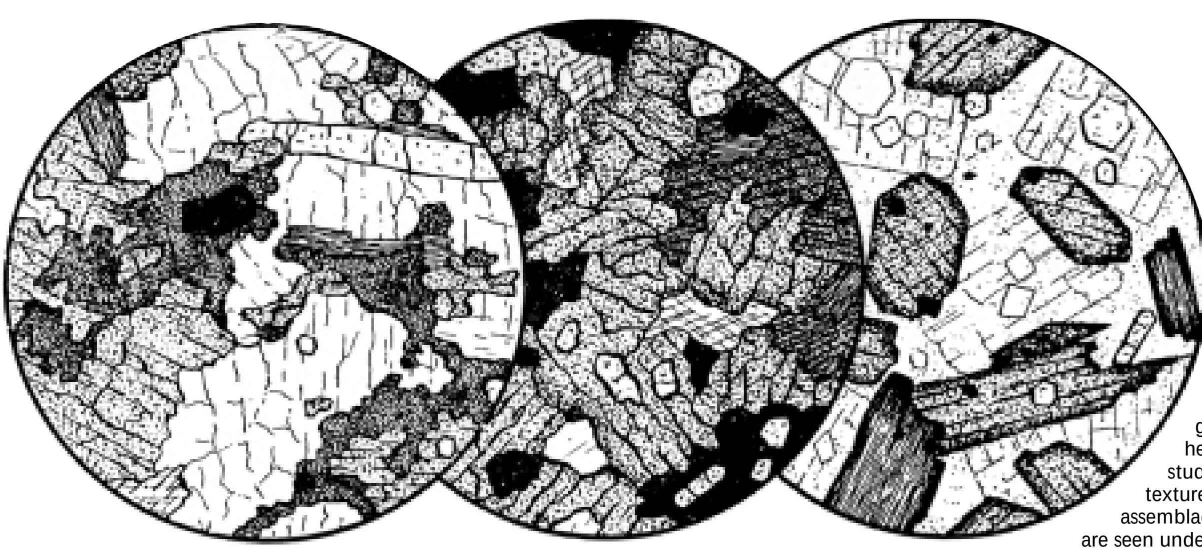
Williams' work in Nicaragua was the beginning of a succession of regional studies which, though less widely known than his work on calderas and domes, were even more remarkable, both for their scope and for the extent of their contribution to the previously little-known geology of Central America. These studies, together with a survey of the Galapagos Archipelago completed in 1969, covered large regions where few, if any, geologists had gone before. The studies allowed us to start from scratch, working out broad structures, regional stratigraphy, and the evolution of an entire volcanic province. Less interested in the eruptive phenomena of active volcanism than in broad structural and lithologic relations, Williams had a masterful ability to decipher the form and past activity of large volcanic complexes. Many have commented on his instinctual ability to find the critical outcrop that resolved a puzzling question. With his uncanny eye for landforms and the regional significance of lithologic variations, he could synthesize the volcanic history of a broad region from a few seasons of field reconnaissance and petrographic analyses.

In addition to regional field studies, Williams produced a widely used textbook on petrography in 1954, and, in 1979, a comprehensive treatise on volcanology. The former was the result of collaboration with Frank Turner and Charles Gilbert at the University of California; the latter a product of the years he spent with me at the University of Oregon after his retirement from Berkeley. Published only two months before his death, *Volcanology* summed up a lifetime's experience and, despite more recent advances, is still regarded as one of the most comprehensive works on the subject.

Williams' most conspicuous personal trait was his sparkling wit and unfailing sense of humor. Until one became acquainted with him, his jokes could be disconcerting. Encountering one of his students crossing the campus he might ask, "Why are you wandering about at this hour wasting valuable time? You should be in your office working!" Or, upon entering a laboratory, he would pretend to check the settings of the instruments and offer a "correction factor" in the form of a complex differential equation incorporating the effects of daily weather conditions on analytical results. But beneath his jovial manner there was a personal reserve that only those who knew him well could fully appreciate. His irreverent wit concealed an uncompromising code of personal conduct.

A natural scientist in the classical tradition, Williams stressed meticulous observations, thorough research, and sound interpretations presented in elegant, lucid prose. With his ability to read geological literature in English, French, German, or Spanish, he could trace the historical development of ideas and synthesize diverse views with simplicity and clarity. The same qualities pervaded his teaching. His courses in petrography and regional geology were enlivened with amusing historical anecdotes and illustrated by artistic hand-drawn diagrams that left an indelible impression on hundreds of students.

In the closing years of his life, Williams saw the classical methods of scholarship give way to complex geochemical investigations and thermodynamic calculations compiled on computers and reported in hastily prepared, multiauthored papers of transient interest. Although he himself contributed to this change and on balance approved of it, he inspired in his students a respect for the traditional standards that make his work stand out, even today, as enduring contributions to volcanology. ■



Howel Williams' hand-drawn illustrations of petrographic thin sections helped thousands of students understand the textures and mineral assemblages of rocks as they are seen under the microscope.

Mojzsis and Harrison ("Vestiges of a Beginning: Clues to the Emergent Biosphere Recorded in the Oldest Known Sedimentary Rocks," *GSA Today*, v. 10, no. 4) stated that methane in experiments from Horita and Berndt (1999) may have been derived "exclusively from bio-organic contaminants in the reactant olivine" and cited McCollom and Seewald (1999) to support this view. While Mojzsis and Harrison's interpretation of isotopically light carbon in Archean metasediments could well be correct, we object strongly to the notion of biologic contamination in our experiments. In particular, methane production was monitored before any $NaHCO_3$ was injected into our experiments, and no significant contamination was observed. Conversion of dissolved CO_2 to CH_4 commenced immediately after the $NaHCO_3$ was injected and occurred on a scale that would overwhelm any potential contamination from other carbon sources. Furthermore, McCollom and Seewald (1999) reported preliminary results and interpretations from an isotope tracer experiment that was performed to help quantify sources of methane produced during hydrothermal alteration of olivine. Horita and Berndt's experiments did not involve the reactant olivine so the two studies are unrelated. Therefore, Mojzsis and Harrison's reference to our study is unfounded.

References Cited

Horita, J., and Berndt, M.E., 1999, Abiogenic methane formation and isotopic fractionation under hydrothermal conditions: Science, v. 285, p. 1055–1057.

McCollom, T.M., and Seewald, J.S., 1999, Rapid equilibration of CO_2 and formate under hydrothermal conditions (with a comment on the abiotic synthesis of hydrocarbons during serpentinization): Geological Society of America Abstracts with Programs, v. 31, no. 7, p. A-431.

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Mojzsis and Harrison reply: Berndt et al. (1996) reported the reduction of CO_2 to methane and higher hydrocarbons formed under reducing conditions according to the reaction: olivine = serpentine + magnetite + H_2. In attempting to reproduce the results of Berndt et al. (1996), McCollom and Seewald (1999) stated that, "isotopic labeling and blank experiments indicate that the most likely source of the observed hydrocarbons is decomposition of trace contaminants rather than abiotic synthesis." We acknowledge that McCollom and Seewald (1999) in fact were claiming that the results of Berndt et al. (1996), and not Horita and Berndt (1999), are due to bio-organic contamination of the reactant olivine.

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Peter A. Slovinsky
Donald W.L. Smellie
Erik A. Smith

New Members
continued on p. 32

New GSA Members
continued from p. 31

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Michael E. Smith
Charles B. Snell
Bogie Soedjatmikoet
Gary S. Solar
Anton I. Sotirov
Michael Sperazza
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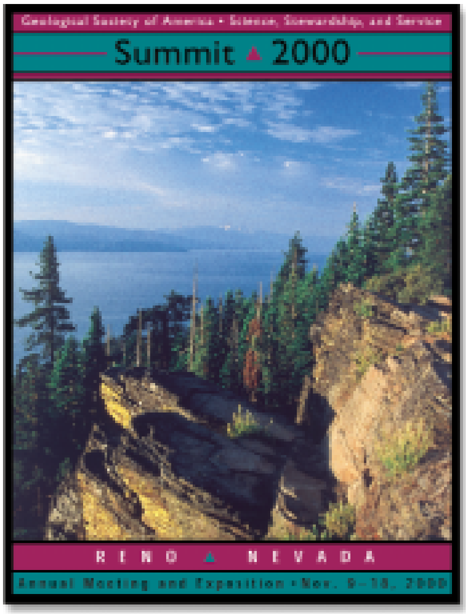
Summit ▲ 2000



GSA Annual Meeting and Exposition
Reno, Nevada
November 9–18, 2000

GSA will feature great science at Summit 2000!

Pardee Keynote Sessions
(invited speakers)

This year's Pardee Keynote Symposia features eight topics of broad interest to the geoscience community.

Sessions for Monday, November 13, and Tuesday, November 14:

K1 ▲ Geology in the New Millennium I: Resource Collapse, Environmental Catastrophe, or Technological Fix?

Stephen L. Gillett, Mackay School of Mines, Reno, Nevada. Monday, November 13, 8 a.m.–12 noon.

Is the 21st century headed for catastrophic resource shortages or environmental apocalypse, as has been predicted since the 1970s? Or will new technologies come onstream quickly enough to avert disaster? This session contrasts both views, with presentations both by leaders in various emerging technologies and by those who view resource shortages as imminent. ORAL

K4 ▲ A New Age of Planetary Exploration: Sample Returns, In Situ Geological Analysis, and Human Missions to Other Worlds

GSA Planetary Geology Division. Ralph Harvey, Case Western Reserve University, Cleveland, Ohio; Cassandra Coombs, College of Charleston, Charleston, South Carolina. Monday, November 13, 1:30–5:30 p.m.

Sample return missions, new in-situ geological tools, and the return of human geologists to alien outcrops promise to revolutionize planetary geology in the coming decades. Presentations by project scientists will introduce and discuss upcoming or planned planetary missions that exemplify the translation of traditional "hands-on" geology to other worlds, including Mars, the asteroids, comets, the Moon, and the Sun. ORAL

K7 ▲ Nuclear Waste Disposal: Bridging the Gap Between Science and Policy

GSA Hydrogeology Division. Jane C.S. Long, Mackay School of Mines, Reno, Nevada; Kevin D. Crowley, Board on Radioactive Waste Management, Washington, D.C.; Jean M. Bahr, University of Wisconsin, Madison. Tuesday, November 14, 8 a.m.–12 noon.

What is the scientific process of developing confidence in the long-term performance of a repository, and how does this process relate to the policy-making process? Two panels will examine the science of performance prediction and how scientists can communicate the science and its uncertainties to nonscientists and policymakers. ORAL

K6 ▲ Living with Uncertainty: Scientific, Political, and Societal Perspectives

GSA Institute for Earth Science and the Environment. Christine Turner, U.S. Geological Survey, Denver, Colorado; Robert Frodeman, University of Colorado, Boulder. Tuesday, November 14, 1:30–5:30 p.m.

How does science understand uncertainty? What are society's expectations concerning our ability to provide answers to societal problems? Speakers in this symposium will address: shifting priorities in hazards research; how complexity changes our perceptions of nature; the promises and drawbacks of predictive modeling; public perceptions of uncertainty; and how the USGS Center for Science Policy addresses these issues. ORAL

Check your September *GSA Today* for Pardee Sessions scheduled for Wednesday and Thursday, November 15 and 16.

For a complete listing of Topical Sessions scheduled for GSA's Annual Meeting in Reno, visit www.geosociety.org.

TIME CHANGE

ATTENTION, STUDENTS!

President's Student Breakfast Reception at the GSA Annual Meeting

Monday, November 13, 7:00 to 8:30 a.m.

GSA President Mary Lou Zoback invites all students registered for the meeting to attend a free breakfast buffet sponsored by ExxonMobil Corporation. Registered students will receive complimentary coupons redeemable toward the breakfast buffet and will be eligible for prize drawings.

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New GSA Student Associates

The following Student Associates became affiliated with the Society during the period from October 1999 through February 2000.

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Amanda L. Albright
David L. Allen
Katie E. Amos
Philip S. Anderson
Tanya Ariowitsch
Jennifer Aschoff
Rebecca K. Atkinson
Seth L. Atkinson
Nicole M. Badon
Margaret A. Bagby
Stefan Bagnato
Megan S. Barnes
Jennifer A. Barrows
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Laura R. Bassani
Jason A. Batus
Brian C. Bauer
Mark Beaman
Linda R. Bearss
William C. Beck
Kristeen M. Bennett
Jennings Berger
Aaron J. Berndt
Amy K. Bingham
Jennifer L. Blanton
Amanda L. Booth
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Daniel T. Bowen
Kerry H. Bowen
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Jody L. Brandrup
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Robert J. Brown
Amy L. Bruggeman
Jennifer L. Bryson
James F. Bujno
Brad A. Burdick
Sarah R. Burton
Eric M. Butler
Sean K. Canada
John M. Canerdy
Leigh Childs Cantey
Elizabeth A. Carruth
Laura E. Chambers
Heung-ngai Chan
Robert L. Chandler
Mark A. Chapa
Nicholas J. Chrobak
Elizabeth A. Clark
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Alvin L. Coleman Jr.
James P. Conroy
Mary Jane Coombs
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Rhiannon L. Crain
Christopher J. Crosby
James H. Cunningham
Andrew J. Cyr
Ann C. Davis
Caroline A. Davis
Nicholas A. Davis
Christopher M. DeCioccio
Megan K. DeSmedt
Heather L. DeStefano
John L. Dolde
Carolyn Domrose
Franklin Dorin
Kathleen E. Dotson
Jason P. Dowdy
Andrew J. Downs
Kelly A. Dreibelbis
Kelly C. Driggers
Alison R. Duvall
Amanda L. Eads
Mark J. Earnshaw
Daniel J. Eastmond
Jonathan K. Eaton
Sandi L. Edwards
Amanda I. Ellison
Mathew E. Elwell
Amy C. Englebrecht
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David W. Farris
Nicole A. Feldl
Chad A. Ferguson
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Emily Rose Fojut
Wesley H. Foll
Joshua D. Frank
T.J. Fudge
Stephanie R. Fuentes
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Nicoli Garner
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Emily M. Gilles
Samuel P. Gillet
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Laura C. Kellogg
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Shanna M. Kevorkian
Julie C. Kickham
Leyla D. Kirkpatrick
Jeff C. Kirtley
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Seth C. Kruckenberg
Eric J. Kuhl
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Gabrielle Elise Kurth
Sage A. Kutzman
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Susan K. Larson
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Jamie S.F. Levine
Noel C. Liner
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Patrick Benjamin Luetkemeyer
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Joshua J. Miller
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Matthew D. Mittenthal
Robert F. Montgomery
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Kevin R. Morrison
Ken P. Mueller
Glenn Mutti
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Holly J. Nichols
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Brian E. Nixon
Eric D. Noreen
Vanessa J. O'Brien
Jay C. Odaffer
Julie A. O'Leary
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Dawn L. Wells
Christine R. Wennen
Laura J. Wilcox
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Mark A. Williams
Kyle H. Willis
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GSA Bulletin Adopts New Page Charge Policy

For all new manuscripts received by the *GSA Bulletin* after August 31, 2000, page charges will be voluntary for the first 10 published pages only. All pages in excess of 10 will incur a mandatory charge of $125 per page.

This policy was recommended by the GSA Publications Committee and approved by the GSA Council at its May 2000 meeting. The mandatory page charges are intended to serve as a mechanism to decrease the length of articles submitted, which should result in more papers published in each issue and papers published more rapidly. In this way the *Bulletin* can continue to publish diverse topics without incurring excess publishing costs.

AUGUST *Bulletin* and *Geology* Highlights

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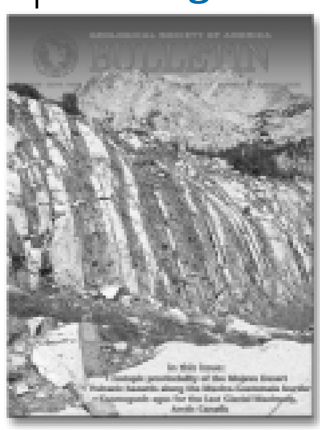
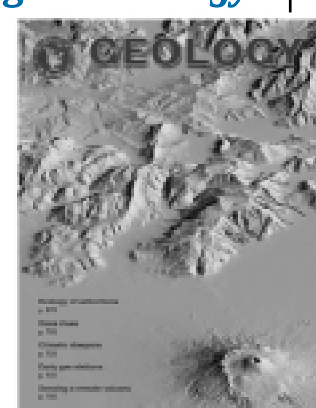
In August *Bulletin*



- Isotopic provinciality of the Mojave Desert
- Volcanic hazards along the Mexico-Guatemala border
- Cosmogenic ages for the Last Glacial Maximum, Arctic Canada

In August *Geology*

- Ecology of extinctions
- Ooze clues
- Climatic diaspora
- Early gas stations
- Sensing a remote volcano



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Hypoxia in the Gulf of Mexico: Causes, Consequences, and Political Considerations

T.M. Kennedy* *and* ***T.W. Lyons,*** *Department of Geological Sciences, University of Missouri, Columbia, MO 65211*

Each year as the snows of the northern plains melt and crop-nourishing rains fall on fields throughout the Mississippi River Basin, a nutrient-rich freshwater plume enters the northern Gulf of Mexico. The resulting biological blooms and subsequent decreases in dissolved oxygen are issues of great ecological concern. Fertilizer use throughout the central United States has been implicated in an ongoing political and scientific debate. However, the pace and mechanisms of corrective action may be dictated more by economics and corresponding political clout than by the severity of habitat perturbation.

With the increasing urbanization of our coastal regions and agricultural expansion in major river basins, oxygen deficiencies are becoming a major environmental problem in coastal waters throughout the world. These deficiencies are referred to as hypoxia when dissolved oxygen levels drop below 2 mg/L relative to ~7 mg/L for nonhypoxic times. Low oxygen concentrations occur naturally in stratified marine settings such as the Black Sea. In recent years, however, increased nutrient runoff from the continents has exacerbated natural hypoxia and has caused hypoxia and anoxia at previously well-oxygenated sites.

Seasonal depletions in oxygen on the Louisiana continental shelf extend westward from the Mississippi Delta and are the most extensive example of marine hypoxia in the United States (Fig. 1A). Like any occurrence of hypoxia, a number of complex processes contribute to its development, the most significant of these being eutrophication and stratification of freshwater over denser saline water. Eutrophication is an enrichment in dissolved nutrients (especially nitrogen and phosphorus) that promotes increased primary production. As the abundant phytoplankton die and settle to the ocean floor, bacterial decay consumes oxygen faster than photosynthesis can replace it. Under ordinary circumstances, oxygen depletions are short-lived because of natural downward mixing of water in contact with the oxygen-rich atmosphere. In some cases, however, density stratification inhibits mixing between fresh and saline waters. In the northern Gulf of Mexico, freshwater inputs from the Mississippi–Atchafalaya River Basin cause such stratification.

The combined influence of stratification and river-supplied nutrients in the Gulf is evident in annual measurements of the hypoxic zone's areal extent (Fig. 1B). The smallest recorded hypoxic zone, for example, occurred in 1988, a drought year. By contrast, a year of severe flooding, 1993, showed an increase in areal extent of >50% beyond the previous year. The hypoxic zone has remained large since 1993, culminating with the largest recorded zone spanning some 20,000 km^2 in the summer of 1999. The seasonal trends for Gulf hypoxia further link the stratification and nutrient enrichments to riverine contributions (Fig. 1C). Depletion of oxygen begins in the spring and reaches its highest point in the mid-summer, reflecting the expected lag between peak river discharge in the late winter or early spring and the productivity-linked consumption of oxygen.

In 1998, Congress passed the Harmful Algal Bloom and Hypoxia Research and Control Act, which allocates approximately $11 million over three years for research and monitoring of hypoxia. In this context, a task force was established to assess the nature, causes, and consequences of Gulf hypoxia and to propose strategies for controlling it. Since the posting of the initial integrated assessment, various special interest groups have responded and remain close to the discussion (their comments and the assessment are available at www.nos.noaa.gov/products/pubs_hypox.html, June 2000). Involvement of these groups has centered on several points of heated controversy, beginning with the primary cause of eutrophication. Mass balance analysis of inputs and outputs within the basin indicates that fertilizer is responsible for 50% of the input of all nitrogen to the waters of the Mississippi–Atchafalaya River Basin, which makes it the primary source of Gulf nitrogen enrichment. Less significant contributors include soil erosion, manure,

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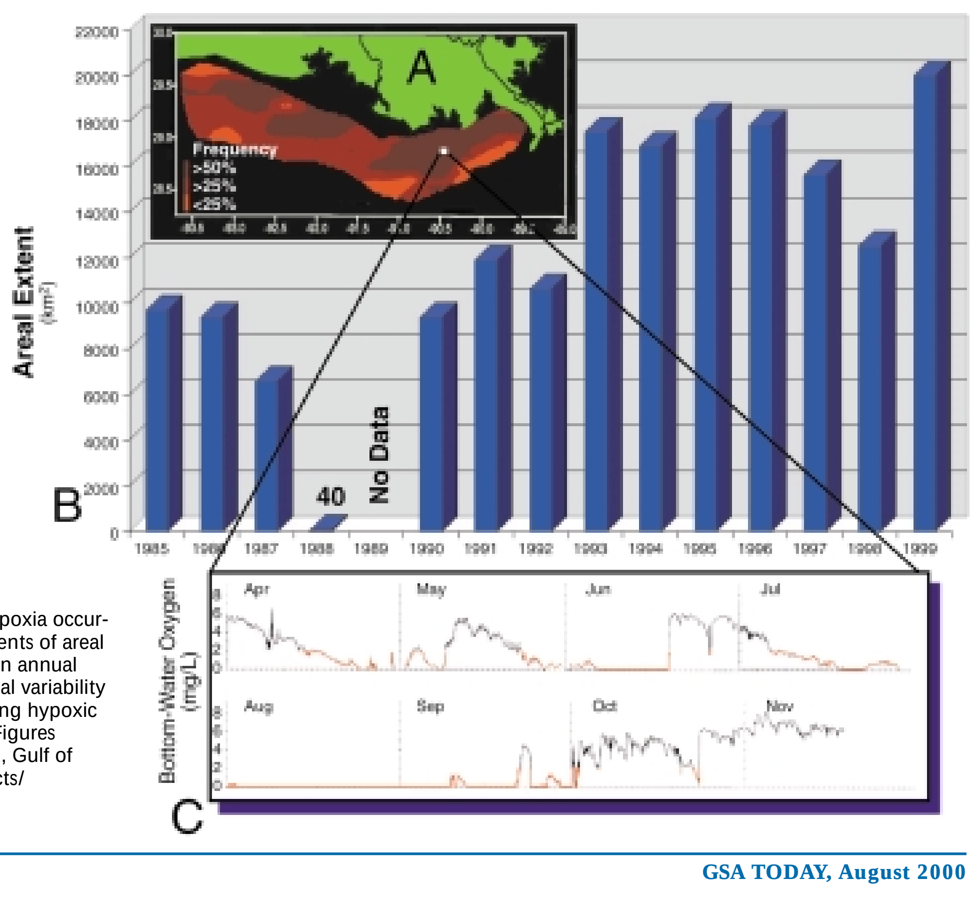
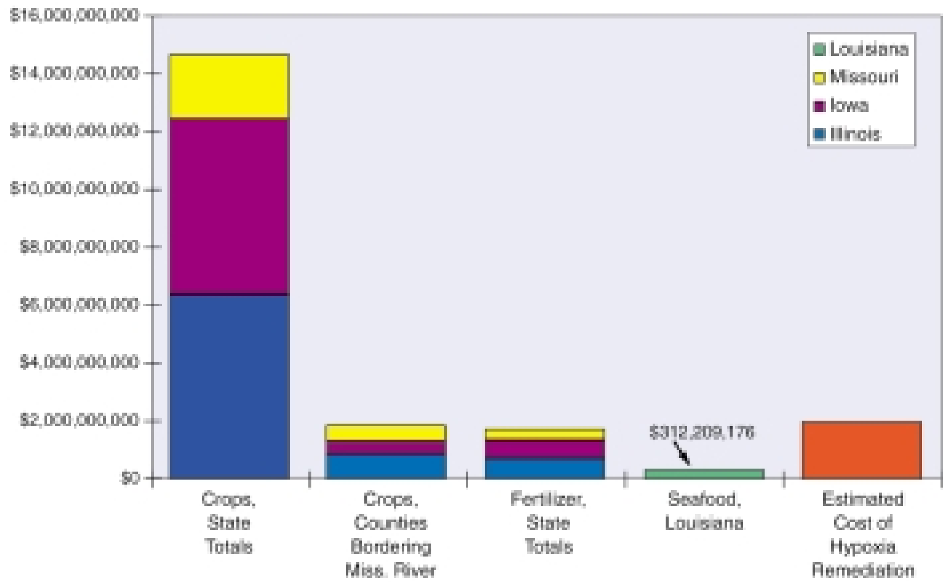


Figure 1. Temporal trends. A. Frequency of hypoxia occurrence, 1985–1997, based on annual measurements of areal extent. B. Areal extent of hypoxic zone based on annual measurements taken in mid-summer. C. Seasonal variability of bottom-water oxygen at a single station during hypoxic interval of 1993. Data in red indicate hypoxia. Figures modified from Rabalais et al. (1999, Topic no. 1, Gulf of Mexico Assessment; www.nos.noaa.gov/products/pubs_hypox.html.

Figure 2. Total market value of crops, fertilizer, and seafood for 1997 compared to the estimated total cost of leading proposal for reducing nutrient loads to Gulf of Mexico. Data from U.S. Department of Agriculture, National Oceanic and Atmospheric Administration, and Doering et al. (1999, Topic no. 6, Gulf of Mexico Assessment; www.nos.noaa.gov/products/pubs_hypox.html).



legumes, atmospheric deposition, and municipal and industrial waste. Nevertheless, the American Farm Bureau and the Fertilizer Institute contend that more research is needed to unambiguously (i.e., quantitatively) link fertilizer to nitrogen runoff into the Mississippi River. The Fertilizer Institute has downplayed the significance of contributions from fertilizer by stressing, among other factors, increased freshwater flow and the resulting relationship between water-column stratification and hypoxia.

A second flurry of controversy is clustered around the effect of hypoxia. When oxygen becomes scarce, faunal communities migrate to areas of higher oxygen or, in the case of many less mobile organisms, perish. This idea of a "dead zone" has attracted the popular press to the issue of hypoxia with a focus typically on the potential damage to the fishing industry. Despite this focus, the sparse existing data suggest that yearly yields in the regional fish and shrimp catch have not been economically affected in any way directly attributable to hypoxia because these organisms are able to escape from areas of low oxygen. Shrimpers maintain their yields by shifting their efforts to the margins of the hypoxic zone where migrating shrimp are in abundance. In fact, Richardson and Jørgensen (1996, Eutrophication in coastal marine systems, Coastal and Estuarine Studies, 52, American Geophysical Union, Washington, D.C.) in their general survey of coastal hypoxia noted that slightly reduced oxygen can be a boon to the local fishery by focusing the fish (and, by inference, shrimp) toward the boundary of the oxygen-deficient region.

This emphasis on the fishing industry diverts attention away from potentially more calamitous consequences. Annual ecological perturbations in the Gulf could have catastrophic long-term impacts by preventing the reestablishment of prehypoxia marine communities. Harmful algal blooms are one example of an ecosystem imbalance associated with the same nutrient fluxes that cause hypoxia. Current policy discussions have alluded to but have never explicitly addressed the essential question: What magnitude of habitat modification and loss of noncommercial species is acceptable in the absence of immediate or even long-term dire consequences to the fishing industry?

Proposed solutions are also controversial. As the integrated assessment notes, water-quality models predict that reducing nutrient loads by 20%–30% should increase dissolved bottom-water oxygen by 15%–50%. Reduction of nutrients by 30%–50% could bring about a 20%–75% increase in oxygen. To make such reductions, researchers recommend multiple strategies, such as construction of wetlands in the Mississippi River Basin, reduction of fertilizer application, use of alternative cropping systems, and reduction of feedlot runoff. Any combination of these strategies would be costly, and models for such a complex system are inherently uncertain. Nevertheless, research summarized in the draft of the integrated assessment indicates that the most cost-effective means of reducing nutrient loads by 20% would be a combination of a 20% reduction in fertilizer application and construction of five million acres of wetlands. According to the Fertilizer Institute, this proposal is too expensive in light of the uncertainty surrounding economic benefits to fisheries and is inadequately justified by existing scientific data. Institute officials specifically noted in their response to the proposed remediation strategies that, "...the recommendations would relegate farmers to economic poverty, and the benefit of this policy is a complete unknown."

Inherent polarity in the scientific interpretations is not the only factor determining what solutions, if any, will be implemented. Economically speaking, agribusiness and the Gulf fishing industry stand at opposite extremes in this debate. Agribusiness is a staple of the American economy, having contributed $98 billion through crop sales in 1997 (www.usda.gov/nass, June 2000). By contrast, the value of commercial fishing in the entire Gulf of Mexico for 1997 was only $762 million (www.st.nmfs.gov, June 2000). Total crop sales in 1997 exceeded $15 billion for the top three buyers of fertilizer in the region most likely to be impacted by Gulf hypoxia reduction policy (Illinois, Iowa, and Missouri). This figure stands in clear contrast to the $312 million value of Louisiana seafood landings in 1997 (Fig. 2). Even when compared only to fertilizer expenditures in Illinois, Iowa, and Missouri, or to the value of crops in only those counties bordering the Mississippi River, the Gulf seafood landings are minor. From a purely economic standpoint, the cash value of these landings fails to justify the $2.08 billion total cost of the proposed solutions.

Differences in the value of crops and landings are reflected in disparities in representation and, ultimately, in relative lobbying strength within the political arena. For example, the American Farm Bureau represents nearly five million families in 50 states and Puerto Rico (www.fb.com, June 2000). By contrast, the largest organization representing Louisiana fishermen on environmental issues has a membership of about 350 fishermen, and annual dues are just $100. Run solely by volunteers, the Gulf Coast Commercial Fishermen's Coalition cannot engage in lobbying activities because of its status as a nonprofit organization.

These inequalities have affected hypoxia policy discussions. The American Farm Bureau, the Fertilizer Institute, and other agribusiness interest groups have aggressively represented their constituents throughout the discussions. These well-funded and well-staffed organizations have attended formal meetings, issued press releases, made extensive public comments, and have lobbied at state and federal levels. According to the Center for Responsive Politics, nontobacco agricultural interest groups reported lobbying

Hypoxia *continued on p. 38*

CALENDAR

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

2000 Meetings

October

October 22–24, American Society for Testing and Materials Committee E29 on Particle and Spray Characterization, Orlando, Florida. Information: Jim Olshefsky, ASTM, (610) 832-9714, fax 610-832-9555, jolshefs@astm.org.

November

November 9–12, Association for Women Geoscientists Fall Board of Directors Meeting, Reno, Nevada. Information: AWG, P.O. Box 280, Broomfield, CO 80038-0280, office@awg.org.

November 13–14, American Society for Testing and Materials Committee E20 on Temperature Measurement, Orlando, Florida. Felicia Quinzi, ASTM, (610) 832-9738, fax 610-832-9555, fquinzi@astm.org.

2001 Meetings

January

January 12–16, International Conference on the Geology of Oman, Muscat, Sultanate of Oman. Information: Organizing Committee, International Conference on the Geology of Oman, Directorate General of Minerals, Ministry of Commerce and Industry, P.O. Box 550, Muscat 113, Sultanate of Oman, geoconfoman@mpi.unibe.ch, www.geoconfoman.unibe.ch. *(Abstract and registration deadline: September 1, 2000.)*

May

May 27–30, St. John's 2001, Geological Association of Canada–Mineralogical Association of Canada 2001 Joint Annual Meeting, St. John's, Newfoundland, Canada. Information: St. John's 2001, c/o Department of Mines and Energy, St. John's, NF A1B 4J6, Canada, (709) 729-2301, fax 709-729-3493, dmp@zeppo.geosurv.gov.nf.ca, www.geosurv.gov.nf.ca/stjohns2001.

June

June 19–22, 17th International Mining Congress and Exhibition of Turkey, Ankara, Turkey. Information: Bahtiyar Unver, Co-Chairman, Organizing Committee, Department of Mining Engineering, Hacettepe University, Beytepe Ankara, 06532 Turkey, 90-312-297-7696, fax 90-312-299-2155, unver@hacettepe.edu.tr, http://www.mining-eng.org.tr. (Abstract deadline: October 31, 2000.)

July

July 7–10, American Rock Mechanics Association's DC Rocks 2001, 38th U.S. Rock Mechanics Symposium, Washington, D.C. Information: John Tinucci, Technical Program Chair, PanTechnica Corporation, (952) 937-5879, fax 952-949-4364, jtinucci@pantechnica.com, www.armarocks.org. *(Abstract deadline: October 1, 2000.)*

August

August 31–September 12, Field Excursion to the Skaergaard Intrusion, Kangerdlugssuaq, East Greenland. Information: Jens C. Andersen, Camborne School of Mines, University of Exeter, Redruth, Cornwall, UK, 44-1209-714866, fax 44-1209-716977, andersen@csm.ex.ac.uk, www.ex.ac.uk/CSM/news/confs.htm. *(Deposit due by September 1, 2000.)*

Hypoxia *continued from p. 37*

expenditures of nearly $52 million in 1998 (www.opensecrets.org, June 2000). The American Farm Bureau alone reported spending over $4.5 million in that year. The fishing industry, by contrast, has been conspicuously absent from nearly all aspects of the policy process.

Ultimately, substantive corrective action will be slow in coming within the muddled political context of Gulf hypoxia. The fishing industry lacks the resources and perhaps motivation to galvanize public and congressional opinion and thus may be ineffective as a political catalyst. While the details of the scientific arguments warrant further study and debate, the preponderance of scientific research has unambiguously identified agriculture as the single greatest contributor to Gulf hypoxia. Ultimately, the issue of fertilizer-linked, seasonal oxygen depletion in the Gulf of Mexico speaks directly to the level of environmental perturbation that may be tolerated in the absence of catastrophic economic loss and imminent threat to public health—particularly given the estimated cost of correction. Like all nonpoint-source pollution in which the effect is spatially decoupled from the cause, and in which scientific details are worked and reworked by multiple groups, it will be a challenge to convince Congress and the public that action is necessary. ■

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Positions Open

LABORATORY COORDINATOR/LECTURER
DEPARTMENT OF GEOLOGY
BRYN MAWR COLLEGE

The Department of Geology at Bryn Mawr College invites applications for a coordinator of introductory laboratories beginning January 2001. This is a full-time (9-month), continuing, non-tenure-track position. Initial appointment will be for three years. Primary responsibilities will include: design and supervision of laboratories for introductory courses in physical, historical, and environmental geology (in cooperation with other faculty); training and supervision of graduate and undergraduate teaching assistants; oversight of laboratory specimens and demonstration equipment; field trip planning and logistics; and oversight of department rock preparation, field, and/or computer equipment. This person will also teach one course each year and may supervise student research.

We seek a dynamic individual with a high level of intellectual curiosity and a demonstrated interest and ability in undergraduate education. While the field of specialization is open, we encourage applications from individuals whose expertise complements existing department strengths in metamorphic petrology and tectonics, paleontology, sedimentology and structural geology. A Ph.D. is required at the time of appointment.

Applications should include curriculum vitae, a description of teaching philosophy and experience, and letters from at least three professional references. Send the applications to: Lab Coordinator Search, Professor M. L. Crawford, Department of Geology, Bryn Mawr College, 101 N. Merion Ave., Bryn Mawr, PA 19010-2899. Review of applications will begin Sept. 1, and the position will remain open until filled. E-mail applications are also accepted—mail to mcrawfor@brynmawr.edu.

Bryn Mawr College is a liberal arts college for women with coeducational graduate programs in sciences, some humanities and social work. The College provides a rigorous education in the context of a diverse and pluralistic scholarly community and participates in consortial programs with the University of Pennsylvania, Haverford and Swarthmore Colleges. Bryn Mawr College is an equal opportunity, affirmative action employer. Members of underrepresented groups are especially encouraged to apply. For more information about the position, the Department and the College, visit www.brynmawr.edu/Acads/Geo.

CENTRAL MICHIGAN UNIVERSITY
MINERALOGY/PETROLOGY
ASSISTANT PROFESSOR TENURE-TRACK POSITION

The Department of Geology invites applications for an entry-level tenure-track position beginning in August 2001. We seek a person with the following qualifications: 1) Ph.D. in geology with a specialty in mineralogy or petrology, 2) demonstrated excellence in teaching is preferred, 3) commitment to field-based studies, 4) demonstrated commitment to high-quality undergraduate research, 5) excellent communication skills. The successful applicant will be required to 1) teach mineralogy, introductory geology, and courses in his or her specialty, 2) develop a successful research program, and 3) develop and submit external grant proposals.

The Department of Geology currently has eight full-time faculty and 40 to 60 undergraduate majors. Teaching loads will range from 9 to 12 contact hours per 15-week semester. The department has a strong record of incorporating research into the undergraduate curriculum. For more information, visit our departmental web site at www.cst.cmich.edu/units/gel/.

Central Michigan University enrolls approximately 18,000 students (87% undergraduate), and is located in the heart of the Michigan Basin. The department has modern and well-equipped facilities which include: automated ARL-SEMQ electron microprobe, Phillips XRD, VG-PQ2 ICP-MS, fluid inclusion lab, rock and mineral sample preparation facilities, a networked IBM and Mac computer lab, geophysical instruments, in-house GIS, access to other modern GIS and GPS systems, and two departmental vans. In addition, the department has access to other computing and analytical facilities on campus and at nearby universities.

Interested persons should send: 1) a resume, 2) statements of teaching philosophy, research interests, and vision for undergraduate education, 3) unofficial transcripts, and 4) three letters of reference to: Mineralogist/Petrologist Search Committee, Department of Geology, Central Michigan University, Mt. Pleasant, MI 48859.

All applications and materials must be received by October 6, 2000.

CMU, an AA/EO institution, is strongly and actively committed to increasing diversity and providing equal opportunity within its community. CMU does not discriminate in employment against any person based on age, color, disability, gender, familial status, height, marital status, national origin, political persuasion, race, religion, sexual orientation, veteran status, or weight (see www.cmich.edu/aaeo.html).

GEOLOGIST/HYDROGEOLOGIST
OGDEN ENVIRONMENTAL AND ENERGY SERVICES

Ogden Environmental and Energy Services has the need for geologists/hydrogeologists in our San Rafael office. MS geology/hydrogeology, CA registered geologist/hydrogeologist, 8–10 yrs professional exp. in groundwater evaluations, site investigations, site remediation & project mgmt required. Prefer candidates with govt & commerical client exp. Please send resume to OEES, 980 Lincoln Avenue, Ste. 200, San Rafael, CA 94901; fax (415) 454-1001 or human_resources@oees.com. EOE/AA.

ASSISTANT PROFESSOR
SOUTHERN METHODIST UNIVERSITY

The Department of Geological Sciences at Southern Methodist University invites applications for a tenure-track faculty position in the broad areas of surficial processes or geodynamics. We seek creative applicants with an excellent understanding of fundamental physical principles and processes, and a demonstrated ability to apply that understanding in a quantitative manner to important problems in the earth sciences. The department seeks an individual who will complement existing strengths in one or more of the following areas: geochemistry, petrology/tectonics, geophysics, planetary dynamics, terrestrial paleoecology. We anticipate making the appointment at the assistant professor level with the appointment to begin no later than Fall, 2001. Applicants are required to have a PhD by the beginning of the Fall 2001 semester. The successful candidate will be expected to teach at the undergraduate and graduate levels, supervise graduate research, and establish an externally funded research program in his or her field of expertise. The committee will begin its review of the applications on or about November 1, 2000. To ensure full consideration, the application should be postmarked by November 1, 2000. Candidates should submit their curriculum vitae, names and addresses of three references, and a written statement of teaching and research interests to: Dr. Lee McAlester, Chair, Department of Geological Sciences, P.O. Box 0395, Southern Methodist University, Dallas, Texas 75275-0395. Email: geol@mail.smu.edu and website: www.geology.smu.edu. SMU is an Affirmative Action/Equal Opportunity/Title IX Employer.

UNIVERSITY OF CANTERBURY
LECTURER/SENIOR LECTURER IN
GEOLOGICAL SCIENCES

Applications are invited for a continuing (tenured) full-time position as LECTURER or SENIOR LECTURER in the DEPARTMENT OF GEOLOGICAL SCIENCES. We wish to recruit a geoscientist with the potential to develop an innovative research programme on the sedimentary record using modern quantitative methods. Development of South Pacific regional geologic interests, either onshore or offshore, and a strong commitment to fieldwork is expected. Applicants should hold a Ph.D. degree or equivalent in an appropriate discipline and have postdoctoral research experience. A commitment to high quality teaching at undergraduate and graduate level, and a willingness to contribute to field courses will be required. The appointee will also be expected to conduct research, to obtain external research funding and to supervise postgraduate students at the M.Sc. and Ph.D. levels.

The University's World Wide Web address is www.canterbury.ac.nz. Academic enquiries only may be made to Professor J.W. Cole, fax 64-3-3642-769 or e-mail: j.cole@geol.canterbury.ac.nz.

Appointment enquiries should be made to hr@regy.canterbury.ac.nz.

Applications, quoting Position No GS126, close on 30 September 2000 with the Human Resources Manager, University of Canterbury, Private Bag 4800, Christchurch, New Zealand.

The University has a policy of equality of opportunity in employment.

FACULTY POSITION IN BIOGEOSCIENCE
DEPARTMENT OF GEOLOGY
UNIVERSITY OF MARYLAND, COLLEGE PARK

The Department of Geology at UM is searching for a tenure-track faculty member who has made fundamental contributions in biogeoscience. We seek an outstanding scientist with research interests in the interdisciplinary field of geomicrobiology/mineralogy, or a closely related field. Research strengths in the Department of Geology are in the broad areas of mineralogy, petrology and geochemistry, in particular, crustal evolution and granites and associated mineralization; structural geology and tectonics; hydrological processes and integration of geomorphology, hydrology and ecology to understand surface environments; and, isotope geochemistry in support of these areas, and in mantle geochemistry, meteoritics, geochronology, carbonate diagenesis, sediment cycling, stratigraphy and paleoclimate studies. The Department of Geology encourages interdisciplinary approaches to the study of the Earth and participates in the Earth System Science Interdisciplinary Center, which is a new Center formed by the University of Maryland and NASA/Goddard Space Flight Center to advance fundamental knowledge about the earth system through preeminent research and teaching programs.

The Department expects to fill this position by Summer 2001. Salary will be commensurate with experience. The appointee is expected to develop and maintain an active, externally-funded research program, to direct graduate students, and to participate fully in teaching at the graduate and undergraduate levels, including courses in the introductory non-major program.

The University of Maryland is an affirmative action/equal employment opportunity employer. Applications should be submitted by September 29, 2000, for best consideration, and should be submitted to: Chair, Search Committee, Department of Geology, University of Maryland, College Park, MD 20742, USA (electronic submissions to: geology@geol.umd.edu). Persons interested in being considered for this position should provide a statement describing research and teaching interests, indicating how s/he envisions contributing to the Department's research and teaching activities, and a current curriculum vitae. Applicants should arrange to have a minimum of four letters of recommendation sent directly to the Chair of the Search Committee before September 29, 2000. The Search Committee encourages applicants to submit copies of up to two recent publications in support of their candidacy.

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BOOKS: Geology, Paleontology, History of Geology. Used, out-of-print, and rare. Free catalog. Patricia L. Daniel, BS, MS, Geology. 618 W. Maple, Independence, KS 67301, ph: (316) 331-0725, fax: (316) 331-0785, email: pldaniel@horizon.hit.net, website: http://users.hit.net/~pldaniel.

Opportunities for Students

Graduate Student Support Opportunities in Earth Sciences, Lehigh University—The Department of Earth and Environmental Sciences of Lehigh University has Graduate Student Fellowships for highly qualified individuals. The department has active research programs in tectonic studies (geochronology, stable-isotope geochemisty, low-temperature geochemistry, seismology, high-resolution geophysics, structural geology, paleomagnetism) and surficial processes (low-temperature geochemistry, fluvial and tectonic geomorphology, glacial geology, hydrology, and limnology). Please contact Prof. D. Morris, Dept. of Earth and Environmental Sciences (dpm2@lehigh.edu) or see our Web page for more details (www.ees.lehigh.edu).

Graduate Study in Marine Sedimentology. The LSU Department of Oceanography and Coastal Sciences is seeking applicants for graduate study in marine sedimentology. Potential research topics include sedimentology of modern deltas, radioisotope geochronology of recent deposits, and impacts of combined event sedimentation and bioturbation on the sediment record. We are seeking a highly qualified individual with demonstrated capacity for independent work. Qualified applicants will be considered for a 4-year fellowship of $16,000 per year. Additional funding will be sought for additional years. Students seeking either the PhD or MS/PhD in geological oceanography should apply by completing and submitting the graduate program preapplication (found at www.oceanography.lsu.edu/application.html) for a start date as soon as August 2000. For questions or to request a mailed preapplication, contact Dr. Larry Rouse, Graduate Advisor, (lrouse@lsu.edu, 225-388-2953) or Dr. Sam Bentley (sjb@lsu.edu, 225-388-2954), Coastal Studies Institute, Howe-Russell Geosciences Complex, Louisiana State University, Baton Rouge, Louisiana 70803, USA. ■