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INSIDE

Changing Magma Conditions and Ascent Rates during the Soufriere Hills Eruption on Montserrat

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ABSTRACT

The Soufriere Hills volcano on the resort island of Montserrat caught the world's attention when phreatomagmatic explosions began in July of 1995. In late 1995, andesitic lava appeared as a dome in the central crater. Lava dome formation continues today, although sectors of the dome have periodically collapsed, generating pyroclastic flows. By integrating data from phenocryst analyses from the andesite (60 wt% SiO_2) with experiments, we have determined the temperature and depth at which the pre-eruption magma equilibrated, identified a pre-eruption heating event, and documented order-of-magnitude changes in the rate of magma ascent. Phenocryst-melt equilibria indicate that the andesitic magma was equilibrated in a storage zone at ~840 °C and 130 MPa (~5 km depth) prior to heating. Heating took place several weeks before the eruption and has continued. As the water-rich Soufriere Hills andesite magma ascends, the rate of magma rise is reflected by the thickness of reaction rims developed on hornblende phenocrysts in contact with melt, and by the extent of groundmass crystallization. These reactions, which have been experimentally calibrated, are variably observed in Soufriere Hills samples. The magma ascent rate at Soufriere Hills increased by a factor of 10 during the first four months of 1996, culminating in a large dome collapse and a large explosive eruption in September 1996. Most magma erupted in 1996 ascended from 5 km depth to the surface in <4 days. After slowing during the fall of 1996, the magma ascent rate increased again in spring 1997. This period of high ascent rate was followed by explosive eruptions throughout the fall of 1997. Both periods of high magma ascent rates correlate with times of high dome-volume growth rate.

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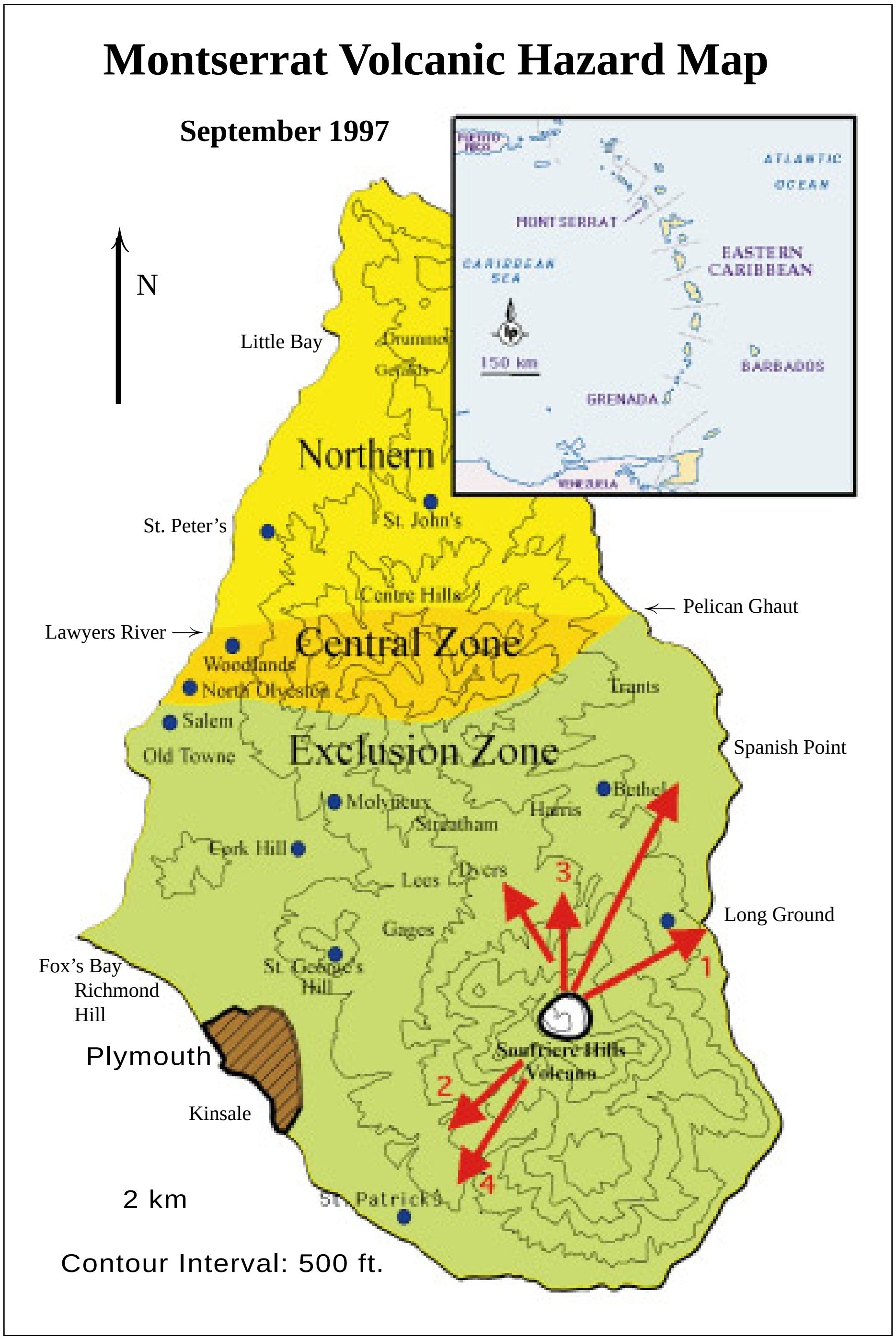

Figure 1. Map of Montserrat Island showing the Soufriere Hills volcano and the September 1997 volcanic hazard zones (after Montserrat Volcano Observatory Web site map, January 1998). The arrows show the directions taken by pyroclastic flows: (1) before January 1997, (2) in early spring, 1997, (3) following the large dome collapse of June 25, 1997, and (4) on December 26, 1997. The inset shows the position of Montserrat in the northern Lesser Antilles Volcanic Arc.

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In Memoriam

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Austin, Texas
January 28, 1998

Raymond E. Birch
Palm Harbor, Florida
September 16, 1997

Thomas E. Bolton
Ottawa, Ontario
November 21, 1997

Louis DeGoes
Bellevue, Washington
November 23, 1997

Valerie M. Ewing
Flower Mound, Texas
March 9, 1996

Ross R. Heinrich
St. Louis, Missouri
December 18, 1997

Henno Martin
Göttingen, Germany
January 7, 1998

Correction

The correct dates for the Penrose Conference "Ophiolites and Oceanic Crust" are September 13–17, 1998. The announcement in the January 1998 issue of *GSA Today* contained incorrect dates. We apologize for the inconvenience.

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INTRODUCTION

Montserrat Island lies in the northern section of the Lesser Antilles volcanic arc (Fig. 1). Although the island has undergone several seismic crises in this century (Wadge and Isaacs, 1988), no historic eruptions had been known before the Soufriere Hills volcano began erupting in November 1995. The volcano, which is in the southern part of this popular resort island, has a central crater about 1 km in diameter that opens to the northeast (Fig. 1). Prior to the present eruption, this crater was partially filled by a dome that formed at about 350 yr B.P. (Young et al., 1997). Older volcanic deposits record earlier eruptions, at about 3950 yr B.P. The Soufriere Hills volcano itself contains many deposits produced by dome collapse from 26 to 16 ka (Wadge and Isaacs, 1988).

The present eruption began with precursor seismic activity, which increased in intensity from 1992 to late 1994, and a phreatomagmatic event in the Soufriere Hills crater on July 18, 1995. One of us (Devine) was in the Caribbean in July 1995 to study the dynamics of dome-forming events in Montserrat and Nevis; that project was quickly modified to include study of the modern Soufriere Hills eruption. The first dome-forming magma reached the surface between November 14 and 16, 1995. Since that time there has been nearly continuous extrusion of a hornblende-rich andesite, regular collapse of gravitationally unstable new dome segments producing pyroclastic flows like those shown in Figure 2, and occasional periods of explosive pressure release.

Several events stand out in the history of this eruption. On September 17, 1996, a collapse involving approximately one-third of the preexisting dome produced huge pyroclastic flows, and was followed by an explosive eruption of magma from depth which lasted several tens of minutes. The ash column rose to 14,000 m, and a pumice was deposited over the island. In late 1996 and early 1997, rapid dome growth on the south side of the new dome gradually filled the preexisting crater and weakened the crater wall. The first sizable pyroclastic flows to go to the south (flow 2 in Fig. 1) went over the wall in the following months, devastating a heavily settled (although evacuated) part of the island. New dome growth moved to the north side of the edifice in May 1997, and six weeks later a major collapse sent pyroclastic flows over the north wall of

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the crater (flow 3 in Fig. 1), essentially completing the circle of pyroclastic flow devastation around the volcano. One of these flows closed the Montserrat airport. Very active dome growth punctuated by numerous explosions continued throughout the summer and fall of 1997. In late December, the dome was still growing without explosive eruptions. A large collapse of the wall and adjacent dome on December 26, 1997, produced a flow that reached the ocean (flow 4 in Fig. 1).

The staff of the Montserrat Volcano Observatory (MVO) is continuously monitoring the eruption seismically, by helicopter flights, and by measuring dome volume changes using a combination of techniques (Sparks et al., 1998). Members of the observatory staff and visiting scientists also regularly measure gas release and deformation around the mountain, and collect samples (Young et al., 1997). Samples have not been easy to collect because the eruption is occurring in the crater, but accelerated dome growth is often closely followed by collapse and pyroclastic flows that allow new magma to be sampled. We have studied these samples under a microscope, have done chemical analyses by electron microprobe, and have performed hydrothermal experiments on a sample of the andesite to determine the depth, water content, and temperature of the magma storage region, and have deduced changes in magma ascent rate over time.

PRE-ERUPTION MAGMA

The dome-forming magma erupting at Soufriere Hills is an andesite (~60 wt% SiO_2) consisting of phenocrysts of variably zoned plagioclase, hornblende, orthopyroxene, embayed quartz, magnetite, ilmenite, and apatite in a microcrystalline groundmass (Fig. 3). The mineralogy of the groundmass is the same except that clinopyroxene, an anhydrous mineral, is present instead of hornblende, which is hydrous. There has been no change in the magma composition since the eruption began. Interestingly, it is also essentially identical to the magma that formed the Castle Peak dome 400 yr B.P. (Devine et al., 1998). Inclusions of a more mafic basaltic andesite are common in the erupted magma. Many of these inclusions are glass-bearing, and some contain hornblende, indicating crystallization at depth in a water-rich magma. This more mafic material appears to have been added to the andesitic magma over time at a range of *P-T* conditions (Murphy et al., 1998).

MAGMA STORAGE ZONE

The temperature, pressure, and water content of the magma storage region

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In cooperation with the Association of American State Geologists (AASG), GSA makes an annual award for the best paper on environmental geology published either by GSA or by one of the state geological surveys. The award is a $1000 cash prize from the endowment income of the GSA Foundation's John C. Frye Memorial Fund. The 1998 award will be presented at the autumn AASG meeting to be held during the GSA Annual Meeting in Toronto, Canada.

Nominations can be made by anyone, based on the following criteria: (1) paper must be selected from GSA or state geological survey publications, (2) paper must be selected from those published during the preceding three full calendar years, (3) nomination must include a paragraph stating the pertinence of the paper.

Nominated papers must establish an environmental problem or need, provide substantive information on the basic geology or geologic process pertinent to the problem, relate the geology to the problem or need, suggest solutions or provide appropriate land-use recommendations based on the geology, present the information in a manner that is understandable and directly usable by geologists, and address the environmental need or resolve the problem. It is preferred that the paper be directly applicable by informed laypersons (e.g., planners, engineers). Deadline for nominations for 1998 is **MARCH 30, 1998.**

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The deadline is **April 30, 1998,** for submitting nominations for these four awards: William T. Pecora Award, National Medal of Science, Vannevar Bush Award, Alan T. Waterman Award.

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Figure 2. View from the northeast of the Soufriere Hills lava dome in March 1997. A partial dome collapse has just occurred, and a pyroclastic flow is moving to the east down the steep slope of the volcano.

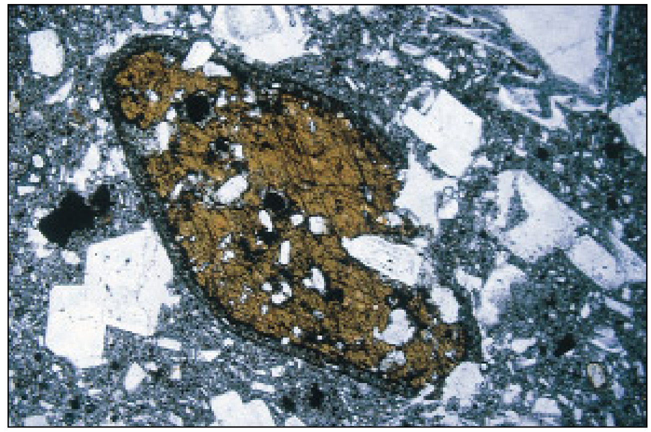

Figure 3. Photomicrograph under crossed polarizers of the December 1995 Soufriere Hills andesite. Mineral phenocrysts include a 2-cm-long, inclusion-filled hornblende grain (brown), complexly zoned plagioclase crystals (white), and a euhedral magnetite phenocryst (black). These phenocrysts occur in a largely crystalline matrix. The dark reaction rim on the hornblende crystal is 120 μm thick.

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beneath the volcano have been determined using the compositions of phenocrysts and glasses in the Soufriere Hills andesite (Devine et al., 1998). Particular emphasis has been placed on explosively erupted, rapidly quenched pumiceous samples that have not been affected by reactions occurring in more slowly cooled dome samples.

Pressure information can be derived from the aluminum content of hornblende in multiphase, quartz-bearing assemblages as discussed by Hammarstrom and Zen (1986). Use of Al-in-hornblende geobarometry is justified in estimating the storage depth for the Soufriere Hills magma, because quartz phenocrysts are present in all samples, and these phenocrysts appear to have been in equilibrium with hornblende before any changes took place in the magma storage region. The Soufriere Hills hornblende phenocrysts are generally uniform in composition, and contain 6.2 wt% Al_2O_3. Putting their composition in the Johnson and Rutherford (1989) geobarometer yields a pressure of 130 ± 25 MPa (~5–6 km depth).

Temperature estimates can be obtained from coexisting Fe-Ti oxide phases. Adjacent magnetite and ilmenite phenocrysts in the Soufriere Hills samples have homogeneous cores and zoned 15–25-μm-thick rims where they are in contact with each other. Calculations using the core compositions yield an equilibration temperature of 840 °C at relatively oxidized conditions (f_{O_2} equal to 1 log unit above the NNO oxygen buffer); rim compositions yield higher temperatures (830 to 930 °C). These observations suggest that the magma storage zone was at ~830 °C and ~5–6 km depth at some time just before the eruption.

Analyses of melt (now glass) trapped as inclusions in plagioclase and pyroxene phenocrysts indicate that the pre-eruption Soufriere Hills melt contained 4.7 wt% dissolved water. This is exactly the amount expected if the pre-eruption magma were saturated with a water-rich vapor phase at 130 MPa. It is possible that the water content of the melt in the andesitic magma decreased somewhat after the heating (mixing) event, but it clearly remained above ~4.0 wt% because hornblende remained stable in the heated magma.

The final evidence pertaining to conditions in the pre-eruption magma comes from phase equilibrium experiments carried out on a sample of the Soufriere Hills andesite. Samples of the powdered andesite were sealed in noble metal tubes along with excess water and held at a given *P*, *T*, and f_{O_2} for times up to 10 days. Most of the experiments were run using a sample previously held at either a higher or lower temperature (Fig. 4; see caption). These experiments show that both quartz and Al-poor (6.2 wt%) hornblende would be stable along with plagioclase, orthopyroxene, magnetite, and ilmenite at 830 °C and 130 MPa when the magma was saturated with a water-rich vapor (Barclay et al., 1998). These experimental data also show that if the temperature in this magma is increased above 830 °C at constant pressure and water content, melting occurs at the expense of the phenocrysts,

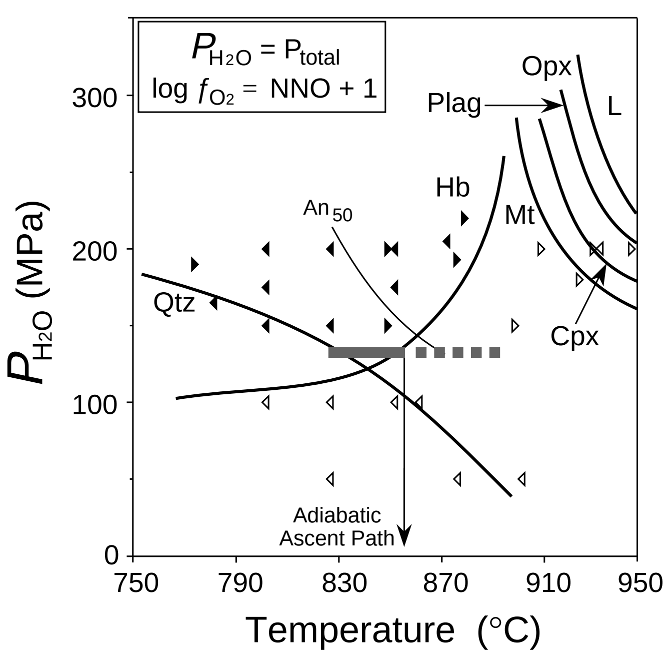

Figure 4. Experimentally determined phase equilibria of the Soufriere Hills andesite modified after Barclay et al. (1998). Curves show the onset of crystallization of individual phenocryst phases as temperatures drop. Phenocrysts are: Hb—hornblende; Opx—orthopyroxene; Cpx—clinopyroxene; Plag—plagioclase; Fe-Ti oxides—magnetite; Qtz—quartz; An_{50}, plagioclase composition in equilibrium with melt. The Hb curve represents a reaction of melt with clinopyroxene to form hornblende. The horizontal bar indicates *P* and *T* of pre-eruption magma; the pressure estimate is from Al-in-hornblende geobarometry. Pre- and postheating temperature estimates are from Fe-Ti oxide geothermometry discussed in the text. Arrowheads indicate individual experiments and direction of approach to final temperature. At 130 MPa, heating of a magma to >860 °C, or ascent of magma, results in hornblende breakdown.

plagioclase becomes more Ca-rich (anorthitic), and the hornblende coexisting with the melt becomes more Al-rich. Phenocrysts in the Soufriere Hills samples indicate that these compositional changes were taking place just prior to eruption.

PRE-ERUPTION HEATING EVENT

All samples studied display characteristics of a pre-eruption heating event in the Soufriere Hills magma storage region. The most direct evidence of this event is compositional zonation in the magnetite and ilmenite phenocrysts; the core compositions yield temperatures of 840 °C, whereas rims of some adjacent crystals last equilibrated at ~900 °C. What caused this heating? Was it an influx of new hot magma? How hot did it get? Did the heating occur as one event or has it been continuous throughout the eruption?

These questions are still being investigated, but it appears that the phenocryst-rich andesitic magma residing in the 130 MPa (~5 km deep) magma storage region was intruded by a higher temperature, more mafic magma just prior to the eruption. Evidence for a higher temperature magma comes from the basaltic andesite inclusions containing rhyolitic glass that are scattered throughout the Soufriere Hills magma. When hornblende is present in these inclusions, it is more Al-rich (8–15 wt% Al_2O_3) than that in the andesite, indicating crystallization under higher temperature conditions. Another indicator of heating is the presence of clinopyroxene overgrowths on orthopyroxene and quartz crystals. The fact that hornblende remains stable at the same time that Ca-pyroxene overgrowths show no sign of reaction with the surrounding melt to form hornblende suggests that conditions just prior to the eruption (after heating) were essentially at the phase boundary where hornblende reacts to form clinopyroxene + melt (see Fig. 4). An observation that neither supports nor rules out magma mixing in the storage region is the constancy of the bulk composition of the magma that erupted from 1995 to 1997.

Evidence on when heating caused by magma mixing could have occurred comes from arrested mineralogical reactions. Particularly important is the compositional zonation observed on rims of magnetite and ilmenite phenocrysts in contact with each other. The thickness of such diffusional zones on magnetite phenocrysts depends primarily on temperature and the interdiffusion coefficient of Fe and Ti in the crystal. Both existing diffusion data and recent experiments suggest that it takes two to four weeks to develop a 20–25-µm-thick diffusion profile on magnetite if the temperature of the andesite storage zone is at 850 °C. Less time (5–10 days) is required if the temperature is at 880 °C (Venezky and Rutherford, 1998). The presence of similar diffusional zonation profiles in samples from both the September 1996 and June 1997 eruptions suggests that heating has been ongoing. If heating had occurred only in late 1995, the thickness of the diffusional zones in crystals from samples erupted in 1997 would be much thicker than those in the earlier erupted magmas.

Amazingly, evidence of an earlier magma chamber heating event appears to have survived in all of the Soufriere Hills andesitic lavas erupted from 1995 to 1997. This evidence comes from a small relict population of hornblende phenocrysts with very thick breakdown rims (300–400 µm). The hornblende surrounded by these thick rims has a higher aluminum content than the main population of hornblende phenocrysts, which are characterized by very thin or no reaction rims at all. Crystals with intermediate thickness reaction rims are generally not present. These observations are interpreted to mean that the phenocrysts with thick rims are the only hornblende crystals that survived an earlier heating event. The interiors of these crystals underwent little or no change in composition during ascent because they had limited or no contact with the melt. Subsequent cooling and crystallization of the magma with temperatures reaching 830 °C produced most of the hornblende phenocrysts present in the erupted lavas.

MAGMA ASCENT RATE CHANGES: ERUPTION STYLE IMPLICATIONS

The rate of magma ascent from the ~5-km-deep storage region to the surface at Soufriere Hills has changed significantly over the two-year period of the eruption. This interpretation is based primarily on variations in the thicknesses of the reaction rims present on the main population of hornblende phenocrysts in magma extruded at different times. When a water-rich magma like the Soufriere Hills andesite ascends from depth, water in the melt is readily lost to gas bubbles. This decrease in the meltwater content causes hornblende in contact with the melt to become unstable, and after a short (~4 day) nucleation period, to develop a reaction rim. The rate at which rim growth occurs has been experimentally calibrated for dacitic composition magma (Rutherford

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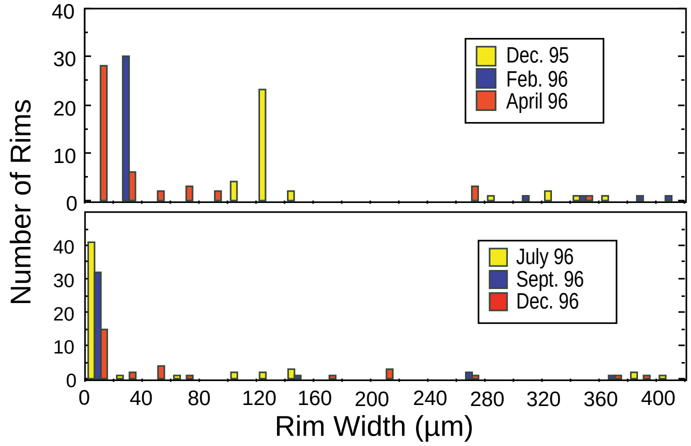

Figure 5. Histograms showing the number of hornblende phenocrysts vs. the thickness of the reaction rims in Soufriere Hills andesite samples erupted at various times from December 1995 through 1996. Rim thickness of the main hornblende population was used to calculate the ascent rates shown in Figure 6. The significance of the small thick-rimmed population is discussed in the text. The population with intermediate thickness rims erupted late in 1996 is thought to represent a mixing-in of some andesitic magma from earlier ascended material. The large populations of hornblende phenocrysts in the July to December 1996 samples plotting to the left of 10 µm all have near zero rim width.

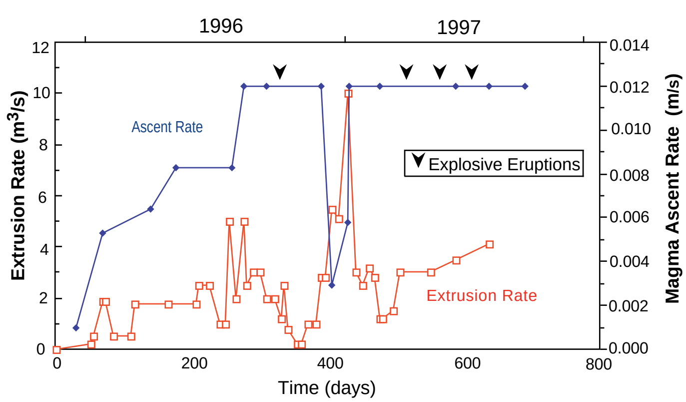

Figure 6. Average magma ascent rate and extrusion rate plotted against time during the ongoing Soufriere Hills eruption that began at the end of November 1995. The ascent rate estimates are based on hornblende reaction rim thicknesses (Devine et al., 1998), and an experimental calibration of thickness vs. time. The extrusion rate curve is from Sparks et al. (1997). See discussion in the text.

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and Hill, 1993), and this calibration has been used to estimate average ascent rates for the Soufriere Hills magmas.

As shown in Figure 5, a summary of the changes in reaction rim thicknesses in hornblende crystals for samples erupted over time, the December 1995 samples contain a main population of hornblende phenocrysts with 120 ± 20-µm-thick reaction rims formed where the crystals were in contact with melt (Fig. 3); the other 10% of the phenocrysts present have the very thick (300–400 µm) reaction rims discussed above. The same main hornblende population had only 18 µm rims in the February 1996 magma, and by April 1996, the rims on the main hornblende population had decreased to 10 ± 3 µm. Most hornblende crystals in samples from the July through September 1996 magmas had no reaction rims.

If we use the Rutherford and Hill (1993) experimental calibration of rim width vs. ascent time, the rim data for the hornblende phenocrysts from the various samples give average magma ascent rates that vary from 3.5 m/hr to > 42 m/hr (0.001 to >0.012 m/s in Fig. 6). The importance of the hornblende reaction rims is not so much to determine the absolute ascent rate estimates, but rather to determine the relative ascent rates over the duration of the eruption. The calculated rates plotted in Figure 6 indicate a sharp increase in the magma ascent rate in January 1996 following the initial extrusion of the dome lava in late 1995. This increase in magma ascent rate continued through the summer of 1996, culminating in the explosive eruption of September 17, 1996. The limit for the use of hornblende rims in estimating ascent rates was reached early in the summer of 1996, when the thickness of the hornblende rims went to zero. As a result, the magma ascent rates estimated for August and September 1996 (days 275–310) are minimum estimates.

Interestingly, there was a more or less steady increase in extrusion rate (see Fig. 6) over this initial eruption period, as indicated by dome volume growth (Young et al., 1997; Sparks et al., 1998). The correlation of increasing ascent rate with increases in the rate of dome growth (extrusion rate) over this period indicates that the change in extrusion rate resulted from accelerated magma ascent rate, and not from an increased conduit diameter.

Following the September 1996 eruption, dome growth quickly resumed. The hornblende reaction rim data indicate that there was some mixing of old conduit or dome magma with new magma from the storage region to form the samples obtained during the December 1996 events (see Fig. 5). However, early in 1997 the hornblende rim widths again became very thin and then the rims disappeared, indicating that the erupting magma was once again ascending rapidly (average rate >0.012 m/s) from the 5-km-deep storage zone. The rate of dome growth was also determined to be very high during this period. The rapid magma ascent through the early spring of 1997 was an indication that a period of occasional explosive activity was likely to occur, given the 1996 eruption history of this volatile-rich magma. As magma ascent rates increase, there is less opportunity for release of volatiles from the ascending magma. Periodic explosive eruptions such as were seen in the summer and fall of 1997 are the result.

PETROLOGICAL CHANGES VS. SURFACE OBSERVATIONS AND GEOPHYSICS

The petrological indications of magma storage zone conditions and magma ascent rate are generally consistent with results of other geological and geophysical studies of the Soufriere Hills Volcano. Seismic data appear to rule out magma storage at <5 km depth, but do not outline an aseismic magma storage zone. Much of the seismicity at the volcano is associated with shallow degassing or with dome collapses and rock falls (Montserrat Volcanic Observatory Web page, January 1998, http://www.geo.mtu.edu/volcanoes/west.indies/soufriere/govt/).

Mattioli et al. (1997) used surface deformation monitored by GPS measurements to model a shallow 1-m-wide feeder dike connecting to a deflating magma source region at 6 km depth. Spectroscopic measurements of the volcanic gas cloud indicate SO_2 emissions that are within the 50 to 500 tons/day range observed for other dome-forming eruptions (Young et al., 1997). Higher emissions (>1000 tons/day) are observed during periods of more rapid dome growth and pyroclastic flow emplacement. This observation supports our sample analyses, which show extensive degassing of dome magma samples, but relatively vesicular and undegassed samples erupted during explosive eruptions.

CONCLUSIONS

A combined petrographic, analytical, and experimental study of samples from the 1995 to 1997 Soufriere Hills eruptions on Montserrat Island has allowed us to determine that the pre-eruption andesitic magma was in a deep storage zone at a temperature of 830 ± 20 °C and a pressure of 130 ± 25 MPa (5–6 km depth), and was probably very close to being saturated with a water-rich fluid phase. While in this storage zone, the magma was variably heated for the 2–4 weeks prior to eruption. This heating almost certainly resulted from the intrusion of a more mafic magma, relicts of which are among the mafic inclusions in the dome andesite. Ascent rates for andesitic magma erupted from 1995 to 1997 at the Soufriere Hills Volcano have been determined by using the thickness of reaction rims developed on hornblende phenocrysts. The rim-thickness data show that the average ascent rate for magma erupted at different times has varied by a factor of 10, with high rates correlating with rapid rates of dome-volume growth.

ACKNOWLEDGMENTS

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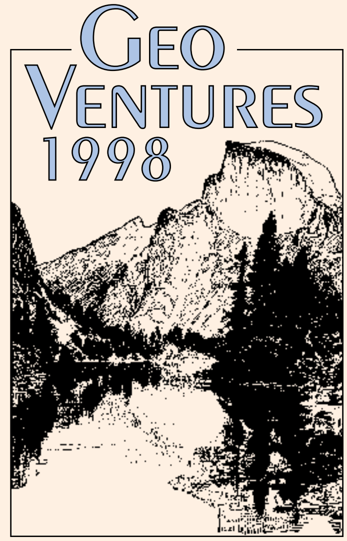

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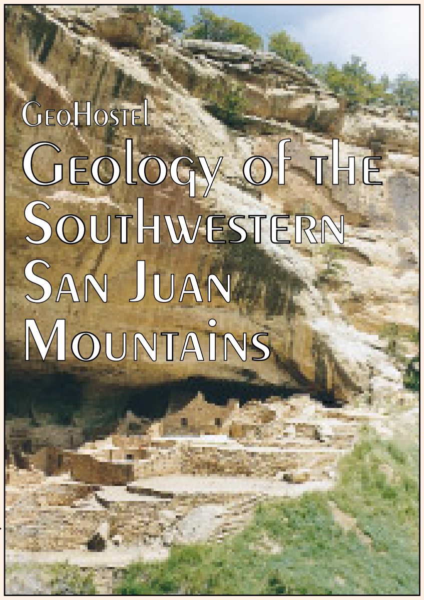

Photo by Ken Kolm.

Fort Lewis College, Durango, Colorado
June 27–July 2, 1998
6 days, 6 nights

Scientific Leaders:
Gregory Holden and Kenneth Kolm, Colorado School of Mines, Golden, Colorado

Greg Holden and Ken Kolm are experienced GeoHostel leaders and ran a Durango GeoHostel in 1992. Both are associate professors at the Colorado School of Mines and know the Durango area well. You will find them informed, informing, and enthusiastic.

Description

Durango, Colorado, was founded more than a century ago as the supply center for the mining camps of the San Juan Mountains. Located at the boundary of the Colorado Plateau and the Colorado Rockies, the town today is the recreational center for some of the most scenic, historic, and geologically diverse country in the west. The Durango townsite was the terminus to the Ice Age Animas River glacier, largest to drain the San Juan icefield. Fort Lewis College is 300 feet above the town, on the remnant of an outwash terrace. Erosion during Neogene uplift has exposed Precambrian basement rocks, a complete Paleozoic and Mesozoic sedimentary section, and Tertiary caldera-related pyroclastic rocks and associated mineralization. The area is home to the historic Durango & Silverton Narrow Gauge Railroad, Anasazi Indian ruins, ghost towns, and spectacular mountain wildflowers and scenery.

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WASHINGTON REPORT

Bruce F. Molnia

Troubled Waters Mark the Start of the Year of the Oceans

"It gives me great pleasure to see that over 1,600 leading marine scientists and conservation biologists from around the world have signed the Troubled Waters: A Call for Action statement. Not since the Stratton Commission over 25 years ago have we seen this much attention provided to our world's oceans. But much work still needs to be done. I recently made a pledge to many representatives from our Nation's leading oceanographic universities and institutions who were visiting Washington a few months ago. I told them that I would not rest until the United States focuses the same amount of time, money and energy toward understanding the marine environment as we have learning about space over the past 30 years. I make that same pledge to you here today."

—Representative Curt Weldon (R—PA)
addressing the "Troubled Waters" press conference

Less than a week after the start of the United Nations International Year of the Ocean, a call for action, signed by more than 1600 ocean scientists from 65 countries, including more than 900 from the United States, was released in Washington, D.C., warning about "perils" threatening the world ocean. This unprecedented warning, addressed to the world's governments and citizens, states that the sea is in trouble from five causes: (1) overexploitation of species, (2) physical alteration of ecosystems, (3) pollution, (4) alien species from distant waters disrupting local food webs, and (5) global atmospheric change. Titled "Troubled Waters: A Call for Action," the document summarizes these urgent threats to marine species and ecosystems and calls for immediate action to prevent further damage. "Troubled Waters" paints a dismaying picture of the destruction of marine biological diversity.

"Troubled Waters" claims that overfishing has decimated commercial fish populations and caused the collapse of many fisheries worldwide, such as the cod fisheries of Georges Bank offshore New England. It describes destructive fishing methods, such as bottom trawling, that have crushed and buried bottom-dwelling species and scoured vast areas of seabed. It mentions other human activities, such as coastal development, which have consumed mangrove forests and salt marshes, and new diseases, perhaps caused by pollution, that are impacting coral reef communities and marine mammals.

This call for action has been signed by academic scientific leaders from many well-known marine research institutions on six continents, including the Australian Institute of Marine Sciences and the Russian Academy of Sciences, and by marine scientists from federal agencies, local governments, tribal fisheries commissions, conservation groups, and private industry. Endorsers include Jane Lubchenco, past president of the American Association for the Advancement of Science; Paul Dayton of Scripps Institution of Oceanography; Sylvia Earle of Deep Ocean Exploration and Research; Edward O. Wilson of Harvard University; Peter Raven of the Missouri Botanical Garden; and Michael Soulé, the father of conservation biology. Signatures were collected in only eight months, starting in June 1997.

Using press conferences to mobilize the media and getting large groups of scientists to sign statements or letters expressing a particular point of view about our changing environment have become accepted ways of lobbying Congress, the UN, and the public. Last year, Lubchenco and Raven were two of the leaders of the petition effort that collected more than 2,000 signatures from scientists proclaiming that "human activity was irrefutably causing climate change." The "Troubled Waters" signature collection effort was coordinated by the Marine Conservation Biology Institute (MCBI), a nonprofit, ocean watchdog organization.

At the January 6, 1998, press conference announcing the release of "Troubled Waters," Elliott Norse, a marine ecologist and President of MCBI, described a recent New York Times poll which reported that only 1% of Americans consider the environment the most important problem facing our country. He continued "Because few of us spend much time below the surface, it is easy to overlook signs that things are going wrong in the sea…. But the signs are increasingly obvious to the experts. The scientists who study the Earth's living systems are far more worried than the public and our political leaders. That's a wake up call that nobody can afford to ignore."

A statement released at the press conference by JoAnn Burkholder of North Carolina State University, a marine biologist studying the linkage between coastal pollution and outbreaks of fish-eating *Pfiesteria piscicida,* and another press conference participant, stated, "It's hard to imagine that farming on land and building in cities could harm the marine environment and fishermen, but it does. The tons of sewage produced by millions of people don't just go away when we flush, a lot of it winds up in our coastal waters. And construction, agriculture and logging send clouds of choking sediments and excess nutrients into marine waters, smothering sensitive habitats. What we do on land profoundly affects life in the sea."

At the press conference, M. Patricia Morse, a marine biologist from Northeastern University stated, "If it's business as usual, we'll see more declines in corals, fishes, marine mammals and seabirds. That spells disaster for industries like fishing and tourism that depend on healthy marine life, and for every human on Earth, because we all use goods and services provided by the sea every day. Oceans regulate our climate, provide a breathable atmosphere and break down wastes. Coastal wetlands protect our shores from flooding and storm damage, improve water quality and provide crucial habitat for fishes and other marine life. When we destroy these ecosystems, we lose both their products and services."

"Troubled Waters" calls on citizens and governments to act now to reverse current trends and avert even more widespread harm to marine species and ecosystems. It outlines needed changes, including elimination of government subsidies that encourage overfishing, an end to fishing methods that damage fish habitat, reduction of non–point-source pollution from activities on land, cuts in emissions that cause global warming, and the creation of an effective system of marine protected areas from the shore to the open ocean.

"Getting scientists to agree on anything is like herding cats," said Elliott Norse, "so having 1,600 experts voice their concerns publicly highlights how seriously the sea is threatened. He continued, "Troubled Waters" shows that the world's experts want the public and our leaders to know that threats to marine species and ecosystems are urgent, and that we must change what we're doing now to prevent further irreversible decline. A White House Conference on the Marine Environment would help to highlight what's known about marine environmental problems and to address the most pressing ones. YOTO [Year of the Oceans] provides the ideal opportunity to move forward in protecting, restoring, and sustainably using life in the sea. We need to do it for two reasons: because it's essential to our well-being and survival and because it's the right thing to do."

The text of the statement is as follows.

"We, the undersigned marine scientists and conservation biologists, call upon

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Investigations of Natural Background Geochemistry—Scientific, Regulatory, and Engineering Issues

Donald D. Runnells, *Shepherd Miller, Inc., 3801 Automation Way, Suite 100, Fort Collins, CO 80525*

The characterization of natural background chemistry affects decision-making in such diverse areas as regulatory affairs, agriculture, risk assessment, engineering design, and geochemical exploration. My goal here is to introduce the reader to the subject of natural background geochemistry and to illustrate the many applications that are being made of studies in this area. For purposes of this paper, we will define natural background chemistry as: the identification and characterization of natural concentrations of elements and chemical components in geologic materials, in the absence of anthropogenic effects.

At present, the study of natural background geochemistry is receiving great emphasis in the regulatory arena ("arena" is probably the most accurate choice of a word, with its implication of "conflict" or "confrontation"). For example, the importance of natural background geochemistry is specifically recognized within the Superfund regulatory structure, in which the cleanup of contaminants to concentrations that are below natural background levels is not enforceable. Thus, in the application of Superfund laws to site assessment, remediation, and reclamation of areas, including historic mining districts, that are contaminated with metals, much time and money may be expended by both sides of the contest in trying to define natural background concentrations of metals, which can be very difficult in mineralized areas in which mining, milling, and smelting have been conducted.

The study of natural background geochemistry also has important current applications to agriculture and aquacultural enterprises, in which the natural concentrations of chemical elements (e.g., selenium, arsenic, chromium, lead, cadmium, copper) may affect the cultivation of particular foodstuffs, such as grains, legumes, or shellfish. A goal of some of the most interesting work in the field of natural background geochemistry, by the British Geological Survey, was to identify and assess the impact of historical mining and smelting activity on agriculture and aquaculture. Geochemical maps of Great Britain show clear-cut evidence of ancient mining and smelting sites, as revealed by elevated concentrations of arsenic, lead, zinc, and copper in stream sediments and soils. Other elements, such as selenium and molybdenum, show naturally elevated concentrations in outcrop areas of black shale. Similarly, geochemical maps of Finland reveal naturally elevated concentrations of fluoride in water, in association with alkaline granitic rocks. With such information in hand, better decisions can be made as to the most appropriate

Geochemistry *continued on p. 11*

Washington Report *continued from p. 9*

the world's citizens and governments to recognize that the living sea is in trouble and to take decisive action. We must act quickly to stop further severe, irreversible damage to the sea's biological diversity and integrity.

Marine ecosystems are home to many phyla that live nowhere else. As vital components of our planet's life support systems, they protect shorelines from flooding, break down wastes, moderate climate and maintain a breathable atmosphere. Marine species provide a livelihood for millions of people, food, medicines, raw materials and recreation for billions, and are intrinsically important.

Life in the world's estuaries, coastal waters, enclosed seas and oceans is increasingly threatened by: 1) overexploitation of species, 2) physical alteration of ecosystems, 3) pollution, 4) introduction of alien species, and 5) global atmospheric change. Scientists have documented the extinction of marine species, disappearance of ecosystems and loss of resources worth billions of dollars. Overfishing has eliminated all but a handful of California's white abalones. Swordfish fisheries have collapsed as more boats armed with better technology chase ever fewer fish. Northern right whales have not recovered six decades after their exploitation supposedly ceased. Steller sea lion populations have dwindled as fishing for their food has intensified. Cyanide and dynamite fishing are destroying the world's richest coral reefs. Bottom trawling is scouring continental shelf seabeds from the poles to the tropics. Mangrove forests are vanishing. Logging and farming on hillsides are exposing soils to rains that wash silt into the sea, killing kelps and reef corals. Nutrients from sewage and toxic chemicals from industry are overnourishing and poisoning estuaries, coastal waters and enclosed seas. Millions of seabirds have been oiled, drowned by longlines, and deprived of nesting beaches by development and nest-robbing cats and rats. Alien species introduced intentionally or as stowaways in ships' ballast tanks have become dominant species in marine ecosystems around the world. Reef corals are succumbing to diseases or undergoing mass bleaching in many places. There is no doubt that the sea's biological diversity and integrity are in trouble.

To reverse this trend and avert even more widespread harm to marine species and ecosystems, we urge citizens and governments worldwide to take the following five steps: 1) Identify and provide effective protection to all populations of marine species that are significantly depleted or declining, take all measures necessary to allow their recovery, minimize bycatch, end all subsidies that encourage overfishing and ensure that use of marine species is sustainable in perpetuity. 2) Increase the number and effectiveness of marine protected areas so that 20% of Exclusive Economic Zones and the High Seas are protected from threats by the Year 2020. 3) Ameliorate or stop fishing methods that undermine sustainability by harming the habitats of economically valuable marine species and the species they use for food and shelter. 4) Stop physical alteration of terrestrial, freshwater and marine ecosystems that harms the sea, minimize pollution discharged at sea or entering the sea from the land, curtail introduction of alien marine species and prevent further atmospheric changes that threaten marine species and ecosystems. 5) Provide sufficient resources to encourage natural and social scientists to undertake marine conservation biology research needed to protect, restore and sustainably use life in the sea.

Nothing happening on Earth threatens our security more than the destruction of our living systems. The situation is so serious that leaders and citizens cannot afford to wait even a decade to make major progress toward these goals. To maintain, restore and sustainably use the sea's biological diversity and the essential products and services that it provides, we must act now." ■

Geochemistry *continued from p. 10*

agricultural and aquacultural activities in a particular region.

Extensive studies of natural background geochemistry, conducted by the U.S. Geological Survey in the United States in the 1970s, had three primary purposes: (1) geochemical exploration for new mineral deposits (e.g., in the Coeur d'Alene District of Idaho), (2) determination of natural background chemistry in areas of urbanization (e.g., the Colorado Front Range), and (3) establishment of the range and variability of natural concentrations of elements on a regional scale (e.g., a geochemical survey of the entire state of Missouri). Following the surge of activity in the 1970s, the USGS put the topic of natural background geochemistry on the back burner (except for exploration for mineral deposits), until the early 1990s, at which time it again became very active in the field. The recent surge of activity by the USGS has been largely in response to regulatory concerns at historical mining districts, such as Leadville and Summitville, Colorado. The USGS currently has several studies underway in both the applied and fundamental aspects of natural background chemistry, on scales ranging from the local to the continental. In fact, one of the major initiatives within the 1996 Program Plan for the Geologic Division of the USGS was that of natural background chemistry.

Another area of great interest is the international geochemical mapping program. The concept of international geochemical survey procedures was introduced in the 1970s by the International Atomic Energy Agency. The Scandanavian countries and the United Kingdom were the first to undertake nationwide geochemical surveys, and they established many of the procedures and protocols that are now widely used in regional geochemical surveys. As of 1995, the United Kingdom, Finland, and Norway had 100% geochemical mapping coverage. At present, the federal geological surveys of more than 40 other countries are actively engaged in sampling and analysis of geologic materials, primarily stream sediments and soils, with the ultimate objective of producing geochemical atlases. Summaries of the international geochemical surveys are summarized in "A Global Geochemical Database for Environmental and Resource Management, Recommendations for International Geochemical Mapping" (Earth Sciences 19, Final Report of IGCP Project 259, International Union of Geological Sciences and other organizations, published by UNESCO, Paris, 122 p.), together with recommendations for standardized procedures for collection, analysis, and presentation.

Of the various applications of studies of natural geochemical background, by far the most widespread and intensive are those that are directed toward exploration for new mineral deposits. This field of specialization was developed by Scandinavian and Russian geologists and chemists during the first few decades of the 20th century, and it has been highly successful in the discovery of numerous new ore deposits throughout the world. Of course, in the case of geochemical exploration, we are looking for geochemical anomalies above the regional background values, in the hope that such anomalies reflect the presence of hidden ore deposits. This field of specialization is represented by a professional organization, the Association of Exploration Geochemists (AEG), established in 1970, with a current membership of about 1200 scientists worldwide. An enormous amount of highly useful geochemical background information, with direct applications to environmental and regulatory issues, can be found in the publications of the AEG, including the *Journal of Geochemical Exploration*. For example, analyses of stream water from mineralized areas in the Northwest Territories of Canada, obtained for purposes of geochemical exploration, show concentrations of copper up to 68 mg/L (milligrams per liter) and zinc up to 16 mg/L, with pH values as low as 3.0 (E. M. Cameron, 1978, *Journal of Exploration Geochemistry,* v. 10, p. 219–243); in the absence of such information from mineralized but nonmined areas, such high concentrations of metals and low pH values, if observed in disturbed areas, would invariably be attributed to anthropogenic activity.

The relationship between engineering applications and the scientific and regulatory issues is that engineering approaches will generally be required to remediate a particular site, on the basis of the scientific and regulatory aspects of the problem. The engineering fix must, however, be appropriate to the problem. For example, failure to recognize that the natural background concentrations of metals are always elevated in mining districts could lead to inappropriate engineering designs for remediation. It is important for regulators and engineers to recognize that mines are located where they are precisely because of anomalous concentrations of elements.

"Metals in Water: Determining Natural Background Concentrations in Mineralized Areas," by D. Runnells, T. Shepherd, and E. Angino (*Environmental Science and Technology*, v. 26, p. 2316–2322) makes the very simple point that the concentrations of metals in natural waters are orders of magnitude higher in mineralized areas than in nonmineralized areas. This point is based on chemical analyses of waters from mineralized, nonmined areas throughout the world. This is certainly no surprise to the practicing geochemist, but it is not necessarily an obvious conclusion to an engineer or a regulator. Much of the chemical information in our publication was taken directly from papers in the *Journal of Geochemical Exploration*. With accurate and representative geochemical information, the regulator can set realistic goals for remediation, and the engineer can devise a scheme that is directed toward remediation of the human-made part of the contamination, but need not waste time and financial resources on naturally elevated concentrations of the contaminants of concern.

Theme sessions on the subject of natural background geochemistry were held at the 1997 meeting of the Geological Society of America and at the 1997 session of the Northwest Mining Association. For the next several years, and perhaps for the next several decades, we can expect to see increasing attention paid to this old but reinvigorated area of geochemistry. ■

Roy J. Shlemon Mentor Program in Applied Geology—1998—It's a Winner!

This year the Northeastern, Southeastern, Cordilleran, and Rocky Mountain sections of GSA are hosting the Roy J. Shlemon Mentor Program in Applied Geology at their meetings. Topics of discussion will include, but are not limited to: making the transition from academia to the workplace, environmental hydrogeology, consulting, and engineering geology. The Shlemon Mentors are chosen from a variety of business and professional disciplines; each brings specific expertise in and understanding of the real world of geology.

"Of all that we teach, there are two items that seem to elude us most: (1) the application of technical theory to practice, and (2) the unwritten, nontechnical rules of conduct of the profession," wrote Allen W. Hatheway, professor of geological engineering at the University of Missouri—Rolla. "Each of us learns so much so late…." ("Making It in Professional Practice; Sixty-Seven Rules for Your Consideration," *AEG News,* v. 35, no. 3, July 1992, p. 39–44). The Roy J. Shlemon Mentor Program addresses both of these issues and facilitates hands-on learning for those inexperienced in the workplace.

For senior undergraduate and graduate students, the Shlemon Mentor Program is a once-a-year opportunity to engage in discussions with experienced, professional geologists. Students can ask the questions they have hesitated to ask; the answers are often surprising. For geologists intrigued with the role of mentorship, the knowledge and experience brought to this program are priceless and very much appreciated.

For more information, consult a member of the program committee from your section, or check the final announcements for the 1998 meetings of the Cordilleran, Rocky Mountain, Southeastern, and Northeastern sections in the December 1997 and January and February 1998 issues of *GSA Today.*

This program is administered by the John F. Mann, Jr. Institute for Applied Geoscience.

GEOLOGICAL SOCIETY OF AMERICA
MEDALS AND AWARDS FOR 1997

PENROSE MEDAL
presented to
JOHN D. BREDEHOEFT

Citation by ROGER G. WOLFF

The French philosopher Marcel Proust made an observation about life that I will paraphrase: The things we are likely to regret bitterly are those things we never let our hearts long for. As evidenced by the presentation of this award, it is clear that John Bredehoeft will certainly have no such regrets with regard to his professional achievements.

John's expertise is in water resources, especially groundwater; however, he also made major contributions on many other water-related geologic problems. I will attempt to summarize some highlights of John's career.

In the late 1960s John and George Pinder developed and documented the first numerical model for simulating ground-water flow. Soon after, they coupled this model with the method of characteristics to simulate contaminant transport. These models were the precursors of the USGS's numerical flow and transport models (MODFLOW and MOC3D), which are now extensively used by hydrologists worldwide.

John also participated in investigations of the economics of ground-water development at Resources of the Future, where he and Bob Young were the first to use distributed parameter numerical ground-water models for the economic analysis of optimal groundwater development. John, B. Raleigh, and J. Healy conducted a field-scale experiment near Rangely, Colorado, where they were able to show the role of pore pressure in controlling earthquakes—the only successful experiment of its kind on record. In another field-scale experiment, while working on the determination of the amount of ground water to be pumped in mining oil shale in the Piceance Basin of Colorado, John and I conducted state-of-the-art hydrofracing to determine the state of in-situ stress; this was also the first experiment of its kind on a regional scale.

In some of his early work, John showed that water wells can respond to earth tides, i.e., they can be used as strain meters. In 1980 he installed a water-well monitoring network at Parkfield, California, to monitor tectonic stress as part of a USGS experiment in earthquake prediction. These wells continue to sense tectonic strain at Parkfield, especially creep events on the San Andreas fault.

Among John's numerous publications there are quite a few papers that have influenced the approach to our national nuclear waste disposal policy. He has served extended details on NAS/NRC advisory committees for the Waste Isolation Pilot Plant in New Mexico and the Yucca Mountain repository in Nevada.

John's interests in ground-water flow spanned from the local scale, where he investigated the analysis of data from drill-stem and slug tests, to the investigation of the hydrodynamics of regional fluid movements in deep sedimentary basins, including the Dakota Sandstone and associated aquifers in South Dakota, the Denver Basin, the Caspian Basin in the former Soviet Union, the Big Horn basin in Wyoming, and the Uinta basin in Utah. Each of these basins exhibits anomalous conditions that John was able to address at the regional scale.

In the tradition of the USGS, John has also applied his technical expertise to management roles, first as an overseer of the Water Research Program of the USGS, and then as regional hydrologist for the eight western states. As in research, John's unique ability to foresee critical areas in need of attention was also effective in his management roles.

The significance and breadth of John's contributions led to his induction into the membership of both the U.S. National Academy of Engineering and the Russian Academy of Natural Sciences. He has also received a host of other prestigious honors and awards, and he was, and continues to be, a highly active participant on major scientific committees and panels. John retired from the USGS in 1995 and founded the consulting firm Hydrodynamics Group, where he continues to apply his technical skills in ground water to the solution of real-world problems.

Among those who affected John's career, there are three influential mentors that I want to identify because their vision was an inspiration to John and is reflected in his life's work. The first of these mentors was Burke Maxey, John's Ph.D. thesis advisor at the University of Illinois. John's career epitomizes Burke's insistence on bold and original thinking. The other two important mentors were Bob Bennett and Hilton Cooper at the USGS.

When Luna Leopold established the water research program at the USGS during the early 1960s, there was a group of researchers located in a semi-secluded cul-de-sac of offices in a building across the Potomac from the USGS managers. That original group consisted of Bennett and Cooper as its senior members and John and Stavros Papadopulos as its junior members. George Pinder and Peter Trescott joined the group later.

Bennett and Cooper not only provided to John and the team's other junior members a high degree of knowledge based on practical experience from the field, they also embodied and passed down the finest traditions and ethics of the profession and of the USGS to the junior members. The dynamic coupling of Bennett and Cooper's real-world common sense with the progressive and fresh knowledge and energy of John and the other junior members resulted in an explosively productive and stimulating scientific environment in the field of hydrogeology. John was deeply impacted by the ideals personified by Bennett and Cooper, and he in turn has been an effective emissary in passing on these traits to a new generation of geologists and hydrogeologists.

Central to John's entire career has been his great pleasure in promoting students. Some students have benefited through the opportunity of working directly with John, while others were assisted by his finding for them stimulating positions throughout the Water Resources Division of the USGS. Still others benefited from his role as visiting professor at the University of Illinois and as consulting professor at Stanford, UC Santa Cruz, and San Francisco State universities. Many of today's leading hydrogeologists have been helped by John in his capacities as mentor and teacher.

It is my most sincere pleasure, as a friend and colleague of John's, to present him to the Society for the official designation as the 1997 R.A.F. Penrose, Jr., Medalist. It is the award that John himself has categorized as "the most distinguished award a geologist can receive."

Response by JOHN D. BREDEHOEFT

Each of the last several recipients of the Penrose Medal expressed surprise at being chosen. I too am surprised; never in my wildest dreams could I imagine receiving the Penrose Medal. I have personally known a number of previous medalists: two of my professors at Princeton, Harry Hess and A. F. Buddington; a Chief Geologist at the USGS, Wilmot Bradley; and several others, Bill Rubey, King Hubbert, Luna Leopold. Over the past seven decades, the recipients of the Penrose Medal were the giants of the profession. When I think of how they shaped earth science and compare my own contributions, it is a humbling experience.

I knew from the beginning of my research career, in the early 1960s, that studying fluids in the crust was not considered mainstream by the geologic profession. It interested me; it was certainly stimulating and important, in my mind at least—but I could accept that the rest of the profession was preoccupied with other things. I have tried to understand the many facets of fluids in the crust. Mostly, studying fluids has been fun.

Upon receiving my Ph.D., I was lucky to have gone to work at the U.S. Geological Survey. I arrived at a time when I could apprentice with some of the best professionals engaged in the study of ground water. It was with Bob Bennett, Hilton Cooper, C. V. Theis, Bob Stallman, Herb Skibitski, Jacob Rubin, and Walter Langbein that I was able to learn my profession. These individuals, mostly unknown outside the water community, built much of ground-water science as we know it today. Many young people do not have the opportunity to apprentice with a group of senior mentors as I did at the USGS. I owe my maturity as a scientist to them.

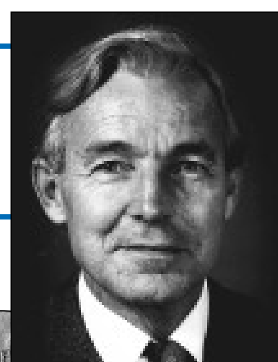
The USGS gave me the opportunity to pursue my research more or less unfettered. Like any successful individual, I paid my dues both in doing research that furthered the everday missions of the Water Resources Division and, in the tradition of the USGS, in stints of administration. I had the best opportunity to do the research that interested me. I am the first geologist to come from the Water Resources Division of the Survey to receive this award; my award recognizes the support for first-class science in water within the USGS. I left the Survey in 1994 to do something different during the rest of my life—to build a consulting business; that too has been fun.

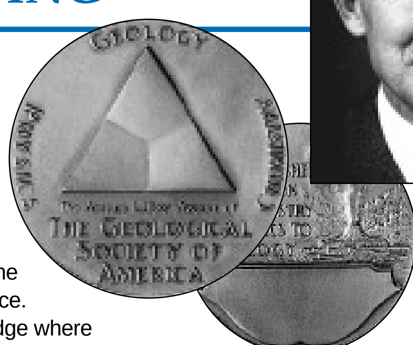
It is especially rewarding to have one's colleagues recognize your work. Perhaps more than just my work is being recognized; this award shows that the geological profession now recognizes the study of fluids as an important part of geology. Ike Winograd suggested I was the first hydrogeologist to receive the Penrose Medal. He is incorrect; perhaps I am the first to call myself a hydrogeologist. N. H. Darton was a very accomplished ground-water geologist; he worked on the Dakota Sandstone as an aquifer at the turn of the century. His work on the Dakota shaped our thinking regarding extensive artesian aquifers. King Hubbert mostly worked on fluids in the crust his entire career; his work with Bill Rubey on the role of fluids in overthrust faulting revolutionized geology. We are mostly following their leads.

One does make major contributions in any of life's endeavors with the support of one's family. My family has been most supportive—especially my wife, Nancy.

I am pleased to accept the Penrose Medal for myself as well as for my colleagues in research at the USGS, and especially my other colleagues who study fluids in the earth. The award to me recognizes all of us.

DAY MEDAL
presented to
EDWARD IRVING





Citation by NEIL OPDYKE

It is my privilege and pleasure to give the citation for the Day Medal to Edward Irving. Ted's accomplishments are many, and some have changed the way in which we view earth science. As a graduate student at Cambridge where he studied with S. K. Runcorn from 1951 to 1954, he demonstrated that rocks as old as Precambrian could retain their original directions of magnetization unchanged. In the same rocks, he also showed that reversals of directions of magnetization occurred in stratigraphic sequence. He carried out the first test using paleomagnetism of continental drift, with rocks from the Deccan traps of India. However, the results of this study were not published until after he left Cambridge for the newly created Australian National University, where he worked from 1954 to 1964.

It was in Australia that Ted produced some of his most important papers. In 1956 he published a paper showing that the polar wander curve from North America was systematically offset to the west of the polar wander curve from Europe, indicating the opening of the Atlantic Ocean. In the same paper he presented the paleomagnetic poles from the Deccan Traps of India and the Tasmanian dolomites of Australia. These poles fell in the Atlantic Ocean about 90 degrees away from the North American and European polar wander curves, again supporting continental drift. In this paper, he also compared climatically sensitive sediments to their paleolatitudes derived from paleomagnetism, and he showed that they agreed within each continent but were in conflict when intercontinental comparisons were made. In 1957 he published the first polar wander curve from Australia which demonstrated that polar wander alone could not account for the distribution of paleomagnetic poles. He tested the reconstruction of Gondwanaland proposed by A. DuToit; using paleomagnetic data, Ted demonstrated a reasonable agreement between Mesozoic poles from the southern continents. These papers essentially reopened the continental drift debate and opened the way for the emergence of plate tectonics.

During his stay in Australia, Ted made many technical contributions to paleomagnetism. One of his most important contributions was the recognition of the long period (50 million years) of reversed polarity in the late Carboniferous and Permian, a period he called the Kiaman reversed polarity interval. In 1964 he wrote the first and one of the best books on paleomagnetism, *Paleomagnetism and Its Application to Geological and Geophysical Problems.*

In 1964 Ted traveled to Canada, going first to Ottawa from 1964 to 1981 (except for a short stay in Leeds), then to the Pacific Geoscience Centre at Sidney, British Columbia. During this time he made many contributions, particularly with respect to the origin of magnetization of oceanic crust and the apparent polar wander curves for North America in the Paleozoic and Proterozoic. He remained actively engaged in trying to understand plate reconstructions and was the first to propose the Late Paleozoic "Pangea B" model based on paleomagnetic data.

Since moving to Vancouver Island, Ted has concerned himself with translation and rotation of terranes along the western margin of North America. He has championed the view that terranes have been moved thousands of kilometers, and with colleagues he has amassed a large amount of data that support this conclusion. Although nominally retired, he remains intellectually involved and continues to produce interesting and important science—for example, he has recently been involved in understanding Pleistocene glaciations of Canada as well as returning to Australia to help determine the age of the base of the Kiaman.

These important contributions to our understanding of the Earth have been widely recognized and have led to many honors. Ted is a fellow of the Royal Societies of London and Canada. He has received the Christien Mica Gondwanaland Medal, the Logan Medal of the GAC, the Bucher Medal of AGU, the Wilson Medal of the Canadian Geophysical Association, and the Alfred Wegener Medal from the EGU.

Response by EDWARD IRVING

Some years ago the Geological Society of America honored paleomagnetists by awarding the Day Medal to the late Alan Cox. Thank you for honoring them again. My thanks to Myrl Beck for nominating me and to others who lent support. Thanks to those people who gave me a start in research. Thanks to colleagues of many expeditions, many discussions, many tall stories. I am very grateful to institutions that have employed me and provided facilities. At a deeper emotional level, I also want to thank my parents, my sister, my wife Sheila, and our kids, for their good humor and love.

I would like now to say a few words about possible and impossible thoughts and about sitting on the fence. My remarks are directed especially to younger workers, because what I have to say derives mainly from my early experience.

Good scientists and normal adolescents think lots of impossible thoughts. Thoughts that are considered impossible or foolish by others. I recognized the importance of impossible thoughts in 1951, when, under the direction of the late Keith Runcorn, I began studying the magnetism of the Precambrian Torridonian Sandstone of Scotland. At his behest, I tried to observe the secular variation of the Precambrian geomagnetic field. His was an idea ages ahead of its time. Even today, it would be a herculean task, and, of course, I got nowhere. But it was not a waste of time, because it opened an Aladdin's cave of scientific treasures. So, I am grateful to Keith for his impossible thought.

In 1954 I went to Australia to measure its motion relative to Europe. Most people then believed that continental drift was impossible, and that ours was a fool's errand. But J. C. Jaeger of the Australian National University had faith and funds, and it worked out just fine.

More recently, paleomagnetists have measured displacements of several thousands of kilometers in the western Cordillera. "Impossible," the critics cry "bah to Baja BC." With breathtaking omniscience, the critics declare that they have not seen the big faults, and therefore no such motions have occurred. But we all spend much of our time gazing at things and not recognizing them for what they are. We all know that unseen things exist. If it were not so, there would be no purpose in taking observations, science would not exist, and the life of the imagination would wither away. So please join me in honoring impossible thoughts.

If success in science depends on a willingness to entertain impossible thoughts, it also, in my experience, depends on a judicious choice of possible thoughts—the thoughts that we allow ourselves to have. When addressing problems, we, intentionally or unintentionally, draw limits around them within which we seek solutions, and outside which we forbid our thoughts to trespass.

Expand limits too widely, and imagination reels out of control. If you are a too-wide-limit-drawer giving a lecture, your audience probably shuffles uncomfortably. Afterwards, no questions are asked for fear of prompting further indiscretions. Some listeners may even walk out.

By contrast, drawing limits too tightly squeezes out speculation. If you are a too-tight-limit-drawer giving a lecture, you describe a great deal of data, and you end with a plea for more data. Your lecture should be scheduled late on Friday afternoon to allow us the weekend to forget. Your notice should offer drinks afterwards to boost attendance.

If making appropriate choices of possible and impossible thoughts is the stock-in-trade of useful science, then, to my mind, fence-sitting is its antithesis. Fence-sitting is the sin of not deciding, the dithering sin.

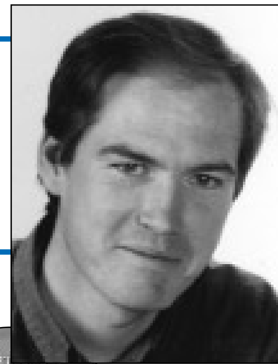
There are many degrees of fence-sitting. Moderate fence-sitters commonly suffer only mild neurosis. They may be observed wringing their hands as heterodox thoughts are put into words and uncontrolled happenings occur without their prior approval. But extreme fence-sitters are in real danger. Remember that this was ill-fated Hamlet's sin. Dante reserved a special place in Hell for those who linger too long on the fence. Should friends show fence-sitting tendencies, it is your solemn duty to warn them of the melancholy consequences.

The Society's award of the Day Medal to a paleomagnetist sends a renewed message of encouragement to our small, argumentative, and creative community. Let me, on their behalf, again say thank you.

YOUNG SCIENTIST AWARD (Donath Medal)

presented to

EDOUARD G. BARD



Citation by THURE CERLING

Edouard Bard has made many important contributions to the study of the Quaternary. It has been said that a scientist's greatest tool is imagination. This is illustrated in Edouard's contributions, which have been remarkable in their broad scope, and in his skills at getting "more from less."

His earliest work was on determining, using accelerator mass spectrometry, precise ^{14}C ages of foraminifera in deep-sea sediments. This work set the stage for studying the complex interactions between the coupled ocean–atmosphere-cryosphere system at the last deglaciation. It is now routine to use AMS in oceanographic studies, but it was not routine when he did them.

He went to Lamont as a postdoc and worked on comparing ^{14}C and U-Th ages of corals. This remarkable study has contributed to solving several very important problems. This work has made it possible to calibrate the ^{14}C age scale beyond the limit of tree-ring chronology to more than 30,000 years ago. It shows that ^{14}C ages are too young by 3000 years at 18,000 ^{14}C yr B.P. Determining the "offset" between ^{14}C ages and absolute ages solves many problems in Quaternary studies, ranging from the use of other cosmogenic isotopes to ice core studies. Further, this study leads to an understanding of sea-level variations at the end of the last glacial cycle.

After a few years at Lamont, Edouard moved to the University of Aix-Marseille, and he is currently at the Center for Geoscience and the Environment near Aix-en-Provence in southern France. He is working on using coupled gas chromatography–mass spectrometry to study alkenone biomarkers in deep-sea sediments, in order to determine paleotemperatures of seawater to compare to the sea surface temperature estimates of the CLIMAP Project.

He has not abandoned the problem of ^{14}C and other cosmogenic isotopes. Production rates of cosmogenic nuclides have varied considerably in the late Pleistocene and Holocene. The cosmogenic nuclides, including ^{3}He, ^{10}Be, and ^{26}Al, as well as ^{14}C, are finding wider uses in earth science problems. ^{14}C is modulated strongly by the solar wind and has the complication of being involved in the global CO_2 cycle, while other cosmogenic nuclides are not. In this field, too, he is making significant contributions.

The French scientist Louis Pasteur once said, "Where observation is concerned, chance favors only the prepared mind." Edouard Bard prepared his mind with an early fascination for archaeology, followed by the study of mathematics, engineering, and geochemistry at the University of Nancy and the University of Paris. This preparation, thorough attention to detail, a fertile imagination, and a lot of hard work have allowed Edouard to contribute to a wide diversity of problems.

Response by EDOUARD G. BARD

I feel extremely honored and pleased to receive the prestigious GSA Donath Medal and to be cited by Thure Cerling, a renowned expert on several aspects of isotope geochemistry. I warmly thank Wally Broecker for nominating me for this award and for his mentoring during the last 12 years, first indirectly through his literature and then by direct interaction when I worked at Lamont-Doherty Earth Observatory of Columbia University .

A scientific career is often a complex mixture of vocation, taken and missed opportunities, and accidental meetings with other scientists. Some of you may be curious to know my trajectory, and I will thus briefly describe my version of the story, also giving me the opportunity to thank individuals without whose help, patience, and advice I would not be standing here.

My love for geology started quite early, in fact as long as my memory can recall. This was probably the influence of my parents—my mother being a high school teacher in geography and history, and my father being a computer staff engineer in high-energy physics. Both cultivated my interest in mineralogy and paleontology over the years, and, as a teenager, I spent most of my vacations digging prehistoric sites and searching for minerals and fossils. At the end of high school it was time to make an important decision and choose a way for a real career. My parents disagreed on what I should do: my father's advice was to pursue geology at the university, while my mother, skeptical about this way of getting a job, recommended engineering sciences. I was faced with a big choice, which is rather common in France because there is a clear-cut separation between scientific studies at regular universities and in engineering schools, which are industry-oriented. Choosing the latter would mean that I would forget my dreams of mineralogy, paleontology, and archaeology and spend most of my time focusing on applied math, physics, or chemistry.

After some enquiry, I found a way to compromise, which was to gain the qualifications necessary to enter the only engineering school in France that includes the word *geology* in its title: Ecole Nationale de Géologie Appliquée et de Prospection Minière, in Nancy. I later realized that the school prepared one to work for oil and mining industries and in civil, hydrological, and chemical engineering, but this was the only way to reconcile my parents and satisfy my aspirations in the future. When I finally succeeded in entering the school at Nancy in 1982, the director told me that he had no problem having a student interested in fundamental geology. To convince me that I was not the first with this "problem" he cited the recent example of a fellow who was fond of fossil echinid systematics when he came to Nancy and is now working in the cement industry!

In the long run, I do not regret my choice, mainly because it exposed me to painstaking and rigorous tools in math, physics, and chemistry—tools that make possible true quantification of geological processes. Another advantage of the school at Nancy is its link with scientific laboratories, among them a geochemistry center (Centre de Recherches Pétrographiques et Géochimiques) in which several influential professors were doing their research (Francis Albarède, for example). As an undergraduate, I spent many days at CRPG to synthesize tourmaline and cordierite at high pressure and high temperature, under the supervision of Alain Weisbrod, who is partly responsible for my orientation in geochemistry.

At that time, during my summer vacations I became more and more involved in prehistoric excavations, and I decided that isotope geochronology would be the best way to keep one foot in geochemistry and the other in archaeology. In 1984, I spent some time digging at la Caune de l'Arago in the Pyrenees, an early Paleolithic site famous for the discovery of a skull and bones of one of the earliest Europeans. Henry de Lumley, chief scientist of the excavation, later introduced me to geochronologists working at the Centre des Faibles Radioactivités in Gif-sur-Yvette, and I joined the accelerator mass spectrometry (AMS) team and began to prepare a thesis using this technique for the measure of ^{14}C. From those Ph.D. years, I thank particularly Maurice Arnold, who taught me the basics of AMS and the painful way to become a careful analyst. The work assigned by my advisor, Jean-Claude Duplessy, was twofold: dating deep-sea sediments and using bomb-produced ^{14}C as a transient tracer in modern oceanography. With such a Ph.D. project dealing with Quaternary paleoclimates and the fate of CO_2 in the ocean, I inevitably came across the abundant literature of Wally Broecker, in particular his book, with Tsung-Hung Peng, *Tracers in the Sea.* Lamont was thus the center of my scientific world, and quite naturally I applied there for a postdoc fellowship. Today I appreciate better how competitive Lamont is and how lucky I was to be awarded the only postdoc for which I applied after getting my Ph.D.

My subsequent years at Lamont were very intense but friendly, as I interacted with a crowd of young scientists such as Dorothy Peteet, Delia Oppo, Maureen Raymo, Christina Ravelo, Julie Cole, Jonathan Overpeck, Chris Charles, and Pete deMenocal. I was very lucky to arrive at the time when Rick Fairbanks was planning his drilling offshore Barbados. My second stroke of luck was that there was no accelerator facility at Lamont, and thus I was compelled to find something else to do as lab work. At about that time, the Caltech isotope geochemistry team published their important papers on U-Th dating by mass spectrometry. This was precisely the same approach as AMS for ^{14}C: counting radioactive atoms directly before they decay. After some discussions, Rick, Wally, Alan Zindler, Bob Anderson, and Bruno Hamelin all agreed that this would make a good postdoc project, and that I could use a rather old Micromass 30 to implement the new technique and apply it to date Barbados corals with high precision. Minor isotopes of uranium and thorium are difficult to measure. I am particularly grateful to Bruno, who spent days teaching me how to separate and purify these elements, and how to analyze them with a thermal ionization mass spectrometer. Without his involvement in this collaboration, we would not have produced the numerous ages of fossil corals which allowed us to study past sea levels and to pursue the calibration of ^{14}C.

A significant part of the scientific community was very skeptical about the very large discrepancies between ^{14}C ages and U-Th ages that we reported. I remember my tormented nights before and just after the publications came out. Wally was not really aware of this, because he convinced me to organize a NATO workshop in Italy to gather the strongest opponents to what we had just reported. The week in Erice was devastating and at the end of the meeting I was no longer sure that U-Th ages were really valid. However, Wally's way of organizing confrontation workshops was truly efficient, because it forced the researchers to reassess critically their data on Greenland ice cores, varved sediments from lakes, and subfossil trees. This saved us from years of endless controversies.

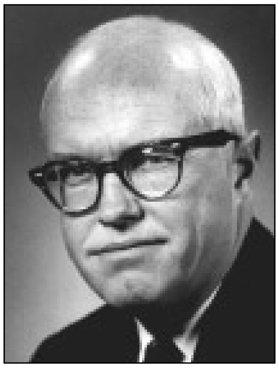
Back in France, Bruno, Daniel Nahon, and Annie Michard convinced me to help them build new geochemistry laboratories from scratch in a newly refurbished building located in the pine woods between Marseille and Aix-en-Provence. This has been a difficult experience, as it inevitably slowed down our research output, but it proved to be useful because we had no real limitations. For example, this project allowed me to get involved in applications of organic geochemistry in the field of paleoclimatology. For this most recent part of the story I thank my wife and colleague Frauke Rostek, who now spends most of her working time struggling with gas chromatographs. I also thank Frauke for the love and patience that allowed her to cope with my torments and anxiety.

DISTINGUISHED SERVICE AWARD

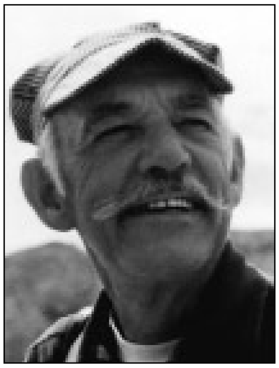
presented to

ROBERT L. FUCHS, RICHARD A. HOPPIN, FAITH E. ROGERS, BENNIE W. TROXEL


Fuchs


Hoppin


Rogers


Troxel

ROBERT L. FUCHS

Citation by Brian J. Skinner

(presented by George A. Thompson)

When Bob Fuchs agreed to become Treasurer in 1983, the finances of the Society were in a parlous state and stretched to the breaking point. It was a time of great changes, both in the science and in society as a whole, changes to which, as it soon became clear, the Society had to respond. In order to do so, fiscal stability was essential. Under Bob's careful direction a slow recovery to fiscal health was commenced, and the programs chosen by Council were started.

When the position of president of the GSA Foundation became vacant in 1987, Bob changed hats and assumed the position. Here, too, he faced a major financial challenge. The Society, through its Foundation, had been successful in raising money from major donors, mainly industrial, for the DNAG project. Under Bob's leadership the Society's first major comprehensive drive was started, a drive that has raised $8.5 million so far, with a year still to go. A fund-raising drive of the kind that the Foundation has been conducting for the Society is a new activity, both for GSA and for professional societies in general. We have blazed new trails under Bob's able direction, and we are proud of both Bob and the fine response the drive has elicited.

Bob's efforts have been standouts for both the present and the future health of the Society. He always kept a level head when hopes and desires exceeded resources, a steady hand on the tiller when major new programs consumed funds faster than anticipated, and an unfailingly cheerful and enthusiastic attitude on the fund-raising trail.

Bob, for your many years of hard work and financial good sense, I am proud to present you with the Distinguished Service Award for 1997.

Response by Robert L. Fuchs

The first Distinguished Service Award was presented in 1988. I have always felt that it was the brainchild of John Maxwell. When John and I were Trustees of the Foundation in the early 80s he said to me "we need an award for people who are not going to get scientific awards." I think that he may have been telling me that I was not on the fast track for the Penrose Medal, but I didn't realize it until tonight. Thanks to you, John, and to President Thompson, the Executive Committee, Council, and the Foundation Trustees and staff.

The history of GSA philanthropy began in 1931, with a very important gift of $3.9 million from R. A. F. Penrose, Jr. In 1981 the Foundation was formed, and since then additional gifts totaling $14.5 million have been received, enabling the Society to undertake major new programs in science, education, and outreach.

I would like to accept this award on behalf of the many who have participated in GSA's philanthropy: R. A. F. Penrose, Joe Pardee, John Mann, Storrs Cole, Phil LaMoreaux, Roy Shlemon, and about 3,000 other members, companies, institutions, and friends. They have made possible what, for me, has been a wonderful and personally satisfying opportunity extending over 23 years, and I thank them all.

RICHARD A. HOPPIN
Citation by George A. Thompson

Richard Hoppin is well deserving of the GSA Distinguished Service Award for serving as Books Science Editor and member of the Committee on Publications from 1989 to 1995. At the request of former Executive Director Michael Wahl, he even cheerfully agreed to stay on an extra year past his two three-year terms.

During his tenure, Dick skillfully shepherded hundreds of manuscripts through the review, revision, and acceptance stages, resulting in the publication of at least 60 Special Papers and 14 Memoirs. He was also adept at tactfully turning down those manuscripts deemed unsuitable—not an easy task. His conscientiousness and dedication kept up the tradition of high standards that have come to be expected of GSA's book series. His efforts toward this end are greatly appreciated. Dick, it is my privilege and pleasure to present the Distinguished Service Award to you.

Response by Richard A. Hoppin

Thank you, George. It has been my privilege to serve as books editor. The success of GSA book publications really depends on the fine efforts of many persons: the editors of the symposium volumes who so skillfully brought their books to completion; the authors who worked and reworked their papers into excellent final form; the reviewers who provided very helpful comments and were willing to accept this important role; the headquarters staff who put it all together into the final superb volumes. My role was to serve as the facilitator, or shepherd, as George noted. The increasing number of proposals attests to the success of the role of the GSA books series in providing a quality outlet for research publication. I am pleased to have had a role in these efforts.

FAITH E. ROGERS
Citation by George A. Thompson

Faith Rogers has dedicated herself to the enterprise of the journal *Geology* for more than two decades. The high quality of this technical geoscience journal is the most telling testimonial of her commitment, diligence, experience, creativity, and wisdom as managing editor. Faith has been instrumental in the exceptional quality, high standards, and excellent international reputation of the journal. She has worked on broader issues such as GSA's editorial policy and guidelines, computerized manuscript tracking systems, and electronic publication, just to name a few. For the past 13 years, Faith has also overseen editorial functions for all GSA publications, including *Geology,* the *Bulletin, GSA Today,* and the GSA book series.

Those who have worked with Faith know her commitment to excellence. I am pleased to acknowledge her efforts by presenting to her this Distinguished Service Award.

Response by Faith E. Rogers

I have had the privilege of working with many talented and dedicated people during my years at GSA, starting with Bennie Troxel, who was the in-house science editor when I first walked through the front doors at headquarters. Through all the editors who volunteered for the arduous task of evaluating the papers submitted to GSA publications, through all the changes GSA and publishing have weathered, it has been a challenging 25 years.

You are among those who give of their time and expertise to assure that GSA publishes high-quality science. We who work in the Editorial Department at headquarters have the privilege of helping you in your efforts as authors, reviewers, and editors. Your energy and dedication impress us, and we take pride in the opportunity to help you with that paper, whether it's a masterful synthesis or a hot new discovery. If as an author you find us annoying in our insistence on straightforward and consistent writing and illustrations, please note that our blue editing pencils have erasers. We aim to please.

The electronic publishing revolution is full upon us all, and it's changing the way scientific studies are disseminated, but some things will not change: GSA will continue to publish excellent science, presented well.

It's a pleasure to work with you. On behalf of myself and the rest of the GSA editorial staff, I thank you for that opportunity, and for this recognition of our efforts.

BENNIE W. TROXEL
Citation by Terry L. Pavlis
(presented by George A. Thompson)

It is a tremendous privilege to present this citation for Bennie Troxel. Bennie could not make it to the meeting, and those of us who know Bennie can tell you that that is really unfortunate because it would have been a great pleasure to see his beaming smile as he was presented with the award.

This distinguished service award is, in my view, something that is very overdue; nonetheless, the timing is good because this year marks the 25th anniversary of *Geology* (the magazine, not the science!). If it were not for Bennie, this premier journal of the earth sciences would not exist. It was through his efforts during his tenure as GSA editor in the early 1970s that the idea for *Geology* was formulated and implemented. I think surprisingly few people are aware of that. For that contribution alone Bennie deserves recognition by the Society, but there are many other things that are far too numerous to mention in this brief statement. He's made major contributions to the science, much of it through his famous collaborative works with Lauren Wright on the geology of the Death Valley region; those contributions are well known. What makes Bennie stand out for this award is the way he has inspired generations of geologists—both students and professionals—with his love for geology in general and field geology in particular. I've heard him described as a geologic guru and the Yoda of geology, and I think that pretty well summarizes his impact on people. His love for life and the way it spills over into his science is truly infectious. So as you go out this evening to dinner, raise a toast to Bennie and use the words to describe him that I've seen him use so many times to describe someone else "Ja, he's a really neat guy."

Response by Bennie W. Troxel

I am truly grateful to Terry Pavlis for his very kind remarks and am pleased to be selected as a recipient of the Distinguished Service Award of the Geological Society of America. Had I been at the presentation during the annual meeting, as Terry said, I would have had a beaming smile on my face.

A bit of history regarding *Geology* (the magazine, that is). The idea for such a magazine was conceived during a meeting in the early 1960s of the GSA Committee on Publications, when I was a member of the committee. We recommended, to no avail, that such a magazine be initiated by the Society. Soon after I became science editor for GSA several years later, the idea for the magazine was resubmitted to the Council with the enthusiastic support of Executive Secretary Ed Eckel, the Publications Committee, and myself. The rest is history. I was editor of only the first issue. Henry Spall deserves full credit for making *Geology* a success. He became editor of the magazine after the first issue. My job as science editor was made very easy becaouse GSA had such a capable staff in the Editorial Department.

My enthusiasm for geology is real, and I continue an active interest at the age of 77. I truly enjoy sharing my knowledge of some geologic problems in the Death Valley region by participating in or leading several field trips each year. As most of my geologic acquaintances know, my career in Death Valley geology was initiated by Lauren A. Wright. I am deeply grateful to him for his guidance and companionship for more than 45 years.
Thank you.

RIP RAPP ARCHAEOLOGICAL GEOLOGY AWARD
presented to
TJEERD H. VAN ANDEL

Citation by CURTIS RUNNELS
(presented by Kevin O. Pope)

It is a great pleasure to introduce Professor Tjeerd H. van Andel for the presentation of the Rip Rapp Archaeological Geology Award. In the course of a distinguished career, Tjeerd van Andel made significant contributions in geophysics, sedimentology, and oceanography, before he shifted his attention to archaeological geology. He has enriched the understanding of both earth scientists and archaeologists and has advanced the study of geology and human behavior in its broadest sense. Tjeerd has published some 200 papers and books in earth science and archaeology and has many publications in press or in preparation, including major works on the Paleolithic of Greece and a study of European paleoenvironment in Oxygen Isotope Stage 3 (currently supported by a Leverhulme grant). While it is difficult to summarize his many achievements, those related to geoarchaeology can be summarized under the following heads. His most important contribution to geoarchaeology has been the study of changes in sea level and their effects, both short and long term, on human settlement and land use, and his sophisticated approach to the study of the co-evolution of humans and their physical environment. Another major contribution has been a new and exciting analysis of the timing and intensity of soil erosion in connection with human land use. His investigation of the anthropogenic origin of ancient soil erosion has been the focus of discussion among geologists and archaeologists around the world and has influenced an entire generation of archaeologists. It is safe to say that he is one of the leading figures in the field of geoarchaeology, with a major role in the shaping of the discipline.

These achievements must be viewed within the wider framework of large-scale geologic processes and their impact on the study of the human past, and the explication of such processes to a large audience. His book *New Views on an Old Planet,* intended for general readers, was first published by Cambridge University Press in 1985 and is now in three editions and five translations. In addition to numerous public lectures, Tjeerd was also a contributor of thoughtful and thought-provoking essays in *Terra Nova,* a testimony to his commitment to making the results of new earth science research available to all.

His long-term impact on the study of Quaternary history and human behavior can be measured at two levels, one at the level of specific case studies and the other at the general level of the discipline as a whole. Although most of his field work has been in collaboration with archaeologists working in western Europe and the Mediterranean, he has also done research on important sites in South Africa, Peru, and Honduras.

Tjeerd, like many recipients of awards in this division, did not set out to be a geoarchaeologist (although undergraduate study of archaeology in his native Holland whetted his appetite for the subject), but devoted what would be for most people the most productive years of his career to earth science. His long and varied career extends over a period of 40 years and around the globe, and includes many important contributions to geophysics, oceanography, and sedimentology, a summary of which would take us far from the present subject. His career in earth science took him, after taking his Ph.D. from Groningen University in Holland, to a stint with Shell Oil working in South America, Africa, and Indonesia, then to Scripps in La Jolla and to Oregon State University before going to Stanford University, where he is the Wayne Loel Professor of Earth Sciences (Emeritus), and, currently, the University of Cambridge in England where he is Honorary Professor of Earth History, Quaternary Sciences, and Geo-Archaeology in the Departments of Earth Sciences and Archaeology.

His active involvement in the interdisciplinary study of geoarchaeology began in 1978 when he met Michael Jameson (Stanford University) and joined him as the co-director of Stanford University's Archaeological and Environmental Survey of the Southern Argolid, Greece. From that project he went on to work with other colleagues and a number of his students in almost every part of Greece, and his new career as a geoarchaeologist, now just 20 years old, has resulted in the publication of 30 papers and three books, with more on the way. Although his research has been chiefly connected with the Mediterranean, his geological and paleoenvironmental research has been used by archaeologists farther afield—e.g., his work on the Sahul Shelf in Australia, which is significant for the understanding of early human migration to Australia; his study of the environmental setting of the Klasies River site in southern Africa, which raises important issues in connection with the emergence of early modern humans; and his recent work with Tzedakis and Mellars on the environmental background for the European Neanderthals, which demonstrates the importance of fine-grained reconstructions of environmental conditions as a prerequisite for the study of Neanderthal adaptations and the origins of early modern humans.

Tjeerd's contributions have been so varied it is difficult to choose the most important, but many would single out his investigation of sea-level change and its effect on Mediterranean civilizations. His emphasis on the loss of key habitats for prehistoric cultures when the continental shelf of the Mediterranean was flooded has been of major significance. Likewise, his approach to reconstructing paleoenvironments and paleoshorelines has become a standard in the field, and his study of human impacts on Mediterranean valleys, particularly soil erosion triggered by uncontrolled vegetation clearance from hillslopes, is equally influential. Much of Tjeerd's research in Greece has been carried out in the context of training a select group of outstanding graduate students (e.g., Anne Demitrack, Kevin Pope, and Eberhard Zangger), which means that his impact on the field of geo-archaeology goes beyond the limits of his publications.

Professor van Andel has worked throughout his long career to promote an increasing awareness of interdisciplinary studies, particularly the study of Quaternary geology and geoarchaeology, a role that he continues to play as the chairman of the management board of the Godwin Institute of Quaternary Research at Cambridge. His public and professional service, as seen, for instance, in his many public lectures and long service as an editor or member of editorial advisory boards for conferences and journals, and as an organizer of conferences (e.g., the Godwin International Conference on Climate and Landscapes of Oxygen Isotope Stage Three, in July 1996) are the hallmarks of a distinguished career that is far from over.

Response by TJEERD H. VAN ANDEL

Awards and medals are rare, high ceremonies in the lives of geologists. To cynical recipients they confirm that they are no longer a threat to their colleagues, or so they say. To others they bring money to pay off the mortgage or to buy antiques; for obvious reasons these happy types are not common among those who practice geology on behalf of archaeologists. To most, like me, they are the expression of the respect and the many warm friendships that have enriched our lives. It is in this last spirit that I thank you all; there is little that could be more important to me.

As the citation notes, the award in this case does not honor a life-long career, it marks the point where my life has come full circle. It all began some 65 years ago when, as a small boy growing up in what were then the Dutch East Indies, I was taken by my parents to see the ruins of Hindu empires that flourished there in the first and early second millennia A.D. Sometimes painstakingly restored in their full grandeur, more often mere broken shapes in the jungle, they seemed to me irresistibly romantic, and long after our return to Holland my desire to become an archaeologist and work in Indonesia remained strong. Thus, when I entered university in 1940, I set out to major in archaeology as one among four students of the late great Dutch prehistorian A. E. van Giffen, an early pioneer of biological archaeology. Although the university was soon closed down under German occupation, van Giffen set us to tasks that ranged from Roman excavations to seriating pots, from identifying domestic animal bones from Iron Age marsh settlements to pollen analysis, a diverse training in embryonic science-based archaeology that, as you will see, bore fruit some 35 years later.

When the war ended and the matter of degrees came up, however, those skills suddenly seemed less useful, as few of our seniors appeared ready to abandon their posts by death or retirement on our behalf. Thus, hoping to turn the study of the Quaternary into a back entry into archaeology, I changed my major to geology, notwithstanding the dark hues in which my professor, the late Philip Kuenen, painted a geologist's life. Eventually, Ph.D. in hand, this first major diversion from my intended course packed me off to South America as a Shell Oil sedimentologist.

Sheer luck for me and illness for Professor Kuenen made me the rather ill-prepared leader of one of the earliest expeditions to study modern marine sedimentation. Publication of the results, generously arranged by Kuenen, led to my second major detour when I accepted an offer from Scripps Institution of Oceanography in California to take charge of an American Petroleum Institute project on marine sediments of the Gulf of Mexico and the Sea of Cortez. Several years dedicated to continental margin studies passed, until the Woods Hole Oceanographic Institution research vessel that was to carry me to the margin of northeastern South America first spent several weeks measuring currents in the central Atlantic Ocean. Having little else to do, I watched with fascination images of the Mid-Atlantic Ridge grow on echosounder records as we crossed and recrossed this then still mysterious feature. The die was cast, and in the next few years I turned increasingly to the study of mid-ocean ridge plate boundaries, with perfect timing because of the plate tectonic revolution.

It is not easy to switch from sedimentology into geophysics for a person as poorly equipped with mathematics as I am, but a strong geological background turned out to be very useful in the study of the tectonics and volcanology of mid-ocean ridges.

During that same period, the four major oceanographic institutions conceived the Deep-Sea Drilling Project that continues to overhaul so many concepts, methods, and conclusions of Earth history. Representing Scripps on the planning committee, I was exposed for four years to a truly fascinating mix of organization, science politics, ship design, and project management techniques. The downside was an undesirable impact on my publication rate that did not go unnoticed by those at the University of California who must promote or not promote their competitors on the faculty. And so, looking for a friendlier environment, I went to Oregon State University to help build a new school of ocean science there which soon achieved considerable status. The focus of my own group there was the field of paleoceanography, supported largely by data of the Deep Sea Drilling Project, a fitting reward for the time and effort spent on its development.

The years at Oregon brought much involvement in international ocean sciences and ocean science management. This is the proper moment to mention with deepest gratitude my two close friends and mentors in ocean science politics, both deceased far too early, Chuck Drake and Allen Cox. During this interval, while helping the National Science Foundation to get the International Decade of Ocean Exploration on stream, I had the opportunity to inspire and fund the CLIMAP project, which then produced a revolution in Quaternary science from which, with all of you, I later benefited greatly in my archaeological enterprises. At the same time, I and two others introduced the now common practice of funding multi-institutional research projects on a grand scale; from time to time I wonder whether that was as good an idea as it seemed then. All in all it was an exciting time, and I learned a great deal.

An unexpected dividend of my entry into the field of geophysics and of the skills acquired in developing and managing tricky programs came in the early 1970s in the form of the FAMOUS project, which allowed me to participate in the first geological field mapping of the crest of the Mid-Atlantic Ridge, with the deep research submersible *Alvin.* A few years later it also brought me to Stanford as professor of ocean sciences. Perhaps best of all, the *Alvin* experience inspired me to plan, together with Dick von Herzen of Woods Hole, the *Alvin* expedition that enabled me, on the 17th of February 1977, at 11 in the morning, to be first to see the now so famous deep-sea hotsprings. Few scientists can identify the peak of their careers with such precision.

You may well ask whether we shall ever get back to archaeology, but be patient, I am almost there. In 1976, I came to Stanford and earned for the very first time my whole salary in hard money, a gratifying experience, although I admit that during the many soft-money years I never really worried about where the wherewithal for myself and my team would come from. This may seem innocent to the point of naivete to those who nowadays must struggle in a very insecure world, but it was the same happy-go-lucky self-confidence that supported the many high-tech inventors who gave us Silicon Valley, e-mail, the World Wide Web, and so many other mixed blessings. Stanford brought new experiences, my favored one being the teaching of geology to undergraduates as part of their general education. Teaching has greatly enriched my life and made me the generalist in earth sciences I had long wished to be. On the debit side, being at Stanford accelerated my withdrawal from blue-water oceanography as working on ships and the sailor's life became progressively more incompatible with an orderly academic existence. In truth, I miss the sea-going life a great deal and sometimes wonder whether love of the sea and ships made me an oceanographer more than the science of the ocean itself.

Another chance encounter, another 90° turn, and here we are at last, confronting the human past. At Stanford I met Michael Jameson, a classical archaeologist happily unconcerned about the difference between a geologist and an oceanographer. Jameson, seeing that I was somewhat at loose ends in research, persuaded me to join a diachronic archaeological survey in Greece. At that point a number of experiences emerged from the past: van Giffen's training, early familiarity with Quaternary geology and palynology, lab skills from sedimentology days, and an interest in sea-level changes that went back to work with Francis Shepard and K. O. Emery. There was also, not unnoticed by my archaeological partners, a long, successful experience in raising money. It was Jameson who gave me the opportunity to devote the last two decades and possibly my remaining active years to the blending of archaeology and geology that helps us better understand the remote human past.

Curtis Runnels's handsome citation is an excellent account of what followed, but I cannot resist recalling here that my move from Stanford to Cambridge University in 1988 terminated a promising career in the Division of Archaeological Geology at the level of vice-president.

Teaching and research have always been inseparable for me, neither capable of reaching its peak without the other, and before I get to the peroration, an important obligation must be discharged. Without my graduate students and postdocs the life I have just described to you would have been much diminished in quality, diversity, and above all in enjoyment. I cannot name them all, but for the work of the last two decades I owe a great deal to my former Ph.D. students Kevin Pope, Lisa Wells, and Eberhard Zangger.

I do not wish to speak here about what I may have contributed to archaeology; you are the better judges. My interest remains, as it began, focused on the co-evolution of landscapes and human conditions. A short dozen projects, some 40 papers and three books later, the question of what I personally learned from it is more to the point. What has life taught me in those 65 years since, as a little boy on a pony admiring Hindu temple ruins, I first became enamored of the human past?

Above all, it has convinced me that the key to fruitful interaction between archaeologists and geologists is summarized in only two words: interdisciplinary and collaboration. These words define a joint effort by equals that begins at conception and ends with publication, and that is wholly different from the far more common multidisciplinary mode, which yields archaeological reports trailed at a distance by scientific appendices not or hardly discussed in the body of the work.

What permits the change from multidisciplinary to interdisciplinary research? A carefully prepared set of agreed-upon common goals goes a long way, but that way can be arduous, because neither do we, as scientists, a priori know how we may best serve archaeology nor do many archaeologists perceive clearly enough what we might do for them. There are problems here of communication and of language, of enough and proper advance preparation, and above all of openness and mutual respect. Nothing new here, you may say, because little is more interdisciplinary than the study of the Quaternary. But if that is so, why do we students of the earth, surely altogether also a very interdisciplinary subject, insist on calling ourselves geophysicists (who are not geologists, oh no!) or geochemists (who find communication with paleontologists far from easy) or so many other specialist names? Will not those deliberately erected barriers in the end yield vast mounds of data heaped at the borders between subdisciplines, data that would be so wonderfully informative if we only knew they existed and how to use them? Is perhaps the science of the earth far too often also a multidisciplinary enterprise?

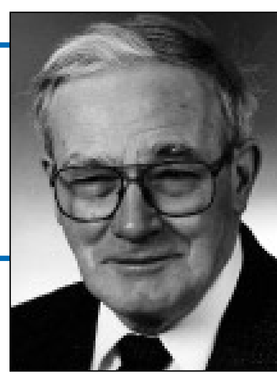
Universities are not comfortable with the idea that the boundaries between disciplines are artificial and find it hard to show their students that those boundaries might be bad for their academic health. Yet it is with the young, with graduate students, research fellows, and the junior faculty, that the hope lies for an interdisciplinary culture where the questions we ask rather than the titles of our degrees guide our research.

How do we create this interdisciplinary community that is not just our best but probably our only hope for a vital, vigorous future for archaeology and geology both? I have no ready answer, but yet one more turn in the path of my life has given me the opportunity to at least face this question, if on a very small scale. The Godwin Institute of Quaternary Science of Cambridge University, the management board of which I chair, has no money, no space, no staff, and no equipment, but sponsored by five departments, it offers a forum where members of all disciplines involved in the study of the last two million years of Earth history can meet if they wish. To make them do so is the challenge, and so far it seems that this ethereal enterprise may well be successful if it focuses on the coming rather than on the past generation.

So here we are after what was, you will agree, a journey full of unexpected detours, none of which I regret. What I do regret is that I cannot attend this ceremony in person to see old friends again and make new ones, but personal economic realities got in the way. Please forgive me and accept my warmest thanks for the honor you have bestowed on me.

GILBERT H. CADY AWARD
presented to

ALEXANDER RANKIN CAMERON



Citation by THOMAS D. DEMCHUK

Few people have had a broader impact on the understanding and nature of Canadian coals than Alexander R. Cameron. Whether it be coal petrography, geochemistry, coalbed methane, influence of depositional environment, or maturation, Dr. Cameron has investigated that aspect of coal, wherever there is coal to be found in Canada. Scientist, mentor or supervisor, he has left his mark on Canadian coal geology, and coal geology in general.

Dr. Cameron's early research involved the petrographic characterization of the Harbour coal seam in the Sydney Coalfield of Nova Scotia. Later works involved the petrographic investigations of various western Canadian coals from the plains and mountain regions, which stemmed from his move to Calgary as part of the newly formed coal geology group at the Geological Survey of Canada in that city. He served as head of the Coal Technology Section at the GSC for numerous years, utilizing his skills as an administrator and mentor, guiding the direction of research within that organization. Under his early leadership, the Coal Technology Group at the GSC in Calgary quickly became one of the world's outstanding coal research organizations, an honor that it can still boast today.

As a visiting professor, Dr. Cameron has passed on his vast knowledge of coal geology to students at Pennsylvania State University, Southern Illinois University, and University of

Newcastle. Although not directly affiliated, many students at the University of Calgary, University of Regina, and University of British Columbia also have benefited from his guidance and wisdom. For that, some of us will be eternally grateful. He has also lent his experience to various organizations, including serving as chair of this very GSA Division in 1978–1979, guiding field trips, and serving on editorial boards. He has been awarded the Reinhardt Theissen Medal from the International Committee for Coal Petrology (1992), and has been recognized in symposium fashion at the Geological Association of Canada Annual Meeting in Wolfville, Nova Scotia, in 1992, a symposium that led to a special issue of the International Journal of Coal Geology honoring his outstanding contributions to Canadian coal geology.

Those of us who have had the distinct pleasure of working beside Dr. Cameron, will attest to his patience and his ability to convey ideas and thoughts for all to understand. His unfailing dedication to his science and his list of accomplishments in Canadian coal geology will serve as a benchmark for future coal geologists to strive for. Dr. Cameron is a well-deserved recipient of the Gilbert H. Cady Award, the true embodiment of its spirit.

Response by ALEXANDER RANKIN CAMERON

I am deeply appreciative of the signal honor conferred on me by the Cady Award selection committee of the GSA Coal Division. It's all a bit daunting to find oneself elevated into the distinguished company of previous Cady Award recipients. It makes me very conscious of the large footprints surrounding the podium on which I stand.

It all started for me on a bright, sunny morning in June 1952, when with my brand new B.Sc. degree under my arm, I walked into the coal research laboratory of the Geological Survey of Canada, located at this time in Sydney, Nova Scotia. A few months before, I had been accepted by the graduate school of The Pennsylvania State University to participate in a coal research program. At the time I knew virtually nothing about coal, so it was a fortunate break for me to get a summer job in coal with the Geological Survey, thus enabling me to get some introductory experience in this area of research. The first person I met that June morning was Peter Hacquebard, the principal coal petrologist in the Sydney lab, and a man with whom I would work and who would be my supervisor for much of the next 25 years.

As it happened, within a few weeks of that first June morning, I was to meet two more of the giants in coal research. The first of these was Dr. Gilbert Cady, no less. He arrived quite unannounced one morning, the primary reason for his visit to Nova Scotia being to attend the Second Crystal Cliffs Conference on Coal, which was held in the latter part of June 1952. Dr. Cady also wanted to renew acquaintance with Peter Hacquebard, who had visited the facilities at the Illinois Survey the previous year. I remember at the time being impressed with Doc Cady's sprightly manner and energy, somewhat remarkable given the fact that he was already retired, and probably close to, if not already in, his early 70s.

The third person of stature I would soon meet was Dr. Bill Spackman, as he also visited our lab that summer. Dr. Spackman would have a profound impact on my career; he became my graduate advisor at Penn State and directed my masters and Ph.D. studies. He was also instrumental in making 1952 a most significant year for coal research at Penn State and for coal research in general. In 1952 U.S. Steel funded a research project at Penn State to study the relationship between coal composition, as determined microscopally, and coke properties. I believe this was the first such project launched in the United States. At the end of the first year of this project, the results were encouraging enough for U.S. Steel to renew the funding; other coal and steel companies joined the bandwagon and the rest, as they say, is history. Soon U.S. Steel and then Bethlehem Steel established their own petrology laboratories, refined the petrographic techniques of describing coal, incorporated reflectance measurements as part of the analyses and in the process made microscopic petrography of coal part of their quality control routine. Petrography had moved out of the groves of Academe and into the world of industrial application. Petrography had come of age.

The effusion of industrial grant money to Penn State had an important spin-off effect. There are dozens of former students, many of us retired, scattered across the continent, indeed across the world, who owe some or all of their support during graduate school to Bill Spackman's tireless efforts, promoting coal microscopy and attracting grant money. In all of the students with whom he was associated, he instilled a respect for excellence and scientific integrity. We thought of ourselves as a team; we shared a camaraderie that was quite heady.

Time moved on and eventually Spackman's team, or at least the version of it with which I am familiar, moved on to other places. I moved on to another team, that of the Geological Survey of Canada Coal Research Section, led by Peter Hacquebard. I joined it permanently in January 1960, in Ottawa (the laboratory had been moved from Sydney in the late 1950s). With the exception of about three years total, a large part of it spent teaching at Southern Illinois University, I have spent all my career from 1960 to retirement with the Geological Survey.

In my time at the Survey, I have seen several peaks and valleys in the activities of the coal group. This pattern has been more or less a faithful reflection of nationwide waxing and waning of interest in coal. For example, in the 1960s interest in coal was low and funding was limited, though we managed to retain our personnel and to continue with our studies of the petrography of Canadian coals and its relation to environments of deposition and to utilization. In marked contrast, the 1970s saw an almost frenzied increase in coal exploration in Canada as the perception took hold that coal might be our security blanket of last resort in an energy crisis. In the Geological Survey the Coal Subdivision was given increased personnel and funding to fill in some of the thin areas in our knowledge about Canada's coal basins. Much has been done in this regard, and though the coal program is presently in a downsizing mode, there are four viable projects in place, yielding exciting results in such areas as coal basin modeling (managed by Dave Hughes), coal bed methane (directed by Mike Dawson), mineral matter and trace elements (studied by Fariborz Goodarzi), and maturation and hydrocarbon source potential of disseminated organic matter (conducted by Lavern Stasiuk).

My career in coal has taken me to most of the coalfields of Canada and the United States. In doing this, I have learned to appreciate the grandeur and diversity of that part of North America occupied by our two countries. In my work I have met probably hundreds of people in the coal mining industry, from company executives to the miner at the face. Remarkably, I cannot recall a single instance in which I was denied the fullest cooperation and assistance. It has been a privilege to have worked for, studied under, and associated with scientists of world repute. A priceless by-product of it all has been the many steadfast friends I've made along the way.

In closing, there are two other people who should be mentioned whose impact on my career has been enormous. The first of these is my dad, a quiet man, who just once insisted that I conform to his wishes. He made me go back to school after I had dropped out at age 15, fully intending not to go back. Needless to say, I'm glad his view prevailed. The other person is my wife, Cathy, a Pennsylvania girl, who, like Ruth in the Old Testament, went where I went, from State College to Ottawa in the dead of winter, from Ottawa to Calgary, when that move occurred in 1973. In the summers when I was in the field she managed to preserve the integrity of the household and her own sanity looking after five rambunctious kids. It's very fitting that she share this moment with me, and that I publicly say, "Thank you." And finally, one last time to the Coal Geology Division of the GSA, let me say, "Thank you." You have made this day for me a red letter occasion, a unique experience. I shall treasure the memory always.

E. B. BURWELL, JR., AWARD

presented to

ROBERT L. SCHUSTER and A. KEITH F. TURNER

Schuster

Turner

Citation by SCOTT F. BURNS

It gives me great pleasure to present the 30th Burwell Award this year to the editors of one of the best selling books in the field of engineering geology, Transportation Research Board Special Publication 247, *Landslides: Investigation and Mitigation,* which was published in 1996. Not only did the two editors, Keith Turner and Robert Schuster, work for over six years developing and coordinating this book, but they both wrote at least three articles apiece for it. This book has become the "bible" for landslide studies worldwide, replacing its predecessor, TRB Report 176, *Landslides: Analysis and Control* which was edited by Schuster and Krizek. This new volume has taken on an international scope and has expanded to 25 chapters with 30 authors. This publication, which is now into its second printing, is very deserving of this award, which is given annually to the paper or book of distinction that advances knowledge concerning principles of the practice of engineering geology.

Keith Turner is a professor of geological engineering at Colorado School of Mines. He received a B.Sc. in geology from Queens University in Canada in 1963, an M.S. degree in geology from Columbia University in 1964, and a Ph.D. in civil engineering from Purdue University in 1969. After receiving his doctorate he became an assistant professor at the University of Toronto before becoming a practicing geological engineer in Canada. He came to Colorado School of Mines 25 years ago and is now a full professor. His specialties revolve around computer applications to geology and environmental studies. He has employed three-dimensional analysis using GIS to characterize Yucca Mountain in Nevada. In 1988 he sponsored a national workshop in three-dimensional GIS modeling, with special attention to hydrogeology modeling. He has been a consultant to the United Nations along with national, academic, and private firms in the United Kingdom, Poland, Germany, Mexico, and South Africa. He has been active with the Transportation Research Board for the past 29 years, serving as chair of the A2LO1, A2LO5, and A2T61 committees.

In 1995, Robert Schuster retired from the United States Geological Survey after 21 years as branch chief of the engineering geology branch, followed by his assignment to the landslide branch. Bob received his B.S. degree in geology from Washington State University in 1950, his M.S. degree in geology from Ohio State in 1952, M.S. and Ph.D. degrees from Purdue University in 1958 and 1960, respectively, and another M.S. degree in soil mechanics from Imperial College in 1965. He was a professor of civil engineering at the University of Colorado in Boulder from 1960 to 1967. He then took the job as chair of the civil engineering department of the University of Idaho for seven years. He left academia for the USGS in 1974. At the national level, he has been the chair of the Geotechnical Engineering division of ASCE and the chair of the Engineering Geology Division of GSA. His vita lists more than two pages of awards from his illustrious career, many of them being related to his landslide work. In 1989 he was the Richard Jahns distinguished lecturer for GSA and AEG. Other awards that he has received are: the Distinguished Practice Award from the Engineering Geology Division of GSA in 1990, the Distinguished Service Award from the Department of the Interior in 1991, life membership in ASCE in 1992, and honorary membership in AEG in 1994. He too has been active in the Transportation Research Board, as chair of the A2LO1 and A2LO5 and vice chair of A2T61.

I congratulate Dr. Turner and Dr. Schuster for a job well done and present to them the 30th Annual Burwell Award for their excellent book.

Response by ROBERT L. SCHUSTER

The Engineering Geology Division of the Geological Society of America has greatly honored Professor A. Keith Turner and me by conferring on us the 1997 E. B. Burwell, Jr., Award as co-editors of the National Research Council volume, Transportation Research Board (TRB) Special Report 247, *Landslides—Investigation and Mitigation,* a title of considerable topical interest to engineering geologists and geotechnical engineers. This book is the third in a distinguished TRB series on landslide processes, investigation, management, monitoring, and remediation. The previous two volumes were TRB Special Report 29, *Landslides and Engineering Practice* (the late E. B. Eckel, editor), 1958, and TRB Special Report 176, *Landslides—Analysis and Control* (R. L. Schuster and R. J. Krizek, editors), 1978. All three volumes have received recognition from landslide researchers and practitioners throughout the world. During the approximately 40 year period between publication of Special Report 29 and Special Report 247, understanding of science and engineering as related to slope stability and landslides, as well as the amount of published information on these and related topics, has increased nearly exponentially. Thus, TRB Special Report 247 necessarily is considerably longer and technically more detailed, and includes a greater amount of subject material, than its predecessors.

Keith Turner and I spent nearly five years in planning, organizing, and editing this book. In addition, between us we authored or co-authored seven chapters. Our efforts were made easier by the fact that Keith's Colorado School of Mines office is only two blocks from my U.S. Geological Survey office. In addition, we share a common approach to use of the English language, which led us to relatively effortless agreement in review of the text. (I might note that both Keith and I did much of our graduate work at Purdue University, albeit in different decades.) However, we were far from alone in this lengthy and strenuous endeavor. Much of the planning and organization of the volume were carried out by our co-members of the 11-person TRB Study Committee on Landslides: Analysis and Control, chaired by Keith. The book was actually written by a total of 29 distinguished authors from American and international universities, research institutions, governmental agencies, and geotechnical consultancies.

I owe much to the previous recipients of the Burwell Award, particularly such distinguished researchers, teachers, and practitioners as D. J. Varnes, E. B. Eckel, E. Hoek, and G. A. Kiersch. Noting, and attempting to emulate, the careers, publications, and personalities of these world-renowned awardees, all of whom I have greatly admired and many of whom have been close acquaintances of mine, has done much to provide me with the inspiration necessary to work toward an honor as prestigious as the Burwell Award. I also would like to note that the following nine professional U.S. Geological Survey colleagues of mine have been past recipients of the Burwell Award: Glenn R. Scott, David J. Varnes (twice), the late Edwin B. Eckel, Peter W. Lipman, Donal R. Mullineaux, Joseph I. Ziony, Richard M. Iverson, and Jon J. Major. I'm truly proud of this distinguished roster, and I thank them for their help, advice, and inspiration through the years. In addition, I thank my many other USGS colleagues who have cooperated on and reviewed my research for the past 25 years. Undoubtedly, some of them will be future Burwell Award recipients. As I write this, I have now been "officially retired" from the USGS for two years; however, I still maintain close contact with these and other USGS scientists in my current and continuing volunteer role as a USGS Scientist Emeritus.

I also thank several of my professors who a few decades ago provided the early academic training and inspiration that has led me to this award. Especially noteworthy are now-retired Professor Robert E. Wallace of the Department of Geology at Washington State College (and of later earthquake-geology fame with the USGS); the late Professor Richard P. Goldthwait, Department of Geology, Ohio State University, who was adviser and major professor for my M.S. studies in geomorphology and glacial geology at that institution, and whose example led me to several years of "cold war" research on arctic glaciers and ice fields; Professor John F. McLaughlin of the School of Civil Engineering, Purdue University, who served as adviser and major professor for my M.S. and Ph.D. degrees in civil engineering; and Professor A. W. Skempton, who was my adviser during postdoctoral soil mechanics studies at the Imperial College of Science and Technology (London). Also to be thanked are the many students and faculty members with whom I was closely associated early in my career while serving on the geology faculty at Purdue University and the civil engineering faculties at the University of Colorado and the University of Idaho.

In summary, I reiterate my personal delight in receiving the 1997 E. B. Burwell, Jr., Award from the Geological Society of America. I consider this award to be among the greatest achievements of my long career.

Response by A. KEITH F. TURNER

It is a great honor to be named a corecipient of the E. B. Burwell, Jr., Award. The list of past recipients includes many renowned engineering geologists. To be included in such company is both humbling and greatly appreciated.

Landslides: Investigation and Mitigation is actually the third in a series of TRB books addressing landslide problems. The first was published in 1958, the second in 1978; so there appears to be an approximate 20 year cycle in the need for fresh approaches to the topic of landslides. Each of these publications has a different title, and the titles mirror changes in societal values at least as much as evolution in scientific knowledge and engineering technologies. The 1958 publication emphasized engineering practice in resolving landslide instabilities along transportation facilities; by 1978 the theme had evolved to strategies for analysis and control of landslides; while this latest version emphasizes the newest investigation and mitigation technologies in light of current societal, economic, and environmental norms.

Landslides: Investigation and Mitigation is of course not entirely "my book." Nor is it my corecipient Robert Schuster's book. This is not to say that Bob and I don't deserve the award! We performed our editorial duties faithfully, dedicating many hours to this task. However, the book is the result of the efforts of many people, including some here today, who volunteered to write chapters or to serve on the Transportation Research Board task force charged with the book's development. The task force consisted of 12 members, and the total number of authors, including task force members, was about 30. As chairman, I thank them all for their contributions, and for their enthusiasm and support. It was a privilege to work with them.

Special thanks must go to Bob Schuster. He has had a long and distinguished association with both TRB and landslide research. In the 1970s he chaired the TRB task force that created the previous edition, known as TRB Special Report 176, *Landslides: Analysis and Control.* My very slight involvement with that effort demonstrated to me that producing these books required a lot of work. Thus, when in 1990 I was informed by TRB that the copies of Special Report 176 were almost exhausted and that I should make a recommendation concerning either reprinting Special Report 176 or producing a new edition, I approached the issue with considerable trepidation. Discussions quickly convinced me of what I initially expected; a new edition was needed. I agreed to undertake the responsibility of chairing a new TRB task force and leading the effort to develop a new edition. Then I received a telephone call from Bob in which he said, "Keith, you take it on and I'll help you." And he did!

Our collaboration was especially close because Bob worked only two buildings down the street from my office on the Colorado School of Mines Campus. We found that our writing styles were compatible so that, although we often found different aspects of the draft texts requiring attention, we readily came to editorial agreement as to courses of action. Bob was willing to work the often-strange hours required to complete the editing process. I think the book benefits greatly from our joint editing efforts. So I wish to record my deepest gratitude to Bob for his unfailing good humor, support, and assistance in the editing process.

I also thank several TRB staff for their help. Especially, I wish to recognize the support given me by G. P. "Jay" Jayaprakash, TRB Staff Engineer for Soils and Geology. Jay provided the essential liaison and logistical support functions for the entire task force. More important to me, however, was his acceptance without complaint of my rationalizations as to why deadlines were being missed. Jay helped me maintain my sanity when things were not going well. His counsel and actions made the book a reality.

I also thank the TRB Editorial Staff and the National Academy Press for producing such a fine-looking book at a very attractive price. To be honest, this was not achieved easily. As task force chairman, with unanimous support of all members, I was adamant that the book should be priced as low as possible. Initial price estimates by TRB and National Academy Press staff were quite high. I believe they thought the landslide book should follow in the footsteps of a very beautiful, but expensive, book illustrating bridge designs. In contrast, we wanted a book that could be purchased and used by anyone dealing with landslides. This was not really resolved until some initial page layouts were sent for my consideration. I must admit I was emotionally attached to the book by this time. But I was horrified at the proofs; the text was in a small font and the illustrations were often too small, because the pages were laid out with large margins! I was so upset that I sought reassurance from my colleagues. Was I overreacting or did they also see problems? One gave me the definitive statement: "No one over 40 will be able to read this book!" Armed with such a response, I was able to get the book layout redone, and you have today a beautiful, functional, and economical book. This achievement, in my opinion, represents a minor miracle, and I thank the many TRB and National Academy Press staff who made it possible.

Finally, I express my sincere thanks to the National Science Foundation for providing critically important financial support to TRB during development of the book. While it is true that all task force members and authors were volunteers, there were nevertheless several meetings required during the five years or so it took to complete the book. The NSF funds made the logistical issues manageable.

Landslides: Investigation and Mitigation represents a distinct departure from earlier editions. It is much more inclusive. As the task force began its work, I had a vision of a book that could be used by three distinct audiences. These were: (a) students wanting to learn about landslides; (b) practitioners who needed a ready reference to assist them in their day-to-day activities; and (c) researchers who wanted a comprehensive reference that provided a point of departure for their investigations.

I am pleased to say that I think *Landslides: Investigation and Mitigation* responds to all three groups. It contains extensive references, ranging from general to specific, and from historical to recent. Moreover, these references support the needs of all three groups, because we avoided the esoteric and selected publications that should be readily found in good university engineering libraries. Several chapters include worked examples. These will be especially useful to students and practitioners. The final seven chapters, placed in a section called "Special Cases and Materials," highlight the necessary adjustments in technique required to investigate or mitigate landslides in such environments as the tropics or the arctic regions, or with problematic materials such as loess, talus, or weak bedrock. While these chapters may be considered of special importance to practitioners, they also serve to broaden the horizons of students. Finally, I hope researchers will find that the balance between theory and practice, present in many of the chapters, will help them design their research projects. In these times, research rapidly advances our knowledge, so that, in far less than 20 years, I expect a new edition will be needed. For the moment, I hope *Landslides: Investigation and Mitigation* will prove to be a worthy compendium of our knowledge concerning landslides.

Toward the end of the writing process, I agreed to write the first chapter, the Introduction, jointly with Jay Jayaprakash. I decided to include, along with the usual information on what the book was about, some materials reflecting the historical importance of landslides. This topic was not included anywhere else in the book, nor was such information readily available elsewhere. In September 1994 I attended the 7th International Congress of the International Association of Engineering Geologists in Lisbon, Portugal. At a conference dinner, I suddenly realized that at my table, and those around me, were gathered all the people who could help me identify the information pertaining to important historical landslide events. I explained my interest and need for information to some companions. That evening remains one of the most cherished memories of my career, because the response was overwhelming. As the word circulated, leads were discussed, theories debated, and notes were made on the backs of napkins. I gathered the napkins, organized some requests and was fortunate to subsequently have the opportunity to visit some excellent research libraries.

I direct your attention to two of the historical landslide events reported in *Landslides: Investigation and Mitigation,* for I think they have special interest and significance. The first is the Bindon landslip that occurred on the south coast of England on Christmas Day, 1839. Because of the date, many ascribed religious significance to the event. The landslide became the subject of much public interest and debate and, as a result, was subjected to extensive scientific investigation by several of the most eminent geologists of the period. Their studies were supported in part by several Church of England bishops. Enormous crowds came to view the landslide, and local farmers charged admittance fees to their fields. It has been reported that it was accorded the unusual honor of having a popular musical score written to celebrate it!

The second is the publication, in 1846, of the results of studies conducted by Alexandre Collin of slope stability along French canals. This publication has not been widely known; in fact I understand there is only a single copy in North America, located at Cornell University. However, Robert Leggett was instrumental in getting an English translation published by the University of Toronto Press in 1956. This translation includes a fascinating account of Leggett's first discovery of this work, during his research of the reports of the Panama Canal Commission, and the difficulties he then encountered in finding a copy and making the translation. Collin's work includes many important "firsts": Collin used the term "soil mechanics" many years prior to what was commonly accepted as its initiation by Terzaghi; he undertook field investigations in a time when such activities were rare; and finally, he collected samples and performed shear tests on them in a laboratory!

Landslides: Investigation and Mitigation is much bigger than its predecessors. In fact, when I first saw it, I was reminded of a major city telephone book. Later, I became very pleased with this similarity. Perhaps you have seen the television advertising for the Yellow Pages books. The slogan is "The One That Is Used!" I hope and trust that *Landslides: Investigation and Mitigation* also will be "The One That Is Used." Thank you very much for this honor.

GEORGE P. WOOLARD AWARD
presented to
ROBERT S. WHITE

Citation by ROBERT S. DETRICK

It is a great pleasure for me to present this citation, on behalf of GSA's Geophysics Division, for Robert S. White as the 1997 recipient of the George P. Woollard Award. This honor, presented yearly, is given to a person who "contributes in an outstanding manner to the solution of a fundamental problem of geology through the application of principles and techniques of geophysics." For someone who on more than one occasion has insisted to me that he is "just a geologist," this award must be particularly satisfying.

Bob grew up in Nottingham in the Midlands—about as far as one can get from the oceans in the British Isles. Before he went to university in 1971, Bob spent a year as a research assistant at the Berkeley Nuclear Laboratories, where his interest in a research career was sparked. Bob took an undergraduate degree at Cambridge University with a major in physics and geology. He stayed on to do a Ph.D. in the famous Department of Geodesy and Geophysics under the supervision of the late Drum Matthews. After a one-year stint as a postdoctoral scholar at Woods Hole Oceanographic Institution in 1978–1979, where we first met, Bob returned to Cambridge, where he has remained ever since. In 1981 he took over leadership of the marine group at Madingley Rise, and in 1989 he was appointed a professor at Cambridge University. Thus, as nearly as I can tell, Bob has been affiliated with Cambridge University more or less continuously, with a couple short sabbaticals, for the better part of 26 years. Despite this obvious handicap, Bob has had an extraordinary career, making fundamental contributions to our understanding of how oceanic crust is formed, how continents rift, and how these processes are influenced by the underlying mantle. These accomplishments were recognized in 1994 by his election to fellowship in the Royal Society.

In his first three years as a graduate student at Cambridge, Bob was sent to sea by Drum Matthews on three separate cruises to the Makran margin in the northwest Indian Ocean. From this experience he developed a lifelong interest in marine geophysics and an unusual aptitude for successfully mounting the kind of large, logistically complex seagoing programs that have been a hallmark of much of his work ever since. Over the past 20 years he has led some nearly two dozen different field programs, mostly at sea, but also including onshore-offshore experiments, and in recent years on-land work in Iceland. In an era of increasing specialization, with experts on a single isotope system or one narrow subfield of geophysics, Bob has employed a wide variety of methods in his work, including gravity, magnetics, heat flow, seismic reflection and refraction techniques—even rare earth element geochemistry (!)—to address a broad range of fundamental scientific questions on the structure, composition, and tectonics of Earth's crust and lithosphere. This breadth of interests, and approaches, is surely something that George Woollard would have applauded.

Bob has published over 120 papers to date in peer-reviewed journals, and it would be almost impossible for me to summarize all of his contributions, and those of his many Ph.D. students, here. But let me try to give you just a sampling of his work. In the late 1970s Bob did some of the earliest work on gas hydrates in the Gulf of Oman, as well as the previously mentioned studies of the structure of the Makran margin. In 1980 he and Hans Schouten were the first to recognize the existence of non-transform offsets on the Mid-Atlantic Ridge—features they called "zero-offset" fracture zones. Bob and his students helped document the existence of anomalously thin crust at oceanic fracture zones, and they showed that hotspot swells are dynamically supported. His many seismic experiments, mainly in the North Atlantic, have also helped shape our present understanding of both the structure of oceanic crust and the rifted margins bordering the Atlantic. However, there is little question that Bob's most influential research has been his work with Dan McKenzie into the factors controlling volcanism at both continental and oceanic rifts—in particular, why some rifts are associated with vast and catastrophic outpourings of so-called "flood basalts" while others are not.

As they describe it, the key to understanding volcanic margins came to Bob and Dan as they were sitting in the tea room at Madingley Rise in 1987. I don't know whether this is true, but it does make a good story! At about this time, Dan and Mike Bickle were using experimental results from a number of investigators to study mantle melting processes, and they had realized that the amount of melt produced increased dramatically with even small increases in mantle temperature of, say, only 100–200 °C. At this same time, Bob and one of his students, Bob Courtney, had been investigating the origin of the broad topographic swell surrounding the Cape Verde Islands. They had found that the topography, gravity, and heat flow on the Cape Verde Rise could be explained by the spreading of a 1500-km-wide mushroom of hotter-than-normal mantle beneath the base of the lithosphere. From these two apparently unrelated studies, one showing how mantle plumes could influence mantle temperatures over distances of 1000 km or more and the other showing the dramatic effect this increased temperature would have on the amount of melt produced, Bob and Dan came up with a wonderfully simple model that related the amount of rift-related magmatism to the temperature of the underlying mantle. When rifting induces upwelling of hotter-than-normal plume mantle, they predicted, large amounts of magmatism, in the form of both extrusive volcanism and underplating of intrusives at the base of the crust, are produced. Bob took this model and used it to explain the occurrence and composition of flood basalts from the Archean to the Tertiary, from the Deccan traps in western India to the Paraná flood basalts in South America to the huge outpourings of lavas in the great North Atlantic Tertiary volcanic province. He used it to predict the uplift and subsidence history of rifted margins and the variation in crustal thickness and basalt chemistry along the great mid-ocean ridge system. And in a series of seismic experiments from Iceland in the North Atlantic to the Southwest Indian Ridge, he measured crustal thickness against the predictions of this model and showed how it could reflect differences in mantle temperature. It is a truly impressive body of work, which has strongly influenced the thinking of earth scientists around the world. While some aspects of what has become known as the "White and McKenzie model" remain controversial and some important features of magmatism at rifted margins remain unexplained, there is little doubt that by providing a quantitative framework and predictive model for rift-related volcanism, Bob's work represents a major advance in our understanding of this fundamental geological process—an accomplishment well deserving of the recognition he is receiving here.

Of course a recitation of his papers and scientific accomplishments gives only a partial measure of who Bob really is. His long list of Ph.D. students, some of whom are now established scientists in their own right, are ample testimony to his skill at teaching and advising. Under his leadership, the marine group at Madingley Rise has also remained at the forefront of marine geophysics, consistently attacking first-order problems in innovative ways. However, perhaps what I have admired most about Bob over the years has been his ability to maintain an apparently sensible balance between the demands of his professional life and his family, church, and community. I may be mistaken, but I attribute this mainly to his wife, Helen, and their two children, Mark and Sarah, who try to keep him from taking his work, and awards such as this, too seriously. One thing many people don't know about Bob is that he is a bit of a hobbyist. For several years he built and flew model airplanes, but he had to give that up when he kept crashing them. He then tried model boats, but despite all his months of sea experience he somehow managed to sink those too. Perhaps Bob should stick to geophysics—it is obviously something that he seems to have a greater aptitude for!

Please join me, and his friends and colleagues around the world, in offering Bob our heartfelt congratulations on receiving the 1997 George P. Woollard Award!

Response by ROBERT S. WHITE

Thank you, Bob, for your kind, if far too generous, words. And thank you to the GSA for this honor; I am only too aware that there are many others who ought to be standing here instead, and that the reason I'm here is largely because of the kindness of my friends.

I would especially like to pay tribute to all the graduate students with whom I've had the privilege of working. They are an exceptional bunch, extremely talented and hard-working, and I am immensely proud of them. Any fieldwork is a team effort, and that is particularly true of marine geophysics. Without them I would have had a far less interesting career; though maybe I might just have had a couple fewer sleepless nights.

I fell into geophysics more or less by accident. Just over a quarter of a century ago, I started as an undergraduate at Cambridge, intending to major in physics. Because I liked hiking and being outdoors, I took geology as a subsidiary option. Well, I liked the people I found there and I continued to like the outdoors, so I just sort of stayed. And I like the physics you find in geology, too. It's the sort you can grasp hold of and understand with calculations on the back of an envelope, even if the full working-out of the ideas takes supercomputers and gigabytes of data.

It is a particular pleasure for me to receive this award because the last Englishman—indeed, I think the only other Englishman—to receive it was Drum Matthews, who was my graduate supervisor. As many of you know, Drum died just this summer. His influence on marine geophysics and on geology generally was profound, not only through his work with Fred Vine which gave us the seafloor-spreading hypothesis, but perhaps more importantly still because he nurtured a generation of students who now occupy positions of responsibility in science around the world. I myself owe a great deal to him: he taught me how to do science; how to ask the seemingly simple yet profound questions; and that people are more important than publications.

I thank my parents, too. One thing I inherited from them is a love of maps. My parents met while both were working for the Ordnance Survey, which is the British map-making organization, and my father continued to make maps all his working life. So perhaps it was no coincidence that almost the first thing I did as a graduate student on my first seagoing expedition was to make a map of the seafloor of the Gulf of Oman. The bathymetry and topography of Earth continue to be an extremely powerful tool in understanding the processes and tectonics of the crust and upper mantle. So I'm pleased to be carrying on a family tradition in this respect.

I've had the good fortune to do field work in some of the most beautiful places on Earth. The other side of the field work coin is, of course, our families left behind, and I thank my wife, Helen, and my children for their patience and support. There seems to be a universal law that domestic disasters always occur while I'm away: the washing machine breaks down or the children get mumps. As Bob intimated, I owe more to my family than I could possibly enumerate here, and much of the work I've done has only been possible because of their support.

Drum Matthews used to say that he entered marine geophysics during the Heroic Age—and heroic it certainly was. For example, during the Indian Ocean expedition on HMS *Owen* that eventually recorded the magnetic anomaly data from which the seafloor-spreading hypothesis sprang, they were at sea for over three months, continually repairing ailing home-made gear, before they recorded a single, uninterrupted 24 hour segment of underway data.

If that was the heroic era, then I joined during the Golden Age, in the mid-1970s. Almost every cruise was to uncharted territory. On my first trip, we discovered a new plate boundary. You couldn't do that nowadays.

In those days a Ph.D. student typically had two or three cruises of his own, often planning them himself, as I did. Nowadays we often squeeze two or three Ph.D. students into a single cruise. And the advance planning and money raising is so detailed that the students often see or participate in little of it. In those days we could sail just about anywhere; now we are constrained by territorial limits and exclusive economic zones that cover most of the seas.

In those days pure research was supported for its own sake; nowadays we operate largely under a narrowly directed system that requires even curiosity-driven research proposals to contribute to wealth creation. I have a notion that such a short-term view of research will in the end be self-defeating. Though everything looks rosy while we live off the fat of earlier years, the danger is that we will erode our intellectual capital and will miss those unexpected and unlooked-for results that are the seed corn for the future. But maybe I'm unduly pessimistic; one of the joys of working in a university is seeing the continual arrival of enthusiastic, clever, and cheerful young people. After all, our future lies with them.

In closing, I'd like to share with you two comments by my children. Children are often very perceptive in what they say. I was talking to my son about what he'd like to do in the future, and he replied very firmly that he didn't want to be an academic because he wanted to do a proper job. My daughter, on the other hand, as I left for this trip, commented that she'd like a job like mine because I was always going off on holiday. Though I might dispute the idea that weeks doing field work, especially at sea, are a holiday, I can't deny that they make a change from sitting on committees or writing reports and grant proposals. Since a change is as good as a rest, as the saying goes, then I suppose she has a point, so a holiday is not a bad description after all.

I have had a lot of fun and pleasure from studying this planet of ours with my friends, and I am pleased if we understand it just a little better as a result.

Thank you.

HISTORY OF GEOLOGY AWARD
presented to
KENNARD B. BORK

Citation by WILLIAM R. BRICE

Life has many pleasures that we can, when fortune smiles favorably upon us, enjoy and savor. One of the greatest of these is the pleasure of knowing and loving our families and the friends that we meet as we move through life. On rare occasions, we have an opportunity to repay them in a small way for the joy they bring into our lives. For me, this is one of those occasions.

We are here to honor Ken Bork for his accomplishments as a scholar, as a teacher, and as a friend—a friend not just in the personal sense, but in the professional sense as well. He is more than just a scholar in the history of geology, he is truly one of us in the Division. But for his untiring efforts on behalf of the Division, we might not be meeting here today. He served as Division vice-chair in 1980 and chair in 1981, at which time he convened our invited symposium at the Cincinnati meeting. Some of you may remember that Ken gathered a distinguished group of speakers, among them Stephen J. Gould, and we had a packed house. And, to quote one of his Division colleagues, "He has served on a zillion committees" as well.

His professional friendship for the history of geology goes far beyond our Division, and I will mention just a few highlights. In 1984 he was elected a Corresponding Member of the International Commission on the History of Geological Sciences, and he served as secretary for the United States Committee on the History of Geology. Over the years Ken has been very active with the History of the Earth Sciences Society (HESS), serving as HESS secretary from 1987 to 1993, and he was the inaugural editor for the HESS journal, *Earth Sciences History,* when Gerry Friedman founded the publication in 1982–1983. Ken is currently president-elect of HESS and will serve his term as president from January 1999 through December 2000. Congratulations, Mr. President, I can think of no one better suited to lead that group into the next century.

Ken has been on the faculty of Denison University since 1966, the year he completed his Ph.D. at Indiana University, and he is highly respected and revered by students and colleagues alike. As a measure of the esteem with which he is held at Denison, Ken was the first recipient of a college-wide Teaching Excellence Award in 1993.

Ken applies the same energy, enthusiasm, and integrity to his scholarship that is manifested in his contribution to the Division and in his teaching; whether the subject is early French geologists or his eloquent expression of the life of Kirtley Mather, *Cracking Rocks and Defending Democracy* (1994, AAAS Pacific Division). His scholarly focus is broad, and his work covers several continents and a time span of three centuries. His early papers were devoted to paleontology (bryozoa) and sedimentology, but he soon turned his attention to a different kind of ancient evidence, namely the development of geological ideas. As most of us are native English speakers, sometimes we tend to overlook the wealth of material not written in our native tongue. But as Ken's skill as a scholar has been augmented by his linguistic abilities, he has been among the researchers who could see beyond the language barriers. Like many of the individuals who grace his papers, Ken made the necessary correlations that clearly demonstrate how wrong-headed our English chauvinism really is. And he has done this not by complaining about the pro-British bias of the late 18th and early 19th centuries, but by using quality scholarship and meticulous research to simply present the facts. A brief quote from a paper on Bertrand illustrates his approach: "They [Bertrand's publications] were not the rash arguments …, nor were they paradigm-shifting insights.… Nonetheless, Bertrand popularized natural history and invited subsequent generations to take up the quest for deeper understanding of nature" (1991, *Earth Sciences History,* v. 10, p. 86).

The Mather biography was the result of many years of painstaking research that no doubt included the reading of countless letters and notes written in difficult handwriting, culminating in much soul-searching. When it came time to put pen to paper, Ken had to present the life of a person whom he greatly admired, but who was, after all, just a person, with all the flaws that come with being human. The published version clearly demonstrates that a biography can be a celebration of a person's life and at the same time it can be realistic and truthful without destroying the integrity of the writer or the reputation of the subject. Ken possessed the consummate skill to do this. I close with a brief passage from the Mather biography: "One lesson learned from Kirtley Mather's life is that the world includes some quietly dedicated people who seek to improve the human condition through education" (*Cracking Rocks and Defending Democracy,* p. 282). Certainly, Kennard Bork is to be counted among them.

Ladies and gentleman, it is my distinct honor and pleasure to present to you our History of Geology Division Awardee for 1997, Dr. Kennard B. Bork of Denison University.

Response by KENNARD B. BORK

The answers to your potential questions are: No, Yes, Yes, and Yes.

(1) No, I did not expect to be standing up here today. When I read François Ellenberger's acceptance response in Seattle (1994), I had not the slightest suspicion that I'd have to say something pithy on my own in three short years. (2) Yes, the magnitude of the contributions of past recipients of this award is abundantly clear to me. (3) Yes, I also have a list of colleagues I would be delighted to see receiving this year's award. And (4) Yes, despite my genuine humility at this moment, I am indeed grateful to the committee for recognizing my mixed blend of scholarly and administrative service to our discipline. And I thank Bill Brice for his generous introduction.

My comments, pithy or not, will focus on *mentoring.* The generosity of colleagues was critical in shaping my entry into the profession, and I believe that it will be important to the future evolution of our discipline. In fact, when I looked at a list of past recipients of the Division's award, I was dazzled by how many awardees had directly helped me in my peregrinations through the halls of geoscience history. I have no desire to turn this into an Academy Awards name-dropping parade, but a brief accounting of my quarter century in the field may illustrate the merits of mentoring.

We have talked a lot about "internalist" and "externalist" issues in the history of geology. Many of us in GSA were trained solely as geologists. Any success in doing history was akin to success in teaching—it came about largely by a sink-or-swim methodology. That is why mentoring has been so critical in the development of so many people in this room. As Gordon Herries Davies noted just last year, a number of informal "teachers" may have contributed in important ways to our appreciation of historical topics.

It took a sabbatical from a liberal arts college to allow my personal move toward historical topics. I will never forget the generosity and good advice extended to me in the early 1970s by George White, Claude Albritton, and Cecil Schneer. Each of them shared insights and information in ways that fueled enthusiasm for the history of geology.

With their encouragement, it was off to Paris in 1973. Paris has served many an American as a City of Lights, in many ways that transcend clichés. For me it was the dual contacts of (1) the amazing Bibliothèque at the Muséum d'Histoire naturelle and (2) contact with Joseph Schiller, the renowned physiologist and historian of biology.

Above and beyond its richness of information, the Bibliothèque shed its own historical glow, as the staff delivered books that had been the personal copies of Georges Cuvier, Napoleon III, or the very person you were studying.

Mentoring is a subtle art. We are well advised to take lessons from people such as Joseph Schiller. While working across the table from me at the Muséum, he saw that I was pursuing topics in 18th century geology. He struck up conversations and was soon conducting me on casual strolls through his own neighborhood—past the homes of Gertrude Stein and Pablo Picasso. We would discuss a wide range of topics of mutual interest. And he would occasionally feign forgetfulness and seek my input. It soon dawned that his technique was Socratic and his memory was in fact phenomenal. But I learned many a lesson through the quiet but potent medium of conversation.

Almost exactly that same serendipitous experience repeated itself during Sabbatical II, in 1980. The Bibliothèque was the same, but the new key contact was François Ellenberger. Not only has he helped many Anglophones appreciate French contributions to geology's development, but also as a one-man cyclone of energy, François founded and guided the Comité Français d'Histoire de la Géologie (COFHRIGEO). A number of us owe major debts to members of COFHRIGEO for their ongoing support and sharing. When mentors share their gifts, we are all enriched.

My 1980 research focused on 18th century topics that intersected with the work of Albert and Marguerite Carozzi. The Carozzis have been extremely supportive over the years, sharing elements of their own work, editing my writing, and offering valuable insights about the francophone geology of the Enlightenment period.

I should also note that my wife, roommate, and best friend, Kay, and our son, Rob, graciously accepted the dislocations involved. (Paris is nice, but it still requires an adjustment for a 5- or 12-year-old from a small Midwestern town.) Although not "mentors" regarding esoterica within geohistory, their support and interest have been invaluable over the years.

On occasion, we can even learn from our own research subjects. What I have learned from Kirtley Mather is a case in point. My academic home, and Kirtley's alma mater, Denison University, is not old by European or Ivy League standards, but it was founded the same month (December 1831) in which Charles Darwin set sail on the *Beagle.* When, in 1981, we celebrated the college's sesquicentennial, I was asked to give a capsule commentary on Mather, as an exemplar of an alumnus who had become a respected scientist but also a champion of liberal arts and all that it entailed. Fear not, I will not use this forum to lecture about Kirtley, nor will I attempt to drum up book sales for Alan Leviton's publishing arm of AAAS.

But here is where it gets weird, and a bit of "Twilight Zone" theme music might be in order. If you are into the arcana of connections and contingencies (à la Steve Gould), please note that Kirtley Mather was on the Harvard geology faculty from 1924 through 1954, and he taught generations of Harvard students to appreciate the history of geology. Claude Albritton, Ursula Marvin, Mary Rabbitt, Cecil Schneer, Sherman Wengerd, and many others, all profited from Mather's dedication to historical threads in the tapestry of modern science. In turn, Gould, Marvin, Schneer, and Wengerd shared with me illuminating Harvard-based stories about Mather as a professor and a person. It's a form of cyclical mentoring.

As a speech at a small-college sesquicentennial grew into a book-length treatment of Mather's life in science and society, I was introduced to the power of editing as a type of teaching. Alan Leviton and Michele Aldrich were superb editors and taskmasters. Be forewarned that anyone working with Michele should be prepared for a stream of humorous but sharply barbed cartoons about the trials of writing and publishing.

Bob Dott and others, in previous comments in this exact setting, have called attention to the need for dialogue among "pure" historians and "pure" geologists. A new day may dawn in which nicely welded geo-historians arise fully fused from sophisticated programs that actively link scientific and historical training. For the nonce, we are fortunate in the Geological Society of America to have human resources such as Michele Aldrich, Ken Taylor, and a generation of younger persons with strong formal training in history who are willing to share ideas, methodologies, and standards.

Speaking of younger people and the dawning of new ages leads to my concluding remarks. In our own attempts to mentor brand-new historians of geology, we need to continue building on the groundwork laid by Gerry Friedman, with *Earth Sciences History,* and Bob Ginsburg, with the "Rock Star" profiles in *GSA Today.* But note that even those innovations are on *paper!* The use of the Internet and its Geo-Clio Web site, proposed and implemented by Léo Laporte, Dean Dunn, and others, may be a way to engage future generations. Cruising the Web is not the same as an enlightening stroll through the streets of Paris, but it may be a viable example of electronic mentoring for the coming millennium.

Thanks again for conferring an exceptional award on a very surprised person.

O. E. MEINZER AWARD
presented to
LEONARD F. KONIKOW

Citation by JOHN BREDEHOEFT

It is my pleasure to present the O. E. Meinzer Award to one of my colleagues, Lenny Konikow. I first met Lenny as a graduate student. He was one of Dick Parizek's students at Penn State; Dick was another of Burke Maxey's many students who pervade my generation of the ground-water profession. He came to work in Colorado to do a Ph.D. dissertation modeling the buildup of salt by irrigated agriculture in the aquifer associated with the Arkansas River—a project I initiated, a project we started when Ted Moulder was USGS District Chief in Colorado. Lenny's dissertation research was the first water-quality modeling effort of its kind. I recall his saying to me later, "It is a good thing I knew how to program in FORTRAN, or I would have been lost." He used a bare bones transport code I wrote that needed modification to do the Arkansas analysis.

Lenny went to work in the Colorado District Office of the USGS, and then joined the water research group in Reston, where he has had a distinguished career. He is one of the key individuals in the USGS National Water Research Program. Much of his work has been on contaminant transport models; he was senior author on the first widely used contaminant transport code—MOC. He recently published an improved and revised 3D Method of Characteristics code—MOC3D, one of the papers for which he is receiving this award.

Lenny pioneered in reevaluating model analyses in an effort to determine how the models performed, especially the model predictions. This led to papers on postaudits, and a paper we authored jointly, on model validation, or invalidation. One of his post-audits involved revisiting the Arkansas Valley. The earlier model analysis indicated that salt would continue to increase in the reach of the aquifer studied. Later sampling did not substantiate the increase; ground water in the area had reached a steady state in concentration—an important conclusion for irrigation in the area. Lenny is now at Stanford teaching Steve Gorelick's courses while Steve is on sabbatical in Australia.

The Meinzer Award is given on the basis of the merit of a single paper, or series of papers. In Lenny's case, it is awarded for the following three papers: "A three-dimensional method-of-characteristics solute-transport model (MOC3D)," by L. F. Konikow, D. Goode, and G. Z. Hornberger, U.S. Geological Survey Water-Resources Investigation Report 96-4267, 1996, 87 p.; "The value of postaudits in ground-water model applications," by L. F. Konikow, in *Groundwater Models for Resource Analysis and Management* (El-Kadi, editor), CRC Lewis Publisher, 1995, p. 59–78; and "Ground-water models cannot be validated," by L. F. Konikow and J. D. Bredehoeft, *Advances in Water Resources,* v. 15, p. 75–83.

Please join me in congratulating Lenny Konikow, recipient of the 1997 O. E. Meinzer Award.

Response by LEONARD F. KONIKOW

Thank you very much, John. Members of the Management Board, friends, and colleagues—I was surprised and overwhelmed to learn that I would receive this honor. It is a high point of my professional career to receive the Meinzer Award.

As I thought about this award and about what to say, I realized that the selection of papers for which I was cited cover an interesting spectrum. The documentation of the MOC3D solute-transport model reflects my work as a model developer and a model user. This type of work led some people to characterize me as a "modeler" and perhaps infer that I had little regard for field work and data collection. Of course, that's not true. The other cited papers, on model postaudits and on the impossibility of validating ground-water models, demonstrated that long-term model predictions often have low accuracy when compared to the actual future outcome. This led some people to characterize me as being "anti-model" and perhaps assume that I believed that all models are unreliable or even worthless. Of course, that's not true either. So what am I, and what am I doing here?

I would characterize myself not as a modeler, but as a *hydrogeologist,* who uses models to help solve *hydrogeologic* problems. This is one reason why receiving this highest award from the *Hydrogeology* Division of GSA means so much to me.

I began my college education intending to be a geologist. As an undergraduate geology major living in New York City, it was hard to see where (or if) one might get a job as a geologist. Oil companies didn't send recruiters to liberal arts colleges on Long Island. I think Phyllis (not yet my wife at that time) and both our families certainly thought it was quite strange that I was majoring in geology, and they were uncertain about what a geologist did. In fact, for several years after I started working for the U.S. Geological Survey, my mother was still telling her friends that I worked for the National Geographic Society.

In 1966, with graduation from Hofstra University approaching, I applied to several graduate schools. One of them was The Pennsylvania State University. My intention was to specialize in geomorphology, and Penn State had a strong program in this area.

Then the first of three critical events occurred on the path to this award. I got a summer job in 1966 working for Geraghty and Miller, Inc., a ground-water consulting company on Long Island, New York. I am grateful to Jim Geraghty, Dave Miller, John Isbister, and Frits van der Leeden, among others there, for showing me what hydrogeology was, how professional hydrogeologists did their work, and why hydrogeology was important enough that people were paying them to study ground water. I saw the light. Here was a field within geology that was quantitative and objective, and also had the fun and the challenge of geologic puzzle-solving. By that, I mean inferring the nature and structure of the unseen subsurface environment from very limited data. But the outcome of hydrogeologic studies also had obvious near-term and practical value, as people would always need adequate supplies of good-quality water. This led to a conclusion of interest to most college students: there was job potential here!

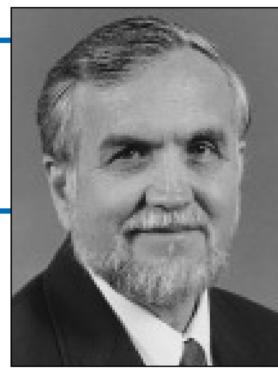
My second stroke of good luck came when I arrived at Penn State, and learned that they indeed had an eminent hydrogeologist on the faculty. With no advance notice that I would be knocking on his door, Dr. Richard Parizek took me under his wing, taught me, and guided me during my 5½ years in graduate school. Dick created a stimulating learning environment for his students, which enabled us to learn from each other, as well as from him, and we enjoyed doing it. I am forever grateful to him for making sure that I got the education, in both theory and practical aspects, that is the foundation of my hydrogeological work.

My third "good-luck" event came when I met John Bredehoeft at a scientific conference in 1970, while I was still a graduate student. Several months later, John asked me to work with him in Colorado for the summer, which, in time, led to my career with the USGS. The impact that John had—and still has—on my work (and on my career) is evident in the papers cited for the Meinzer Award this year. John is co-author of one of them, and another (the MOC3D transport model) is a direct derivative of an earlier 2-D model that John and I documented in 1978, which, in turn, was derived from work that I did with John that first summer in Colorado, and, in turn, was based on work that John did with other USGS colleagues before me. John, you've been a mentor and a role model, and I certainly wouldn't be here today without having received the benefit of your guidance and your generous sharing of ideas. I know I speak for everyone in the Hydrogeology Division in saying that we are enormously pleased and proud that the broader scientific community has honored you this year with both the Penrose Medal from GSA and the Horton Medal from AGU.

As I look back over the 30-plus years since I was introduced to hydrogeology, I realize how fortunate I've been to have met and worked with so many intelligent, wonderful people—people I consider to be my friends. I sincerely thank the Meinzer Award Committee for considering my work to be worthy of this recognition. It is indeed humbling to receive this award and be added to the impressive list of those who have received it previously.

Finally, I thank Phyllis and our two daughters, Julie and Marcy, for their support and encouragement, and for forgiving me when my work and travel sometimes kept me away from home. It's been great to share the adventure of life with them and with you. Thank you very much.

G. K. GILBERT AWARD
presented to
RONALD GREELEY



Citation by MICHAEL H. CARR

It seems quite appropriate that Ron Greeley should receive the G. K. Gilbert Award. Gilbert was first and foremost a field geologist, but frequently turned to experimental modeling to help explain what he had seen in the field. In his biography of Gilbert, Stephen Pyne says of him, "No explanation of a geologic event was complete until it assumed a mathematical-physical form, but no equation, no deduced quantity could repeal a geologic fact." The same could well be said of Ron.

After getting his Ph.D. from Mississippi State in 1966, Ron went to work briefly with Standard Oil, and most of you would be surprised to learn that most of his publications in the late 1960s were on paleontology. In 1967 Ron was drafted, and the Army had the remarkably good sense to send him to Ames Research Center to work on *Apollo*-related problems; from there, his career in planetary science was launched. He retains today close connections with Ames, still being responsible for the running of the Mars and Venus wind tunnels, which he largely conceived, designed, and built. Although Ron had been hired by Don Gault to work on cratering, Don gave Ron a pretty free rein. Soon after arriving at Ames, Ron became interested in lava tubes and lava channels as possible analogs to lunar rilles, and in the early 1970s he published a series of papers comparing lunar rilles with lava tubes and channels in Hawaii and the Snake River Plain. Work in both these areas resulted in publication of two superb field guides, both models in how a field guide should be written. Many of you probably remember the planetology conference in Hilo in 1974 and how masterfully the field trips and the overflights were organized.

During this same period in the early 1970s, probably stimulated by the new *Mariner*-9 pictures from Mars, Ron started using wind tunnels at Ames to simulate how eolian processes might operate on different planets. These experiments led to a succession of very influential papers by Ron and coworkers Pollack, Iverson, White, and several others. These papers combined observation, theory, and very careful, systematic experimental work in an attempt to refine the physics of eolian processes so that we could better understand eolian processes on other planets where conditions are very different from here on Earth. They looked at all aspects of the problem—the formation of wind streaks and dunes, initiation of particle motion, saltation, abrasion by different types of particles, effects of air density, effects of gravity, and so forth, testing the classical theory of Bagnold against a wide range of experimental conditions. While the initial emphasis was Mars, Ron subsequently built a wind tunnel that operates at Venusian pressures, and after the *Magellan* mission, he and his group wrote a series of papers on eolian action on Venus. As a result of all this work, Ron has become recognized not only as an expert in planetary science but also as an expert on terrestrial eolian processes, and he is frequently consulted on problems of desertification and wind erosion. Ron's achievements in eolian processes alone would, I think, justify the Gilbert Award.

But, of course, Ron has done much more. Through the 1980s, he continued his interest in volcanism. With Paul Spudis, he published a summary of volcanism on Mars, which still remains the best summary of what we know about martian volcanism. He made estimates of the volumes of volcanic rocks erupted on Mars as a function of time, and what these estimates might imply about the amounts of water outgassed. With John Guest, he published a 1:15,000,000 geologic map of the eastern hemisphere of Mars; stimulated by the *Voyager* results, he did experimental work on sulfur lava flows and impacts into low-viscosity targets. In fact, the pictures from some of these experiments are remarkably similar to those taken by Gilbert in 1892 of experiments at the Office of Naval Research. One of my most vivid memories of Ron during this period is set in Hawaii. We had gone to the Hawaiian Volcano Observatory in hopes of getting out to an eruption on Kilauea's east rift zone. The only way we could get there was by helicopter, but there was no room inside the helicopter—so we were strapped to the outside, on a shipping pallet. What with the noise, the wash from the blades, the heat from the fire fountain, and the smell of sulfur, it was quite a ride.

Ron, selected for the Galileo Imaging Team, and his group at Arizona State University have been very active both in the sequence planning and in the interpretation of the resulting images. Ron's main focus recently has been on Europa, and he is currently coordinating geologic interpretation of Europa within the team. As a result of his wide-ranging interests and accomplishments, he was asked to chair COMPLEX, a National Academy committee that makes recommendations on the scientific strategy for the exploration of the planets.

I have worked closely with Ron on many projects—on missions, on books, on proposals, on papers—and I think his most outstanding characteristic is his organizational ability. He is a master at dividing complex tasks into their component parts, delegating tasks, coordinating their integration, and leaving no loose ends. He started out his career in the army; had he stayed, I am sure that he would have ended up Chairman of the Joint Chiefs. Ron, congratulations.

Response by RONALD GREELEY

Thank you, Mike. I am deeply grateful to you, the Planetary Geology Division, and the Geological Society of America for this honor, and I am delighted to see so many friends and colleagues here.

I was fortunate in embarking in planetary science in its infancy—seeing new worlds for the first time is not likely to be repeated for a long time. But perhaps more importantly, I have been blessed by associations with people of the highest caliber, including my wife, friends, students, colleagues, and mentors.

My graduate training and initial work were in paleontology. The Missouri School of Mining and Metallurgy was not exactly a hotbed of paleontology, however, and my adviser's specialty was the study of fossil fish ear-bones, or otoliths. Being a naive fellow, it did not occur to me that I ought to focus on my adviser's specialty. Rather, I became intrigued with a different group of microfossils, termed lunulitiform bryozoans. My advisor, Don Frizzel, told me he knew nothing about bryozoans (a bit of an understatement!) and that I would really be on my own if I pursued this topic for a dissertation, but that he could provide general guidance. Although initially this posed some difficulties, in the long run it taught self-reliance and confidence in tackling an "unknown" topic independently.

After going through the Army Image Interpretation Center, I was assigned by the Army in a civilian capacity to the Planetology Branch at NASA-Ames in September 1967 to work for Don Gault on impact cratering and analysis of lunar orbiter pictures. Perhaps the Army thought that someone who worked on lunulitiform "bugs" belonged at NASA. Of course, I knew absolutely nothing about the Moon, NASA, or craters. Within weeks of my arrival, the annual meeting of the Meteoritical Society was held at Ames. This was my first contact with the cratering community and the geologists in the USGS, including Don Wilhelms and, I think, Mike Carr, along with the Barringer brothers, Harvey Nininger, and some 120 others. Up to this time, my experience at scientific meetings had been limited to paleontology sessions, oil company meetings, and military presentations, all of which were pretty staid and conservative, not only in the conduct of the meetings, but in the data content. What a contrast at the Meteoritical Society meeting. Opinions were expressed with such passion—and with so little data! Remember, this was prior to *Apollo,* and the ideas about the lunar surface were pretty unconstrained. What great fun! This was an exciting field with substantial challenges, and I wanted to be a part of it, even if I didn't know anything about the Moon or craters.

Don Gault gave me pretty much free rein at Ames, and within the year, along with Verne Oberbeck and Bill Quaide, I became intrigued with lunar sinuous rilles and possible terrestrial analogs in the form of basaltic lava tubes. Don fully supported an extensive field program on lava tubes, despite a NASA HQ person who said, "If I wanted to know about lava tubes, I would have someone at the USGS do the study." Fortunately for me, Ames chose to ignore HQ, and I was able to devote substantial time and effort to the study of volcanic landforms and processes, partly in the company of my long-standing colleagues and friends John Guest and Jack King.

As the Apollo program started to wind down, changes were occurring within NASA. During an annual HQ review, a new face showed up; Steve Dwornik was building the planetary (i.e., not lunar) geology program and heard presentations on volcanic analogs. He asked if we had an interest in doing Mars research. Most of us were so immersed in the study of the Moon that we really had not thought about much else, but the *Mariner 6* and 7 data were offered, and we said, sure, it might be interesting(!). Within a few months, *Mariner 9* started returning pictures of Mars, and this was the real turning point in understanding martian geology. Steve was a masterful program manager, and most of us in planetary geology owe him enormous gratitude for cultivating a diverse, productive, and cost-effective program.

Not only did Steve support our geology field work and planetary geologic mapping, but when we showed him some experiments run in a makeshift wind tunnel (a box with a fan in one end), he suggested that we consider doing some serious tests to simulate conditions on Mars. Once again, I was faced with a topic about which I knew nothing. But Ames was a pretty good place to think about wind tunnels. I quickly learned, however, that the kind of experiments we wanted to do to simulate aeolian processes were totally different from aircraft development. For some reason, no one at Ames wanted to blow sand and dust through their wind tunnels and screw up their instruments! However, I was told about an aeronautical engineer at Iowa State who liked to do crazy things, and that he might be interested in the problem. After some phone calls and a visit to Iowa, we arranged for Jim Iversen to spend part of his sabbatical leave at Ames, during which time we designed the Mars Surface Wind Tunnel. With the support of Steve Dwornik, we drew together a consortium of investigators to study wind processes on the terrestrial planets. Over the years, the group has included Jim, his former student Bruce White, Jim Pollack, Wes Ward, Haim Tsoar, John Marshall, Rod Leach, and Nick Lancaster.

Planetary geology is driven by missions, and I have had the good fortune to be included in many projects. Close relationships were formed through these missions and, without exception, the project scientists and engineers, team leaders, principal investigators, and colleagues on these projects are outstanding individuals who had and continue to have more influence on me than they might imagine. Equally important, however, are students. Students have a marvelous capacity to keep us honest! They ask fundamental questions that we would otherwise tend to overlook. When Carleton Moore sponsored my joining ASU, I was delighted, and this was a move that I have never regretted. I have had the good fortune to see students and postdocs mature into first-rate scientists who have far surpassed what I have been able to do.

Throughout my career I have had the steady support of my wife, Cindy. Despite my prolonged absences in the field, on projects, or in countless meetings, she has stood rock-solid, always with a smile and positive outlook. Besides that, Cindy is a great editor, who has smoothed many a rough draft of mine, for which I (and my readers) are grateful.

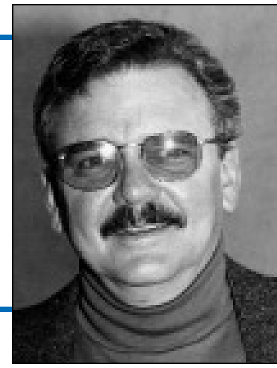
I thank the Planetary Geology Division for the G. K. Gilbert Award. It has been my privilege and honor to work with the extended family of planetary scientists for the past 30 years.

KIRK BRYAN AWARD

presented to

GRANT A. MEYER
STEPHEN G. WELLS
A. J. TIMOTHY JULL

Meyer



Wells

Jull

Citation by FRANK J. PAZZAGLIA

Across old Route 66 from the University of New Mexico there is a greasy-spoon diner with a distinct New Mexican flavor. For years now, the students and faculty of the UNM Quaternary Studies Group have conducted all of their official business there, inspired by the oil-on-black-velvet paintings. Such was the setting in the early spring of 1989 when a new Ph.D. student convened a meeting with his adviser and about a dozen student colleagues. Among the bowls of green chile, this student laid out several potential dissertation topics, ranging from active tectonics to glacial geology, and one by one, his perhaps overly critical peers found too many problems with them. At the end of the meeting, only two things were clear, the Ph.D. student did not yet have a dissertation project, but when he did formulate one it would be done in Yellowstone National Park. The meeting ended with the student and his adviser making one more suggestion: "we could do something with the fires; we should do something with the fires.…"

In the summer of 1988, Yellowstone National Park experienced the most widespread and severe forest fires in the park's recorded history. In the northeastern part of the park, many low-order drainage basins were almost entirely decimated by intense, stand-replacing burns. These basins produced numerous debris flows and floods between 1989 and 1991 that served as excellent modern analogues for similar fire-related debris-flow events throughout the Holocene. It would have been a fine and important contribution for a Quaternary scientist to simply document the hydrologic, sedimentologic, or ecologic response to the fires, but the work of the 1997 Kirk Bryan recipients went well beyond those contributions. Their work stands as an outstanding field-based study that illustrates the links between form and process, hillslope and fluvial systems, and climate change and landscape response.

The 1997 Kirk Bryan Award is for the paper entitled "Fire and Alluvial Chronology in Yellowstone National Park: Climatic and Intrinsic Controls on Holocene Geomorphic Processes," published in 1995 in the *Geological Society of America Bulletin.* The first author and passion behind the paper's research is Dr. Grant Meyer of Middlebury College. The paper encapsulates Grant's dissertation research performed at the University of New Mexico under the guidance and inspiration of his adviser, Dr. Steve Wells. Steve, who is now a director at the Desert Research Institute and Dr. Tim Jull, of the University of Arizona, are Grant's coauthors. Our honorees vividly illustrate how collaborative research and personal expertise can be and should be constructively coordinated to produce a sum far greater than any single effort could realize. For example, the paper shines in the area of debris flow processes and sedimentology, reflecting just one of the areas of expertise of Steve Wells, a geomorphologist who has the unique inspiration and insight of Kirk Bryan's last student, Dr. Charles Stern. There are many individuals here, including Grant and me, who have the distinct honor to have been instructed in field-based process geomorphology in the spirit of Kirk Bryan by Steve. The paper leaves nothing to the imagination with respect to age control, thus underscoring the importance of researchers, like Dr. Timothy Jull, who have devoted their careers to developing and perfecting reliable Quaternary dating techniques. Our discipline owes an important measure of gratitude to these colleagues. It takes a special individual to assimilate and integrate the substantial contributions of collaborators into a paper of the Kirk Bryan award caliber, but this is precisely what Grant Meyer has accomplished.

Grant's research focuses on the northeastern part of Yellowstone National Park, in particular the Soda Butte, Slough Creek, and Lamar River drainages. The Holocene valleys of these drainages consist of relatively flat, wide valley bottoms with well-preserved fluvial terraces, flanked by alluvial fans at the valley bottom–hillslope transition. The paper's first important contribution comes in its carefully laid out stratigraphic and sedimentologic criteria for field identification of fire-related, probable fire-related, and possible fire-related debris flow deposits in the alluvial fans and their relative correlation to terrace deposits. Outstanding age control for the fan and terrace deposits is provided by no less than 78 radiocarbon dates, most of them from Dr. Tim Jull's lab at the University of Arizona. Grant describes how the morphology of the terraces and the fans suggested that the Holocene valleys have at least two relatively stable configurations: one characterized by a low-sinuosity stream in a relatively narrow valley bottom overridden by prograding alluvial fans, and a second characterized by a stream of greater sinuosity in a wide valley bottom where the toes of the alluvial fans are truncated by fluvial processes. Deposit ages nicely show the processes of flood-plain deposition and widening, out of phase with the processes of alluvial fan aggradation by fire-related debris flow activity. The implications of these data are profound. Here, there is an opportunity to propose a clear and irrefutable link between hillslope and fluvial processes. But what is the common thread that ties the changes in hillslopes and rivers together? In the paper's most important contribution, Grant shows that it is basin hydrology, a hydrologic cycle that, not surprisingly, beats to the pulse of millennial-scale changes in Holocene climate.

Fire-related debris flow activity and the subsequent aggradation of alluvial fans are promoted by relatively dry climatic conditions, when moisture is concentrated in few, but intense convective summer storms. Hillslopes are more likely to dry out during these times, producing fires and debris-flow activity, while at the same time promoting a lower base flow and more flashy character for a narrow, incising stream in the valley bottom. In contrast, a climate that favors a slightly wetter, winter-dominated precipitation, which remains as a snowpack longer into the year, suppresses large fires and subsequent debris flows, and promotes a higher, more stable discharge for a meandering stream that does not vertically incise as it intercepts sediment from the fan toes it cuts during valley bottom widening.

All of us young geomorphologists, including Grant, have the distinct advantage of conducting our research in the context of the contributions of the Bulls, Schumms, Ritters, Leopolds, and their students and colleagues who have taught us about complex response and the conceptual links between fluvial and hillslope processes. In my opinion the greatest contribution of Grant's research and what will probably stand as its most enduring legacy is his careful field verification of the various process-response models proposed by the previous generation of process geomorphologists. The next generation of process geomorphology textbooks should rightfully use the research we honor here as the field-based example of precisely how fluvial systems are linked to their hillslopes, in both the sedimentologic and hydrologic senses, where all processes dance to the beat of a changing climate.

On the inside, Grant Meyer is intensely passionate about his geomorphologic research and equally passionate about the role that geomorphologic research should appropriately play in the understanding and protection of our nation's greatest treasures—our National Parks. On the outside, he is a quiet, humble, and unassuming man who has, no doubt by this time, concluded that I have spoken too long. Before I close, I leave you with one last thought. At this and all recent GSA meetings, we could treat ourselves to numerous fine presentations of Quaternary paleoclimatic research, most of which focus on the acquisition and interpretation of high-resolution paleoclimatic proxies. The research we honor here with the Kirk Bryan Award is one of the very few, special examples of geomorphologic research which answers that far more difficult and in my opinion, important question: "How, are changes in climate, especially those that occur on human time scales, manifested in the landscape and the processes that shape them?" In essence, process geomorphology should occupy a critical niche in our ever-expanding pursuit of Earth system science and global change issues. These are the questions and challenges for the future of process geomorphology, and the field is in good hands with young scientists like Grant Meyer assuming the challenge. I hope you will join with me in acknowledging the accomplishments and reception of the Kirk Bryan Award to our tri-authors, Dr. Steve Wells, Dr. Tim Jull, and a very special friend of mine and a most deserving young geomorphologist, Dr. Grant Meyer.

Response by GRANT A. MEYER

My colleagues and I are very grateful to be the recipients of the Kirk Bryan award. I'm glad to be in the company of so many colleagues and friends for this occasion, and I express my deepest appreciation to Frank and everyone who is here tonight to share in this honor.

I'd like to explain some of the details of how I got started on the work that resulted in the fire and alluvial chronology paper. In late June of 1988, when the Yellowstone fires were still small, the only significant thunderstorm to occur that summer generated flash floods that incised alluvial fan channels in the Soda Butte Creek drainage. In exploring the resulting exposures, I saw that charcoal-rich debris-flow deposits were quite common, and I wondered if the debris flows were a product of past fires.

An appropriate modern analog is really necessary to test such an idea. Little did I know that the fires would grow into major complexes containing almost one million acres, and that numerous debris flows and floods would issue from the steeper burned basins in subsequent years. More than once I've been accused of helping the fires out with some matches and gasoline! I believe that we have learned, however, that it takes much more than an ignition source for Yellowstone to burn catastrophically, as it did in 1988; it takes severe summer drought. The Holocene record suggests that drought of this severity develops rarely, but is more common during rather discrete climatic episodes. So there was a major element of chance, or luck if you will, in the opportunity to study fire-related sedimentation in Yellowstone with an actualistic approach. Of course, I was very lucky just to be able to indulge my curiosity about the landscape in such a magical place, not far from where I grew up.

Although I've always had a love of landforms and rivers, it was Bill Locke at Montana State University who taught me the importance of critical thinking and a process-based approach in understanding their evolution. I was also fortunate to work with Steve Wells, at the University of New Mexico, whose broad interests and expertise accommodated the shifts and swings in my search for a Ph.D. research topic, and provided the counterbalance to some of the wilder ideas. I'm grateful for the collaboration that developed and grew to include Tim Jull.

A figure looming tall over the Quaternary geology of Yellowstone and the Rocky Mountains is Ken Pierce, who has been a great source of inspiration and support for me. It is never difficult to talk Ken into a field excursion, no matter how many meters of relief are involved. Back at New Mexico, Gary Smith was of enormous help in interpreting sedimentary processes and deposits, and there's hardly a topic in geology that he doesn't have some interest in or knowledge of. Les McFadden and Roger Anderson also offered new outlooks and methods. On a day-to-day basis, the primary source of ideas and stimulating discussions were my fellow graduate students at UNM—and what a vibrant group of students they were! The graduate students were the critical sounding board for ideas, and I'm grateful for the invaluable help and friendship you have all provided. And UNM is where I met my partner and greatest source of inspiration, Paula Watt.

I'd like to thank the Quaternary Geology and Geomorphology Division for this honor. That honor is shared by many other colleagues past and present, in particular those who have laid the foundations for our efforts, and those who recognize the value of field-based research. I am especially thankful for the remarkable foresight of our predecessors in protecting Yellowstone, for even when the park was established in 1872 there were many who thought it wrong to "lock up" such a potentially profitable area for development. As Aldo Leopold wrote, "I am glad that I shall never be young without wild country to be young in. Of what avail are forty freedoms without a blank spot on the map?" In a literal sense, by the very nature of our work as geomorphologists and Quaternary scientists we fill in those blank spots. Yet if the essential wildness remains, with processes largely undirected by human activities, then the landscape retains its quality and value in a more meaningful sense. Perhaps, through our efforts it may be more valued by virtue of increased understanding; that is my hope and humble wish. Thank you.

Response by STEPHEN G. WELLS

I want to express my deepest gratitude to Frank Pazzaglia and to my colleagues here tonight for bestowing this year's Kirk Bryan Award on Grant, Tim, and myself. It is an unimaginable honor to have our 1995 *GSA Bulletin* paper recognized in this manner by our colleagues in the Quaternary Geology and Geomorphology Division and in the Geological Society of America. It is also an equal privilege to share this award with a colleague who was a former graduate student of mine at the University of New Mexico and another colleague who has collaborated with me on several projects over the past several years. Through his meticulous and devoted efforts, Tim Jull has provided geomorphologists, such as Grant and myself, a clock with which we can establish reliable, lasting chronologies and with which we can accurately measure rates of surficial processes. Without these types of geochronologic databases, studies such as ours would never have been successful. If one measures the richness of professors' lives in the character and accomplishments of their graduate students, I may be one of the richest individuals on Earth. Over the past 21 years in academia, I have been both enlightened and enriched by my students. Sharing the Kirk Bryan Award with Grant Meyer is perhaps one of the highest honors that I will achieve.

I must point out, however, that Frank's generous citation was somewhat unclear on one point: the main reason for holding our meetings at that Albuquerque diner is that true geomorphic inspiration can only be achieved with heavy doses of Hatch green chiles and traditional New Mexican salsa! In addition to such inspirations, Grant's and my suggestion to "do something" with the great Yellowstone wildfires of 1988 was conceived in terms of two basic understandings. First, as Grant's adviser, I clearly saw that Yellowstone, our nation's first National Park, served as a scientific and spiritual Mecca for him. Grant's passion to devote his scholarly efforts and creativity to solve one of the many geologic problems of the Yellowstone region had to be fulfilled. Second, as a member of the National Park Service and U.S. Forest Service's Greater Yellowstone Ecological Assessment Panel in 1988 and 1989, I saw that several challenges faced ecologists and managers charged with interpreting the consequences of the wildfires of 1988. With respect to magnitude of ecosystem responses and the associated implications for landscape management, it was unclear whether the scale of the 1988 fires could be considered natural. Did such extensive burning occur without the influence of human activity? We understood that the Holocene geologic record could provide the necessary clues to help answer this question if the geomorphic and sedimentologic consequences of the wildfires could be used successfully as an analog to interpret the Holocene depositional sequences within the valley floors. It was also our sincere goal as geomorphologists to provide research results that not only elucidated Yellowstone's Holocene history but also could be effectively used by Yellowstone's stewards, who are charged with managing these vast natural phenomena. Allowing the natural fires to burn and maintaining biotic associations that were observed by the first European visitors became a fundamental part of Yellowstone Park management in 1963, when Starker Leopold and a committee of ecologists were charged with addressing wildlife management issues. As pointed out by Schullery in 1989, Yellowstone National Park has been a controversial testing ground for the Leopold report, the 1988 wildfires providing the sternest test. Grant, Tim, and I all share in the hope that geomorphological studies such as ours will contribute to the understanding, maintenance, and preservation of ecological processes within this world treasure.

It is important that I acknowledge a few key individuals who have influenced my life and allowed me to pursue my fundamental passion, field geology, as well as shaped my career. First to my wife, Beth, and my children, Chris and Katie, I express my deepest gratitude for your patience and understanding of a field geologist's nomadic behavior and those long absences during my field excursions. To Lee Suttner and Judson Mead, two mentors who introduced me to Yellowstone and the Northern Rockies during Indiana University Geologic Field Camp in 1969, you gave me the opportunity to conduct my first independent research in fluvial systems and the first opportunity to teach and inspire others. My graduate adviser, Larry Lattman, has always served as a guide and trusted friend during my professional career. He set levels for my scientific standards and gave me the confidence to take those exceptional chances in life's journey. My sincere gratitude goes to a long list of field comrades who have provided intellectual stimulation, creative inspiration, and great friendship in a variety of settings, including soil trenches, deep arroyos, and flickering campfires. Special among these colleagues are Les McFadden, Ray Ingersoll, Tom Gardner, John Hawley, Adrian Harvey, and Aaron Yair.

Finally, I have been fortunate to live, work, and teach in New Mexico, where Kirk Bryan was a native son, was introduced to geology, and later carried out his scholarly studies. I would like to thank a colleague and friend who tutored me through his historical narratives of Kirk Bryan and his knowledge of the Rio Grande rift during my 15 years in New Mexico. Charles Stearns was Kirk Bryan's graduate student in 1950 when Bryan died "with his boots on" at an archaeological conference in Cody, Wyoming. Charles has given me insights into the man we acknowledge and revere with this award. In receiving this award, I would like to share some of Charles's insights which have touched my life. Kirk Bryan was an extraordinary teacher who considered nothing to be more important than his students and who found no greater satisfaction than when one of his students successfully led him to new concepts and thoughts. He guided his students to be independent thinkers and to be active collaborators, "not passive disciples." Bryan used the Rio Grande depression as a training ground because he fundamentally considered geomorphology to be a field science through which geologic debate is founded on thorough field observations. Finally, Bryan had an abiding concern for the relationship of humans to their environment that may have ultimately led him to scholarly studies involving geology and archaeology. Through this award, Kirk Bryan's achievements should serve as a measure for all geomorphologists and Quaternary geologists whose passion lies in teaching and in applying their knowledge to better the stewardship of landscapes.

Response by A. J. TIMOTHY JULL

I also would like to thank the Quaternary Geology and Geomorphology Division for this prestigious award. It certainly came as a complete surprise to me. Grant and Steve have already discussed many aspects of the work that is honored here. This work is an excellent example of what can be achieved by scientific collaboration. This collaborative project is also an excellent example of what can be achieved with accurate and precise dating of very small samples; we can get a lot of information from less than a milligram of carbon. It has been a pleasure to be able to work with two such dedicated scientists, whom I would describe as "gentlemen of science."

I would like to acknowledge the dedicated work of my colleagues and coworkers at the accelerator mass spectrometry (AMS) laboratory at the University of Arizona. Without their dedication to both precision and accuracy, and long hours of work, this particular study would not have been possible. It is easy to forget how much effort is expended by these less visible coworkers, who are no less important to the project.

The work honored here would not have been possible even 15 years ago. It is the continued development of AMS and its wide acceptance that made this type of work feasible.

I think this award is an acknowledgement by the QG&G Division of the contribution of those who do the painstaking dating work in the laboratory, in support of field studies in geomorphology. Clearly, the results of our study, which is honored here and which Grant has so ably described, shows how important the measurements are. A casual glance at GSA's program shows the number and detail of many radiocarbon and AMS applications, and how quickly they have become integrated into all manner of studies.

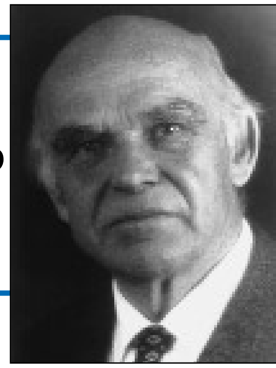
I have been extremely fortunate to be able to contribute to the AMS program at the University of Arizona. I can remember going to Tucson in 1981 and expecting to stay on a short-term postdoctoral position of 2–3 years. Little did I know at that time how successful this field and this particular enterprise would become.

I accept this award not only for myself but also in recognition of the contribution of all my colleagues at the University of Arizona, whose dedication and support made this possible.

STRUCTURAL GEOLOGY AND TECTONICS DIVISION CAREER CONTRIBUTION AWARD

presented to

HANS RAMBERG



Citation by CHRISTOPHER TALBOT and PETER HUDLESTON

Hans Ramberg was born 80 years ago in Trondheim on the west coast of Norway. After a strong grounding in chemistry and physics during his first degree at Oslo University (1943), Hans Ramberg's monumental career began with studies of structural and metamorphic problems in the Norwegian Caledonides for his Ph.D. in 1946 and, for the next five summers, in west Greenland. These field observations led to a deep personal drive to understand the fundamental thermodynamics behind mineral assemblages, his first 30 papers about petrogenesis and mineral chemistry, and his first influential book, *The Origin of Metamorphic and Metasomatic Rocks* (University of Chicago Press, 1952), when he was a professor of geochemistry at the University of Chicago (1948 to 1961).

As a research associate with the Carnegie Geophysical Laboratory in Washington (1952–1955) Hans turned his attention to the origin of structures in pegmatites. He first used engineering theory to attribute natural and experimental boudins with a variety of styles to extension along thin sheets induced by compression across them. His picture of tensile stresses concentrating mid-way along successive generations of boudins, which repeatedly halve in length, was developed in a single paper (1955) and is a concept that has been improved on very little since. Hans then went on to use fluid dynamics to explain the ratios of wavelength to thickness of ptygmatic folds in terms of buckling of thin viscous sheets. In a remarkable suite of about 13 papers (1959–1964), Hans differentiated passive from active folds and accounted for folds in multilayers that could be harmonic or disharmonic and major or minor on scales at which the influence of gravity is significant or not.

Hans returned to Scandinavia in 1961 as professor of mineralogy and petrology at Uppsala University, while maintaining his cross-Atlantic links as visiting professor at universities in Brazil (1959–1960) and Connecticut (1970–1975). His papers on theoretical petrogenesis then diminished to a trickle while he began establishing the tectonic laboratory now named after him. Having equipped himself, he began testing his mechanical theories, first in pure and simple shear boxes and then, having discovered their potential using an old example abandoned in the basement at Chicago, using two special centrifuges (which are still running, now with internal squeeze boxes and heating).

Until then, experimental rock mechanics was only about squeezing and pulling real rocks in real time. Hans's new approach was rigorously based on the principles of geometric, kinematic, and dynamic scaling. By increasing the body force exerted in nature by gravity, complicated 20×2 cm models painstakingly constructed with carefully chosen model materials easily handled at 1 g were then deformed at up to 2,000 g in a centrifuge for about ten minutes to simulate natural crustal structures that took tens of millions of years to form.

Within a few years of start-up, the centrifuges had become a cornucopia. Scaled models produced by Hans's assistants and students simulated crustal isostasy, rift valleys opening to oceans and the growth of continents (1964) and mantle convection. Other models were not only of individual structures such as glaciers (1964), plutons (1970), and salt domes (1970), but also the structural patterns then being mapped in orogens and sedimentary basins of all ages in every continent, from Archean granite-greenstone terrains through nappe-piles in the Alps to salt diapir provinces in extensional basins. Hundreds of these beautiful models illustrated basic theoretical concepts in his second book *Gravity, Deformation and the Earth's Crust* (Academic Press, London, 1967). This book, and its second edition in 1981, helped generations of geoscientists to reach new levels of understanding of the dynamics behind the phenomena they saw in the field or literature. Hans's introduction of scaled analogue experiments had a profound influence on structural geologists and tectonicians at a time when the concept of orogeny was floundering in countless categories of geosynclines. However, the almost simultaneous advent of the understanding of plate tectonics changed the focus of continental geologists toward the lateral forces that open and close oceans due to gravity on a larger scale; gravity overturns of hot crust tended to be relegated to the old "fixist" view. Hans's analogue experimental approach in his "baker's-shop-not-a-laboratory" were condemned by many of his contemporaries as "not real geology" but can now be considered as having been in the mainstream of the geosciences.

While analogue modeling laboratories were proliferating throughout industry and academia (many of the latter under the direction of former students or visitors to Uppsala), Hans was becoming addicted to computers. Thereafter, he left analogue modeling to others while he himself explored the potential of numerical modeling. His first paper in which numerical models joined theory and analogue experiments was with Harald Berner and Ove Stephansson in 1972. Hans went on to develop (1975) analytical theories for particle paths, displacements, and progressive strains and opened up yet another field, the spectrum of pure through subsimple and simple shear to oscillating supershears. On retirement in 1982, Hans was appointed emeritus professor and replaced by two chair positions. He continued publishing on concepts important for an understanding of tectonic processes (1986) and developed numerical models for the gravity spreading and sliding of nappes (1991). Long after his official retirement, when his early students and visitors were becoming professors throughout the world, Hans would appear in the laboratory, peer over shoulders and ask a few pertinent questions that would often change the course of the experiments. For his 70th birthday in 1989, Hans completed the cycle of his career by summarizing the thermodynamics not of petrogenesis but of rock deformation structures.

Many geologists from around the world made their way to Uppsala to visit Hans, and they were always made welcome. They were subjected to close questioning by Hans about their research and usually found their views challenged. Hans would listen intently during seminars, and he enjoyed the debates that followed, frequently playing the devil's advocate in his inimitable impish manner. He welcomed visitors to sit in on his lectures, which he then proceeded to give in English, switching occasionally back into a mixture of Swedish and Norwegian before catching himself.

Nobody could replace Hans Ramberg, but Christopher Talbot, who followed him into the difficult task of keeping the laboratory near the forefront of tectonic modeling, had first met Hans at a conference in the mid-1970s and asked why so many structures attributed to gravity were symmetric about inclined rather than vertical axes. The answer was, "I don't know, but come to Uppsala and find out."

As an undergraduate, Hans had married in 1942 one of his early school friends, Marie Louise (Lillemor), and for more than 50 years they have maintained a summer cottage on a Norwegian fjord the geology of which Hans described in 1973. He always maintained that "without field work there is no geology." Every summer it was open house in Vestranden to a stream of friends prepared to help Hans fish from his boat and be shown the local geology. Social evenings with Hans and Lillemor invariably ended with discussions on the implications of major advances in current science from black holes to the DNA molecule.

Including the two books, Hans Ramberg's publications number "only" about 100, but their extraordinary influence emphasizes their penetrating quality. Hans Ramberg is a giant of the geosciences, and we have been privileged to know and learn from him. He has accumulated many other awards in his career, but the Career Contribution Award of the Structural Geology and Tectonics Division of GSA is for his consistent focus on fundamentals and for his prominent role in bringing first metamorphic petrology and then structural geology and tectonics from descriptive exercises to theoretical and experimental sciences.

Response on behalf of HANS RAMBERG by PAUL H. REITAN

There is no one here more unhappy than I that Hans Ramberg, himself, is not here to receive the 1997 Career Contribution Award of the Structural Geology and Tectonics Division. Unfortunately, Hans is not well enough to be able to make the trip from Sweden; he has begun to show the symptoms of Alzheimer's disease and has started treatment for recently diagnosed cancer. So I, a student and friend of his for 45 years, was asked to be here on his behalf.

Let me begin by thanking you, Peter, and Chris Talbot, too, for the kind and generous citation. When it was read to Hans, his comment, typical of his wry humor, was: "Sounds like an interesting fellow." No one ever expects a recognition and distinction such as this, so it comes as one of life's major pleasant surprises. On Hans's behalf, I express his deep gratitude to the Structural Geology and Tectonics Division of the Geological Society of America. But that gratitude extends back over many years, to all of the people who helped him to accomplish what he has done during his career, including not only those who helped by support and encouragement, but also those who helped by being critical of him and his work. Both have served to stimulate and inspire his efforts. Those efforts have often gone in unconventional directions, and Hans has always been pleased that so many of his colleagues have been able to be receptive to his new approaches.

Right from the outset in the late 1930s at the University in Oslo he was encouraged to explore new avenues. There were giants in geology at that time in Norway. Victor Goldschmidt was breaking new ground in geochemistry. Tom Barth, freshly returned from the Geophysical Laboratory, was full of new ideas about crystal chemistry, mineralogy, and petrology. There was excitement and stimulus for the young Norwegian student, but at the same time there was insistence upon good grounding in chemistry and physics, which were recognized as essential tools with which to explore and test these new ideas. From Olaf Holtehahl, especially, Hans learned great respect and love for field work, and that the field is the source of the most basic facts of our science. Tom Barth had a special role in stimulating Hans with his assumption of professor-and-student-as-equals in the pursuit of answers to questions. Hans has always afterward valued this bedrock grounding for his approach to science that was formed there in Oslo at that time.

Soon afterward, as a new member of the faculty, he entered the environment of the University of Chicago in the late 1940s and early 1950s. There, too, there was freedom to go beyond the conventional routes; there was stimulation and inspiration and discussion in the search for new questions of importance and new ways of examining all questions, old and new. He thrived.

After Chicago he was called to the University of Uppsala in Sweden. Great faith was placed in him by the university and his colleagues there, but also through the years by the Swedish Natural Science Research Council and the Swedish Board of Technical Development, which generously supported and made possible the equipment needed to dare to do things that no one had done before. And again, he thrived.

Throughout his career he has valued highly his continuing free scientific exchange of ideas with colleagues in America, assisted by his association with the University of Connecticut and the many opportunities it provided to return to the United States.

At the universities where he has taught and led research, he has appreciated his many excellent colleagues, assistants, and students, and it is especially those who worked with him in Sweden who share this honor. At the risk of leaving someone out, I must nevertheless mention a few by name: Ove Stephansson, Harald Berner, John Dixon, Subir Ghosh, Håkan Sjöström, Rolf Häll, Surendra Saxena, Hans Annersten, Tom Ekström, Anders Wikström, Genene Mulugeta, Karl-Erik Strömgard, Olle Dahl, Alfred "Mike" Frueh, Ralph Kretz, Harmon Craig, George DeVore, and Bob Miller; all of them are valued in Hans's memory.

Finally, if Hans were here, I know he would close by acknowledging the single constant support from before his career began until after it was finished, his wife Lillemor, who has his undying gratitude.

GSAF UPDATE

Valerie G. Brown, Director of Development, GSA Foundation

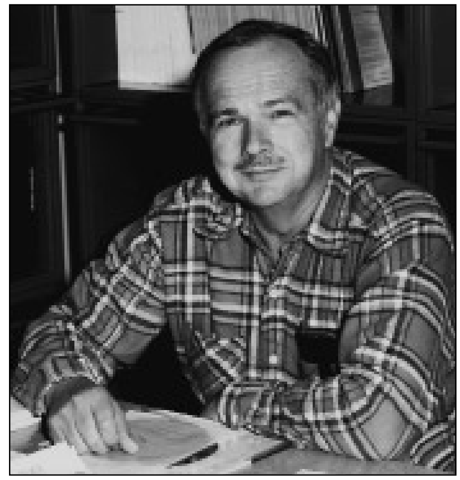
Fund to Honor Gene Shoemaker

Last September, with deepest regret, we carried news of the untimely death of Eugene M. Shoemaker in an auto accident in Australia while he and Carolyn, his wife and colleague, were there doing field work.

This month, with deepest gratitude, we bring news of a fund in Gene's memory established with the GSA Foundation. Gene's family received over $7,000 in memorial gifts from around the world—indisputable evidence of the great regard Gene inspired both professionally and personally. The many generous contributors are recognized in the accompanying list of donors.

In light of such regard, GSA is honored to have a part in perpetuating Gene's name and achievement. The fund will be administered in collaboration with the Planetary Geology Division to provide research grants for young geoscientists studying impact phenomena. The dedication is a singularly appropriate reminder that Gene and Carolyn made history with their identification of the Shoemaker-Levy comet, notable for its spectacular collisions with Jupiter.

Gene Shoemaker heeded John Donne's urging to "Go, and catch a falling star." Investments in the memorial fund will enable GSA to catch the rising stars and to help them on their way.



Gene Shoemaker

Gifts to the Eugene M. Shoemaker Crater Studies Fund may be sent to the GSA Foundation at P.O. Box 9140, Boulder, CO 80301. ■

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Committee on Investments Seeks Members

GSA's Committee on Investments (COI) is charged with the responsibility of overseeing the combined investment portfolio of the Society and Foundation. The current fair market value of that portfolio exceeds $27,000,000. The portfolio is managed with the goal of producing a total annual yield large enough to augment GSA's programs, while simultaneously growing the principal at a rate equal to or greater than the inflation rate.

To accomplish its task, the COI employs money managers and selects appropriate mutual funds. It is assisted by investment consultants who prepare quarterly investment performance reports for each segment of the portfolio, allowing the COI to rebalance the portfolio when necessary to perform its task and meet its objectives.

In all of its activities the COI functions within a framework provided by the Investment Policy Statement and Guidelines (July 1, 1997), approved by the GSA Council, which defines asset allocation constraints, acceptable risk, permissible investments, security guidelines, and the responsibilities of money managers, custodians, and consultants.

A valuable member of the Committee on Investments is one who functions not as a "stock picker," but as an evaluator of the performance of money managers and mutual funds, and one who adheres to the Investment Policy Statement or seeks to revise it with COI and Council concurrence. So the Committee on Investments needs skilled managers rather than investment gurus. Effective service on COI, however, does require an awareness of the performance of the U.S. economy and of financial markets.

In order to expand the pool from which future COI members will be selected, we need to know more about the experience many GSA members may have which would prepare them for COI service. Please write to Don Davidson, Executive Director, Geological Society of America, P.O. Box 9140, Boulder, CO 80301 describing your relevant experience. You may be surprised to find that you are exactly the kind of person we need.

Service on the Committee on Investments is not unduly burdensome. It usually involves a one-day meeting on the Saturday before the GSA annual meeting each fall, and a one-day meeting before the GSA Council meeting each May. Additionally there may be two or three conference calls each year.

If you think you might be interested in serving on the Committee on Investments and want to discuss any aspect of COI service with any member of the present committee (listed below), give any of us a call.

John Costa . . . . (360) 696-7811
David Dunn . . . . . . (972) 883-4044
Mclvin Hill. . . . . (714) 760-9789
Carel Otte, Chair. . . (818) 952-0176
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continued from p. 38

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STUDENT NEWS AND VIEWS

***Brian Exton,** University of Texas at Austin*

Student News and Views provides GSA membership with commentary on matters relating to undergraduate and graduate students in the geosciences. The Correspondent for Student News and Views welcomes comments and suggestions, sent to stumatts@geosociety.org.

How to Get Published—Quick and Easy

At the GSA Annual Meeting in Salt Lake City last October, I had the chance to speak with some of you about your interests and concerns. One of the surprising issues to come out of those informal discussions was a divided opinion on the value of the Internet to geoscience students. The clichés tell the story. On one side, many of you see it as the "World Wide Wait." Granted, a number of factors regarding the technology involved can seriously limit your access to the Web. Those problems notwithstanding, quite a few of you admitted to using it nearly every day. In fact, a recent survey of 650 two- and four-year colleges and universities reported that over 7 million students and faculty use the Internet regularly. I've even seen a bumper sticker on campus that read, "The Internet—Cruise It or Lose It!" Now that may be going a *bit* too far. But most of you agreed that at least the *potential* for creating a usable resource is there.

Here's a question for you: If a publisher were to offer to print your life story and distribute it to millions of people around the world for a few pennies a day, would you refuse? I didn't think so. So why is it that so few of you have Web pages of your own? The Internet provides a golden opportunity for you to get published, the quick and easy way. Okay, so it's not quite the same as a peer-reviewed article of original research in *Geology, Science,* or *Nature*. Actually, in some ways it's better—no deadlines, no editors, and the content is totally up to you (this means, of course, that the information found on the Internet is notoriously unreliable, but that's another subject altogether.)

Within my own department, which boasts one of the largest graduate geoscience programs in the country, only 20% of graduate students have personal Web pages. Imagine if only 20% of all people who owned phones had a telephone number. This figure is likely to increase because every graduate student now in the department has access to the departmental server. If your department has a Web site, students and student organizations should *insist* on being included on it. Disk space is cheap. A few megabytes is probably enough for everyone in your department to have a personal page describing your research interests and including a copy of your resume or CV. And don't be intimidated by the process of Web publishing. Many current versions of word processing programs will save documents in HTML format, and most servers have detailed instructions on how to upload and maintain your account.

Success on the Internet depends on how lofty your goals are. If you are a student doing research for a paper on some geology-related topic, there are quite a few excellent government and museum sites out there. If you are looking for employment, professional organizations (such as GSA) and university geoscience departments are the source for up-to-date listings of job announcements. If you simply want to let the world know that you are a participating member in the geoscience community, then take a few minutes and get published—quick!

A Related Note from Colombia

I received a message the other day from Uwe Martens, a geology student in Colombia, requesting to share "geological information" by e-mail. In my reply, I suggested several general Web sites for him to visit and a few newsgroups he might join. But it wasn't until his second message that I understood the gravity of his situation:

"Something I did not tell on my last mail was that here in Colombia it is extremely difficult to get good information about geology. Our libraries are very bad; we do not have good books nor journals. Books are very old, insufficient; books written in Spanish that deal with geology are too old and too few. So we must import books from the United States, which is very expensive. For example, I am doing a little investigation together with a graduate student about basic rocks (we are trying to perform geochronology of an ophiolitic sequence with the help of a university in Brazil. There is not even one institution in Colombia which is able to establish the age of a rock by means of radioactive substances). There is not even one book in our library which is specialized in basic volcanic rocks. There are a few old and general books about igneous petrology and that is all. So where am I supposed to get info? Well, I believe the Internet would be of big help for me!"

If geologists seek to answer questions on a truly global scale, there needs to be a healthy international geoscience community. In other words, we have a vested interest in the welfare of geoscientists *and geoscience students* in developing countries. They are our future colleagues and collaborators. With this in mind, how should I respond to Uwe's message? What are some ways that we students can help? Send me your suggestions, and perhaps we can solve Uwe's predicament.

Academia vs. Industry

One of the topics I am working on for an upcoming Student News and Views column addresses the nature of undergraduate and graduate geoscience programs as they relate to preparing future geologists. While some of us are interested in employment within academia, others desire positions with industry. How are courses within your own curriculum selected? Are you being adequately trained for what you want to do? Should there be unique programs to handle this dichotomy between academia and industry, or should course work be the same for both? Please share with me your opinions on this issue. ■

About People

The American Institute of Professional Geologists has honored GSA Member **Robert K. Merrill**, UNOCAL, Houston, with its Martin Van Couvering Memorial Award, Fellow **Marcus E. Milling**, American Geological Institute, Alexandria, Virginia, with the Ben H. Parker Memorial Medal, and Fellow **James E. Slosson**, Van Nuys, California, with the John T. Galey, Sr. Memorial Public Service Award.

GSA Fellow **Lee Woodward** is now an emeritus professor of geology at the University of New Mexico, retired after teaching for 33 years.

Shamsher Prakash Research Award

Nominations and applications for the 1998 Shamsher Prakash Research Award for Excellence in Geotechnical Earthquake Engineering are solicited from young professionals (40 years or younger on May 31, 1998). For complete package, contact Sally Prakash, Shamsher Prakash Foundation, Anand Kutir, 1111 Duane Ave., Rolla, MO 65401, fax 573-364-5572 (*51), Prakash@Novell.civil.umr.edu. The deadline for nominations and applications is *May 31, 1998.*

GSA EMPLOYMENT SERVICE

Looking for a New Job?

Are you looking for a new position in the field of geology? The GSA Employment Service offers an economical way to find one. Potential employers use the service to find the qualified individuals they need. You may register any time throughout the year. Your name will be provided to all participating employers who seek individuals with your qualifications. If possible, take advantage of GSA's Employment Interview Service, which is conducted each fall in conjunction with the Society's Annual Meeting. The service brings potential employers and employees together for face-to-face interviews. Mark your calendar for October 26–29 for the 1998 GSA Annual Meeting in Toronto, Ontario. To register, obtain an application form; then return the completed form, a one- to two-page résumé, and your payment to GSA headquarters. A one-year listing for GSA Members and Student Associates in good standing is $30; for nonmembers it is $60. NOTE TO APPLICANTS: If you plan to interview at the GSA Annual Meeting, GSA should receive your material no later than September 15, 1998. If we receive your materials by this date, your record will be included in the information employers receive prior to the meeting. Submit your forms early to receive maximum exposure! Don't forget to indicate on your application form that you would like to interview in October. Good luck with your job search! For additional information or to obtain an application form, contact T. Michael Moreland, Manager, Membership Services, Geological Society of America, P.O. Box 9140, Boulder, CO 80301, (303) 447-2020, or E-mail: member@ geosociety.org.

Looking for a New Employee?

When was the last time you hired a new employee? Did you waste time and effort in your search for a qualified geoscientist? Let the GSA computerized search file make your job easier. Simply fill out a one-page order form available from GSA—and the GSA computer will take it from there. You will receive a printout that includes applicants' names, addresses, phone numbers, areas of specialty, type of employment desired, degrees held, years of professional experience, and current employment status. Résumés for each applicant are also sent with each printout at no additional charge. For 1998, the cost of a printout of one or two specialty codes is $175. (For example, in a recent job search for an analyst of inorganic matter, the employer requested the specialty codes of geochemistry and petrology.) Each additional specialty is $50. A printout of the applicant listing in all specialties is available for $350. If you have any questions about your personalized computer search, GSA Membership Services will assist you. Also, employers are invited to post the position announcement on the GSA Web site for three months at no cost. The GSA Employment Service is available year round; however, GSA also conducts the Employment Interview Service each fall in conjunction with the Society's Annual Meeting (this year in Toronto, Ontario, October 26–29). You may rent interview space in half-day increments, and GSA staff will schedule all interviews with applicants for you. In addition, GSA offers a message service, complete listing of applicants, copies of résumés at no additional charge, and a posting of all job openings. For additional information or to obtain an order form to purchase a printout, contact T. Michael Moreland, Manager, Membership Services, Geological Society of America, P.O. Box 9140, Boulder, CO 80301, (303) 447-2020, or E-mail: member@geosociety.org.

ANNOUNCEMENT AND CALL FOR PAPERS

AADE INDUSTRY FORUM ON

Pressure Regimes in Sedimentary Basins and Their Prediction

September 2-4, 1998
Del Lago Resort at Lake Conroe, North of Houston, TX
Sponsors: AADE, CONOCO, DOE and GRI
Format: SEG Summer Workshop Format

REGISTRATION

Pre-registration Fee is $800 and includes 4 nights of accommodations at the Resort and 3 meals per day during the conference. Attendance is limited to 200 people.

PROGRAM

To bring together geoscientists and engineers who deal with all aspects of pore pressure in sedimentary basins. Session topics will include (1) shale mechanics, (2) overpressure mechanisms, (3) pore pressure and fracture gradient prediction, (4) pressure at the prospect and basin scale, (5) pressure management while drilling, and (6) frontier issues.

ABSTRACTS AND PUBLICATION

Extended abstracts will be published in a preprint volume (6 page maximum with text and figures). **The abstract deadline is March 31, 1998.**

INFORMATION

For additional information on the Forum contact the meeting chairman
Dr. Alan R. Huffman, Manager,
Seismic Imaging Technology, Conoco Inc.
by fax at 580/767-6067, or
e-mail at alan.r.huffman@usa.conoco.com

CALL FOR NOMINATIONS

To reward and encourage **teaching excellence** in beginning professors of earth science at the college level, the Geological Society of America announces:

THE SEVENTH ANNUAL

Biggs Award

For Excellence In Earth Science Teaching For Beginning Professors

ELIGIBILITY: All earth science instructors and faculty at 2- and 4-year colleges who have been teaching full time for 10 years or less. (Part-time teaching is not counted in the 10 years.)

AWARD AMOUNT: An award of $500 is made possible as a result of support from the Donald and Carolyn Biggs Fund.

NOMINATION PROCEDURE: For nomination forms write to Edward E. Geary, Director of Educational Programs, Geological Society of America, P.O. Box 9140, Boulder, CO 80301.

DEADLINE: Nominations and support materials for the 1998 Biggs Earth Science Teaching Award must be **received by April 30, 1998.**

March *BULLETIN* and *GEOLOGY* Contents

The Geological Society of America
BULLETIN
Volume 110, Number 3, March 1998

CONTENTS

GEOLOGY

VOLUME 26
NO. 3
P. 193–288
MARCH 1998

More GSA Company, Consultant/Self-Employed and Government Representatives Needed

In the mid-1980s, GSA launched a new representative program targeting companies, agencies, and consultants throughout the country. The purpose was to broaden GSA's representation to include all employment sectors. The program was modeled on the successful campus representative program that began in 1979 and now includes 550 representatives at colleges and universities throughout North America.

We now have 131 company, 92 agency, and 45 consultant GSA representatives. However, we need more volunteers. Our goal is to designate a representative at all major company offices and governmental agencies throughout the country. We want to develop a similar liaison with GSA members who are self-employed and serve as consultants. They would also represent major cities and geographic regions.

Representatives serve as liaisons between GSA headquarters and their constituency in a particular city or region. They provide information on the programs and benefits of the Society to other members in the region and explain to prospective members the advantages of joining GSA. Each representative receives a notebook containing complete information on all GSA programs, activities, publications, meetings, and other benefits that the Society provides its membership.

We need your help to continue this communication link between GSA headquarters and the membership of the Society. If you are a Member, Student Member, or Fellow (not Student Associate) and are interested in serving GSA as a representative for your company, agency, or group of the employment sector, please contact T. Michael Moreland, Manager, Membership Services, Geological Society of America, P.O. Box 9140, Boulder, CO 80301, (303) 447-2020 or E-mail: tmorelan@geosociety.org.

CALENDAR

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

1998 Penrose Conferences

May

May 14–18, **Linking Spatial and Temporal Scales in Paleoecology and Ecology,** Solomons, Maryland. Information: Andrew S. Cohen, Dept. of Geosciences, University of Arizona, Tucson, AZ 85721, (520) 621-4691, fax 520-621-2672, acohen@geo.arizona.edu.

June

June 4–12, **Evolution of Ocean Island Volcanoes,** Galápagos Islands, Ecuador. Information: Dennis Geist, Dept. of Geology, University of Idaho, Moscow, ID 83844, (208) 885-6491, fax 208-885-5724, dgeist@uidaho.edu.

July

July 4–11, **Processes of Crustal Differentiation: Crust-Mantle Interactions, Melting, and Granite Migration Through the Crust,** Verbania, Italy. Information: Tracy Rushmer, Dept. of Geology, University of Vermont, Burlington, VT 05405, (802) 656-8136, fax 802-656-0045, trushmer@zoo.uvm.edu.

September

September 13–17, **Ophiolites and Oceanic Crust: New Insights from Field Studies and Ocean Drilling Program,** Marshall, California. Information: Yildirim Dilek, Dept. of Geology, Miami University, Oxford, OH 45056, (513) 529-2212, fax 513-529-1542, dileky@muohio.edu.

1998 Meetings

May

May 22–27, **Geochemistry of Crustal Fluids,** Aghia Pelaghia, Greece. Information: Josip Hendekovic, European Science Foundation, 1 quai Lezay-Marnésia, 67080 Strasbourg Cedex, France, phone 33-3-8876-7135, fax 33-3-8836-6987, euresco@esf.org, http://www.esf.org/euresco.

June

June 4–8, **9th Symposium on the Geology of the Bahamas and Other Carbonate Regions,** Bahamian Field Station, San Salvador Island, Bahamas. Information: H. Allen Curran, Dept. of Geology, Smith College, Northampton, MA 01063, (413) 585-3943, fax 413-585-3786, acurran@science.smith.edu.

July

July 26–30, **The Society for Organic Petrology (TSOP) and Canadian Society for Coal Science and Organic Petrology (CSCOP) Joint Annual Meeting,** Halifax, Nova Scotia. Information: P. K. Mukhopadhyay, (902) 453-0061, fax same, muki@ns.sympatico.ca, http://agc.bio.ns.ca/tsophalifax98.

September

September 15–18, **Western States Seismic Policy Council 20th Annual Conference,** Pasadena, California. Information: Western States Seismic Policy Council, 121 Second St., 4th Floor, San Francisco, CA 94105, (415) 974-6435, fax 415-974-1747, wsspc@wsspc.org.

October

October 2–4, **New York State Geological Association 70th Annual Meeting,** Binghamton, New York. Information: H. Richard Naslund, Dept. of Geological Sciences, SUNY, Binghamton, NY 13902-6000, (607) 777-2264, fax 607-777-2288, naslund@binghamton.edu, http://www.library.csi.cuny.edu/dept/as/geo/nysga.html).

October 3–8, **American Institute of Professional Geologists Annual Meeting,** Baton Rouge, Louisiana. Information: M. B. Kumar, P.O. Box 19151, Baton Rouge, LA 70893, (504) 342-5501, fax 504-342-4438.

October 4–9, **International Association for Mathematical Geology 4th Annual Meeting,** Island of Ischia, Italy. Information: Antonella Buccianti, Dept. of Earth Sciences, Univ. Florence, Via G. La Pira, 4 50121 Florence, Italy, phone 39-55-275-7496, fax 39-55-284-571, buccianti@cesit1.unifi.it, http://www.unina.it/dgv/iamg98.html.

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

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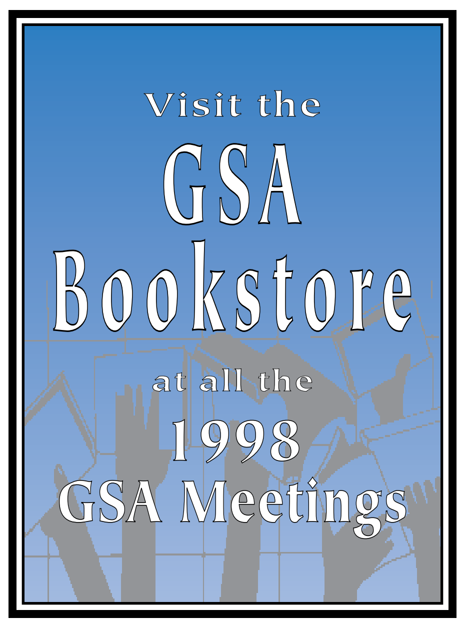

GSA ANNUAL MEETINGS

1998

October 26–29
Metro Toronto Convention Centre
Sheraton Centre Toronto Hotel
www.geosociety.org/meetings/98

Abstracts due: ***July 13***

GENERAL CHAIRS
Jeffrey J. Fawcett, *University of Toronto*
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TECHNICAL PROGRAM CHAIRS
Denis M. Shaw, *McMaster University*
Andrew Miall, *University of Toronto*

FIELD TRIP CHAIRS
Pierre Robin, Henry Halls
University of Toronto

Both technical program and field trip deadlines have passed.

ASSEMBLY OF A CONTINENT

See April GSA Today *for theme sessions, symposia, and the New! Pardee keynote symposia.*

1999

Denver, Colorado • October 25–28
Colorado Convention Center

GENERAL CO-CHAIRS
Mary J. Kraus, David Budd, *University of Colorado*

TECHNICAL PROGRAM CHAIRS
Craig Jones, G. Lang Farmer, *University of Colorado*

Due date for symposia and theme proposals: ***January 6, 1999***

CALL FOR FIELD TRIP PROPOSALS

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

Alan Lester
Department of Geological Sciences
University of Colorado
Campus Box 399
Boulder, CO 80309-0399
(303) 492-6172
fax 303-492-2606
alan.lester@colorado.edu

Bruce Trudgill
Department of Geological Sciences
University of Colorado
Campus Box 399
Boulder, CO 80309-0399
(303) 492-2126
fax 303-492-2606
bruce@lolita.colorado.edu

FUTURE MEETINGS

2000 Reno, Nevada
November 13–16
2001 Boston, Massachusetts
November 5–8
2002 Denver, Colorado
October 28–31

For information on any GSA Meeting call the GSA Meetings Department.

1-800-472-1988 or
(303) 447-2020, ext. 113
meetings@geosociety.org

Or see GSA's Web page at
http://www.geosociety.org

GSA SECTION MEETINGS

1998

NORTHEASTERN SECTION, March 19–21, Holiday Inn by the Bay, Portland, Maine. Information: Stephen G. Pollock, Dept. of Geosciences, University of Southern Maine, Gorham, ME 04038, (207) 780-5350, fax 207-780-5167, pollock@usm.maine.edu.

NORTH-CENTRAL SECTION, March 19–20, Ohio State University, Columbus, Ohio. Information: William I. Ausich, Geological Sciences, Ohio State University, 275 Mendenhall, 125 S. Oval Mall, Columbus, OH 43210, (614) 292-0069, fax 614-292-7688, ausich.1@osu.edu.

SOUTH-CENTRAL SECTION, March 23–24, OU Continuing Education Center, Norman, Oklahoma. Information: M. Charles Gilbert, School of Geology and Geophysics, University of Oklahoma, 100 E. Boyd St., Suite 810, Norman, OK 73019-0628, (405) 325-4424, fax 405-325-3140, mcgilbert@ou.edu.

SOUTHEASTERN SECTION, March 30–31, Embassy Suites, Charleston, West Virginia. Information: Larry D. Woodfork, West Virginia Geological and Economic Survey, P.O. Box 879, Morgantown, WV 26507-0879, (304) 594-2331, fax 304-594-2575, woodfork@geosrv.wvnet.edu.

CORDILLERAN SECTION, April 7–9, California State University, Long Beach, California. Information: Stan Finney, Dept. of Geological Sciences, California State University, Long Beach, CA 90840, (562) 985-8637, scfinney@csulb.edu. *Preregistration Deadline: March 6, 1998.*

ROCKY MOUNTAIN SECTION, May 25–26, Northern Arizona University, Flagstaff, Arizona. Information: Larry Middleton, Dept of Geology, Box 4099, Northern Arizona University, Flagstaff, AZ 86011, (520) 523-2492, Larry.Middleton@nau.edu. *Preregistration Deadline: April 24, 1998.*

CLASSIFIED ADVERTISING

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Positions Open

MOUNT HOLYOKE COLLEGE
VISITING ASSISTANT PROFESSOR

The Department of Geography & Geology at Mount Holyoke College invites applications for a full-time, nine-month appointment as a visiting assistant professor of geology for the 1998–99 academic year. Teaching responsibilities for this position include mineralogy (with lab), petrology (with lab), and one other course or seminar at the undergraduate level in an area to be jointly decided upon by the department and the candidate. This person may also be asked to supervise independent research with one or two undergraduate students. Qualified applicants are expected to hold a Ph.D. in geology and have some teaching experience. To apply, send curriculum vitae and three letters of recommendation to: Dr. Mark McMenamin, Chair, Search Committee, Mount Holyoke College, Department of Geography & Geology, 50 College Street, South Hadley, MA 01075-6419.

Applications will be reviewed as received, but must be received by March 31, 1998. Mount Holyoke is committed to fostering cultural diversity and multicultural awareness in its faculty, staff and students and is an Affirmative Action/Equal Opportunity employer. Women and minorities are especially encouraged to apply.

U.S. REPRESENTATIVE TO THE JOIDES OFFICE
OCEAN DRILLING PROGRAM

The JOI/U.S. Science Support Program (USSSP, see www.joi-odp.org) is seeking applications from U.S. scientists for a 2-year position as the U.S. representative in the JOIDES Scientific Planning Office, beginning January 1, 1999. The JOIDES Office, currently in Woods Hole, Massachusetts (www.whoi.edu/joides) will move to GEOMAR (www.geomar.de), in Kiel, Germany, for the period 1999 through 2000. The successful applicant will provide high level executive support for the Chair of the JOIDES Scientific Community. Duties may include managing drilling proposals submitted to JOIDES, liaison to one or more panels within the advisory structure, editing the *JOIDES Journal*, and assisting the Science Committee Chair in preparation of meeting agendas, agenda books, and meeting minutes. The position requires excellent communication skills and international travel.

A Ph.D. in earth sciences or related fields and previous involvement with the Ocean Drilling Program (www-odp.tamu.edu) are desirable. Salary, benefits, and relocation costs will be negotiated. Qualified applicants should submit a curriculum vitae and three references to Ms. Denise Lloyd, JEX, JOI/U.S. Science Support Program, Joint Oceanographic Institutions, 1755 Massachusetts Avenue, NW, Suite 800, Washington, DC 20036-2102. JOI will begin reviewing applications immediately, and will continue until an appointment is made. EOE.

FACULTY POSITION IN SURFICIAL PROCESSES
FRANKLIN & MARSHALL COLLEGE

The Department of Geosciences invites applications for an entry-level visiting faculty appointment for the academic years 1998-99 and 1999–2000. The successful candidate will teach undergraduate courses in geomorphology, hydrology, introductory environmental geology, and a seminar in environmental problems. Expertise and the ability to teach a course in GIS is also desirable.

A Ph.D. in the geosciences, an ongoing program of research and some teaching experience are required. Women and members of minority groups are particularly encouraged to apply. Please send letter of application including a statement of teaching and research interests, curriculum vitae, graduate transcripts, and three letters of recommendation to: Rob Sternberg, Chair, Department of Geosciences, Franklin & Marshall College, Lancaster, PA 17604-3003 (R_Sternberg@FandM.edu). Review of applications will begin March 16 and continue until the position is filled.

Franklin & Marshall is a highly selective liberal arts college with a commitment to the integration of teaching and research. For additional departmental information, see our web page at http://www.fandm.edu/departments/Geosciences/Geosciences.html EOE/AA.

GEOLOGIST, ARKANSAS TECHNICAL UNIVERSITY

Assistant professor, tenure-track. Arkansas Tech University, a four-year institution emphasizing undergraduate education, seeks a person holding or nearing completion of a Ph.D. in geology who has well developed microcomputer skills for a position beginning in August 1998. Teaching duties: Physical Geology, Historical Geology, Invertebrate Paleontology, Geomorphology, Stratigraphy, and Field Geology. Application must include: vitae, brief statements of teaching style and research interests, transcripts, and three letters of recommendation. Closing date: March 31, 1998 or until filled. Send to: Dr. R. R. Cohoon, Dean, School of Physical and Life Sciences, Arkansas Tech University, Russellville, AR 72801. AA/EOE. http://www.atu.edu/physci/pls2.htm

UCLA
NEOTECTONICS FACULTY POSITION

The Department of Earth and Space Sciences, University of California, Los Angeles, invites applications for a ladder faculty position at the assistant or associate professor level in the general areas of neotectonics, paleoseismology, quantitative geomorphology, and surficial processes. We are particularly interested in candidates who can integrate field observations with one of the following disciplines: (1) quantitative modeling of landform evolution due to interation of neotectonics and surficial processes, (2) monitoring surface deformation and evolution using space geodetic techniques (e.g., radar interferometry, SPOT imagery, GPS), (3) modeling crustal and mantle dynamics using patterns and histories of Quaternary land surface deformation, (4) earthquake hazard assessments, and (5) Quaternary chronology of land surfaces and dating offset geologic features along active faults. The Department has active programs in monitoring and forecasting of southern Californian earthquakes, the tectonics of Asia and North American Cordillera, mantle dynamics, and planetary sciences. Interested applicants should send a resume, a list of three references, and other relevant documentation to: Neotectonics Search Committee, Department of Earth and Space Sciences, P.O. Box 1567, University of California, Los Angeles, CA 90095-1567.

Consideration of applicants will begin on March 1, 1998, and continue until the position is filled. The University of California is an equal opportunity employer.

OKLAHOMA GEOLOGICAL SURVEY
POSITION IN GEOLOGICAL FIELD MAPPING

The Oklahoma Geological Survey is seeking to fill a position in surficial and bedrock geologic mapping. The person selected will be expected to work effectively in field mapping either on single projects or as part of a team on larger efforts. A major part of the OGS geologic mapping program is through the federal National Cooperative Geologic Mapping Act that provides in part for matching funds to state geological surveys to prepare geological maps of priority areas in each state, nominally at a scale of 1:24,000. In addition, digital maps are developed from this more detailed information at a nominal scale of 1:100,000.

The position will be filled at a grade level appropriate to the individual's qualifications and experience.

Individuals interested in being considered for this position should have the following minimum qualifications: A graduate degree in geology with demonstrated training in geologic field methods, a minimum of three years of post-educational demonstrated experience in surficial and/or bedrock geologic field mapping, a demonstrated ability to prepare geologic maps and reports suitable for publication, and good communication skills and ability to complete projects in a timely manner.

To submit an application for this position, please provide the following information: a resume that includes a description of your educational and professional experience, including a list of published and unpublished maps and reports, a certified copy(ies) of transcripts of all college-level work, names and addresses of three individuals who are capable of evaluating your experience in geologic mapping, and a written description of your qualifications in geologic mapping that documents at least three years of geologic-mapping experience.

The application should be sent to: Charles J. Mankin, Director, Oklahoma Geological Survey, 100 East Boyd, Room N-131, Norman, OK 73019-0628.

The closing date for the receipt of applications is March 31, 1998.

The Oklahoma Geological Survey adheres to the policy of The University of Oklahoma as an equal opportunity employer.

USGS
EASTERN REGIONAL GEOLOGIST

U.S. Geological Survey–Eastern Regional Geologist, Senior Executive Service Position – Reston, VA. Salary range from $106,412 to $125,900. Recruitment Bulletin No.: SES-98-1. Open 2/5/98 – Close 3/23/98. Nationwide–Applicants must be U.S. Citizens. All Qualified Applicants may apply. Contact: Sally Lyberger 703-648-6131. Electronic Announcements can be obtained from: http://www.usgs.gov/doi/avads/

The U.S. Geological Survey is an equal opportunity employer. Selection for this position shall be determined on the basis of merit without discrimination for any reason such as race, color, age, religion, sex, national origin, political preference, labor organization affiliation or nonaffiliation, marital status, or nondisqualifying handicap.

The Regional Geologist is the representative of the Chief Geologist in the Region and is the principal agent for the implementation of policies and objectives of the division. Position has full responsibility for the development, execution, coordination, and direction of programs and plans.

The position is interdisciplinary and may be classified as a: Geologist, Physical Scientist, Geophysicist, Hydrologist, Geochemist, Mathematician, Biologist.

INDIANA UNIVERSITY
DEPARTMENT OF GEOLOGICAL SCIENCES
FACULTY POSITION IN BIOGEOCHEMISTRY

The Department of Geological Sciences, Indiana University, Bloomington, invites applications for a tenure-track faculty position. Our objective is to enhance our research strengths in the reconstruction of biogeochemical processes in modern settings and in the geological record through the use of isotopic and molecular proxies.

Applications are encouraged from individuals whose principal interests lie in stable isotopic biogeochemistry, especially those with expertise in the fields of paleoclimatology/paleoceanography, geomicrobiology, chemosynthetic ecosystems or extraterrestrial biochemistry.

Preference will be given to candidates whose research activities can be expected to both utilize and further develop existing analytical facilities within the biogeochemical laboratories. The level of the appointment will be commensurate with qualifications; applicants are expected to possess some post-doctoral experience.

Applications should include a vitae and a statement of research interests accompanied by the names of at least three references with their contact addresses (both mail & e-mail) and numbers (phone & fax). They should be submitted to professor Lisa Pratt, Department of Geological Sciences, Indiana University, Bloomington, IN 47405-1403. For further information about the position please contact either Lisa Pratt (e-mail: prattl@indiana.edu; phone 812-855-9203), or Simon Brassell (e-mail: simon@indiana.edu; phone 812-855-3786).

Indiana University is an Equal Opportunity/Affirmative Action Employer.

Services & Supplies

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

Opportunities for Students

Teaching Assistantships. Geology Department at California State University has teaching assistantships available for students wishing to pursue a M.S. in geology. Appointment carries tuition waiver and $10,000 salary for academic year. Department strengths are in the areas of sedimentary geology, petroleum geology, geophysics, hydrogeology and geochemistry, structural geology, and environmental geology. Bakersfield is located in the heart of California's petroleum and agricultural areas and abundant opportunities exist for industry-supported thesis projects. For additional information and application materials contact: Robert Horton, Graduate Coordinator, Department of Geology, California State University, Bakersfield, CA 93311-1099. (805) 664-3059 or visit the department's web site at http://www.geol.csubak.edu/Geology/

Student Opportunities. University of Kentucky. Graduate student fellowships. The Department of Geological Sciences announces a one-time Fellowship with an annual stipend of $9,800 (plus tuition and fees) for graduate study leading to the M.S. or Ph.D. degrees in field-related geology. The Department also announces four $3,000 Academic Achievement Fellowships as "add ons" to teaching-assistant ($9,600) and tuition fellowships for the Fall of 1998. These Academic Achievement Fellowships are renewable for two (M.S.) or three (Ph.D.) years. The Geological Sciences faculty is currently active in coal geology, hydrogeology, paleontolgy, sedimentology, tectonics, metamorphic and structural petrology, and near-surface seismic studies. For more information visit our website at http://www.uky.edu/ArtsSciences/Geology. Interested students should have a BS degree in geology or a related area and submit general GRE scores, three letters of reference and university transcripts.

Application forms can be obtained via the University webpage at http://www.rgs.uky.edu/gs/gradhome.htm or by calling 1-800-528-4508 or by e-mailing Dr. Kieran O'Hara at geokoh@pop.uky.edu. Our mailing address is Department of Geological Sciences, University of Kentucky, Lexington, KY 40506-0053. Applications will be considered until the Fellowships are awarded. The University of Kentucky is an equal opportunity employer.

JOI/USSAC Ocean Drilling Fellowships. JOI/U.S. Science Advisory Committee is seeking Ph.D. and M.S. degree candidates of unusual promise and ability who are enrolled at U.S. institutions to conduct research compatible with that of the Ocean Drilling Program. April 15, 1998 is the next fellowship application deadline for both shipboard and shorebased research proposals. Shipboard research is related to future ODP legs on which students wish to sail as scientists. Shorebased research may be directed towards broader themes or the objectives of a specific DSDP or ODP leg -- past, present, or future.

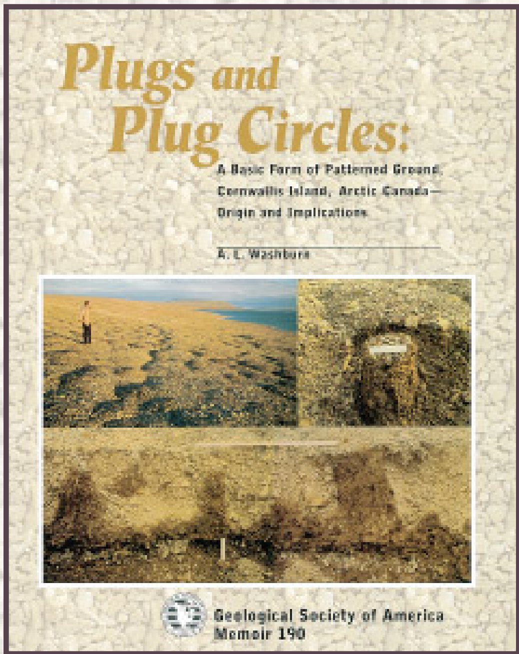
Shipboard proposals submitted for the upcoming April 15 deadline should be based on the following ODP legs: Leg 182 Great Australian Bight, Leg 183 Kerguelen Plateau, Leg 184 East Asia Monsoon, Leg 185 Izu-Mariana, and Leg 186, W. Pacific Seismic Net/Japan Trench, and Leg 187 Australia-Antarctic Discordance. Fellowship candidates wishing to participate as shipboard scientists must also apply to the ODP Manager of Science Services in College Station, TX. A shipboard scientist application form and leg descriptions are included in the JOI/USSAC Ocean Drilling Fellowship application packet.

Both one-year and two-year fellowships are available. The award is $22,000 per year to be used for stipend, tuition, benefits, research costs and incidental travel, if any. Research may be directed toward objectives of a specific leg or to broader themes. For more information and to receive an application packet contact: JOI/USSAC Ocean Drilling Fellowship Program, Joint Oceanographic Institutions, Inc., 1755 Massachusetts Ave., NW, Suite 800, Washington, DC 20036-2102 (Andrea Johnson; Tel: 202-232-3900, ext. 213; e-mail: ajohnson@brook.edu).

Graduate Research Assistantship in surficial processes at University of Cincinnati. The Department of Geography has received an award from NSF's arctic Systems Science program to collect and synthesize standardized climatic, permafrost, and active-layer data at stations located throughout the circumarctic region. The award provides for a full-time doctoral student. We seek a well-trained individual with broad interests in the physical science of cold regions. Applicants should also have substantial skills in one or more aspects of geographic information science, such as spatial database management, GIS, and/or spatial statistics. Primary project-related responsibilities will be management and synthesis of climatic, biological, and geocryological data. The position may also entail field work in Alaska (and possibly Russia). Position begins 1 September 1998. Salary is competitive; and the position includes staff benefits and tuition remission. Interested individuals should contact Dr. Kenneth M. Hinkel at Ken_Hinkel@compuserve.com or (513) 556-3241. Screening will begin in March 1998.

Environmental & Engineering Geoscience Contents

Volume III, Number 4, Winter 1997



A. L. Washburn, 1997

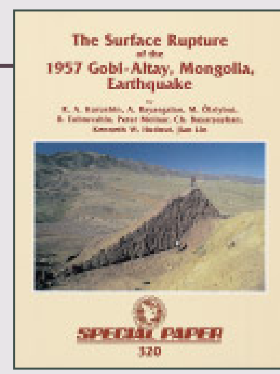
Patterned ground, encompassing circles, nets, polygons, and stripes, indicate soil, temperature, hydrologic, and other environmental conditions, past and present. Plug circles and plugs, a variety of patterned ground, occur in both nonsorted and sorted forms in permafrost environments. Study in the Canadian High Arctic and a review of hypotheses of origin support the conclusion that plug circles and plugs are diapiric forms resulting from frost heaving, and that surfaceward seepage accounts for many occurrences. Plug circles and plugs are perhaps transitional to larger forms with prominent stoney ringlike borders of the classic Spitsbergen variety of sorted circle, whose origin is commonly linked to circulatory soil processes; details of that origin are still somewhat problematical.

MWR190, 102 p., indexed, ISBN 0-8137-1190-8, $45.00, Member price $36.00

Eva Interglaciation Forest Bed, Unglaciated East-Central Alaska: Global Warming 125,000 Years Ago

edited by T. L. Péwé and others, 1997

The ancient, boreal Eva forest, buried in frozen loess of the subarctic, forms the centerpiece in this evaluation of the time and nature of the environment during an interglaciation warmer than that of the present. This book brings together results of examination of hundreds of loess exposures over the past 50 years, when loess faces were still frozen in gold-mining excavations, and new data on the character and age of the deposits from fission-track dating of tephra, paleomagnetism of the loess, thermoluminescence dating of loess, and new radiocarbon dating by liquid scintillation. Dendrochronology studies of trees and $^{13}C/^{12}C$ isotopic ratios of wood from the Eva forest bed are compared to those from trees of the modern boreal forest. This last interglaciation of 125,000 years ago is demonstrated for the first time to be a period of major erosion of loess and deep and rapid thawing of permafrost, followed by emplacement of the Eva forest bed. During the past 100,000 years, the treeless steppe environment returned and the deposits were refrozen.



The Surface Rupture of the 1957 Gobi-Altay, Mongolia, Earthquake
by R. A. Kurushin and others, 1997

The 1957 Gobi-Altay earthquake is the last major earthquake (M ~ 8) to occur in a continental region. The full complement of processes that distinguishes continental tectonics from plate tectonics—internal deformation of blocks, conjugate faulting, variations in amounts of slip along faults, block rotations about vertical axes, basement folding, and even the formation of new faults (through fault-bend folding at the earth's surface)—occurred in 1957 and remain clearly exposed in the arid environment of the Gobi-Altay. Because of the variety of styles and the extent of deformation, the subparallel surface ruptures, ~25 km apart, provide a microcosm of intracontinental mountain building at a large scale.

SPE320, 160 p., ISBN 0-8137-2320-5, $69.00, Member price $55.20

Volumes are 8-1/2" x 11". Prices include ordinary shipping and handling.

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