Vol. 5, No. 3 March 1995

GSA TODAY

A Publication of the Geological Society of America

INSIDE

Late Devonian Oceanic Anoxic Events and Biotic Crises: "Rooted" in the Evolution of Vascular Land Plants?

Thomas J. Algeo, *H. N. Fisk Laboratory of Sedimentology, Department of Geology, University of Cincinnati, Cincinnati, OH 45221-0013*
Robert A. Berner, *Department of Geology and Geophysics, Yale University, New Haven, CT 06511*
J. Barry Maynard, *H. N. Fisk Laboratory of Sedimentology, Department of Geology, University of Cincinnati, Cincinnati, OH 45221-0013*
Stephen E. Scheckler, *Departments of Biology and Geological Sciences, Virginia Polytechnic Institute, Blacksburg, VA 24061*

ABSTRACT

Evolutionary developments among vascular land plants may have been the ultimate cause for oceanic anoxic events, biotic crises, global climate change, and geochemical and sedimentologic anomalies of Late Devonian age. The influence of vascular land plants on weathering processes and global geochemical cycles is likely to have increased substantially during the Late Devonian owing to large increases in root biomass associated with development of (1) arborescence (tree-sized stature), which increased root penetration depths, and (2) the seed habit, which allowed colonization of drier upland areas. We hypothesize that rapidly increasing root mass led to transient intensification of the rate of soil formation and to permanent gains in the thickness and areal extent of deeply weathered soil profiles. In the short term, greater pedogenesis caused increased sediment yields owing to episodic disturbance of developing soils and to increased nutrient fluxes to the oceans as a result of enhanced chemical weathering. Long-term effects included increased landscape stabilization, drawdown of atmospheric CO_2 through enhanced uptake in silicate weathering and burial of organic carbon, and global cooling. Coeval terrestrial paleobotanic developments and marine anoxic and extinction events are likely to have been linked causally through transient nutrient pulses that caused eutrophication of semirestricted epicontinental seaways, stimulating marine algal blooms. Correlativity of black shale horizons and episodes of extinction of tropical marine benthos implicates oceanic anoxia rather than global cooling as the proximate cause of the Late Devonian biotic crisis.

INTRODUCTION

The origin of the Late Devonian biotic crisis is a subject of continuing debate. Although various causes have been proposed, including bolide impacts, oceanic overturn, sea-level changes, and global climate change (Copper, 1986; Geldsetzer et al., 1987; McGhee, 1991; Claeys et al., 1992), none has gained general acceptance. Few, if any, of these theories have attempted to link Late Devonian extinctions to coeval paleobotanic events; however, the Givetian–Famennian epochs are characterized by important paleobotanic developments, including large increases in the maximum size of vascular land plants, in the biomass and complexity of floral communities, and in the geographic distribution of terrestrial vegetation (Fig. 1; Scheckler, 1986; Gensel and Andrews, 1987). In this paper, we propose that evolutionary innovations among vascular land plants were the ultimate cause of both the Late Devonian biotic crisis and a variety of coeval sedimentologic and geochemical anomalies. The main lines of evidence supporting this hypothesis are (1) close temporal relations between Late Devonian paleobotanic developments and major episodes of oceanic anoxia and mass extinction, and (2) a model that successfully links these paleobotanic developments to the Late Devonian biotic crisis and coeval sedimentologic and geochemical anomalies through changes in pedogenic rates and processes.

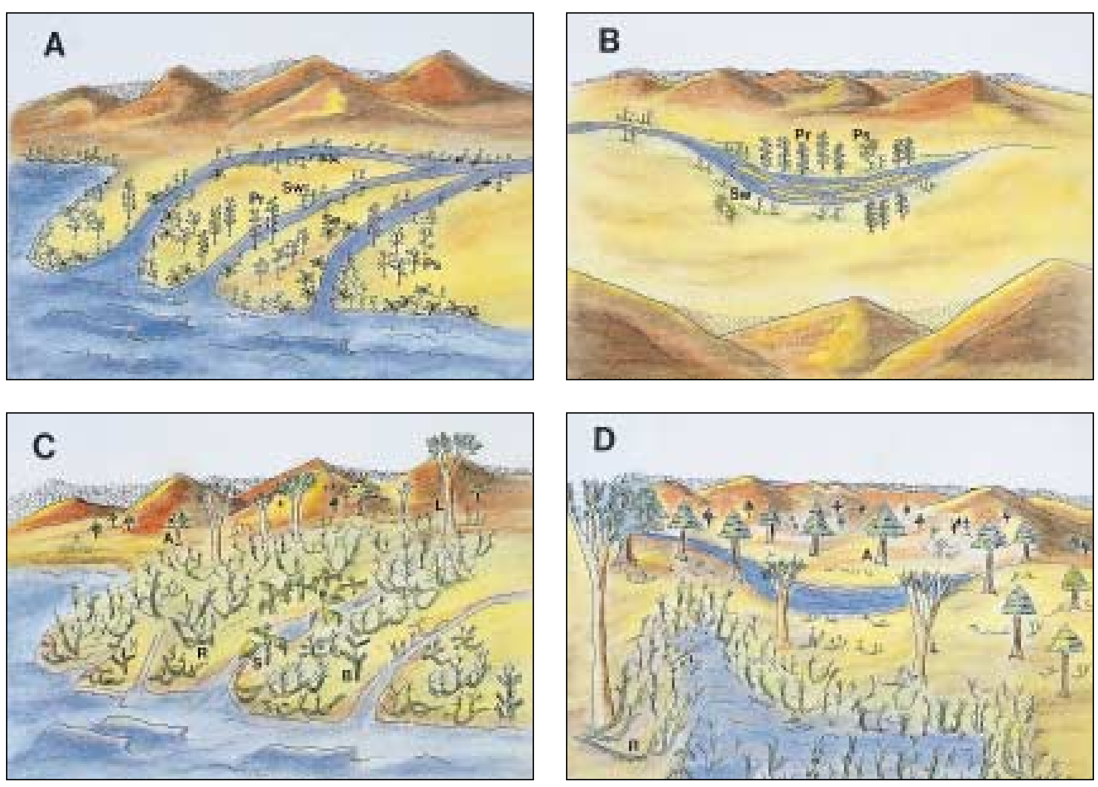


Figure 1. Paleobotanic reconstructions of (A) an Early Devonian coastal delta, (B) an Early Devonian upland flood plain, (C) a Late Devonian coastal delta, and (D) a Late Devonian upland flood plain. Early Devonian plants: Pr = *Pertica*, Ps = *Psilophyton*, Sc = *Sciadophyton*, and Sw = *Sawdonia*; Late Devonian plants: A = *Archaeopteris*, B = *Barinophyton*, L = tree lycopod, R = *Rhacophyton*, and S = seed plant. Data from Scheckler (1986), Gensel and Andrews (1984, 1987), and P. G. Gensel (personal commun.).

LATE DEVONIAN BIOTIC CRISIS AND ANOMALIES

During the Late Devonian biotic crisis (Frasnian-Famennian extinction), about 21% of families and 50% of genera among marine organisms disappeared (Sepkoski, 1986). This event was unusual in three respects (1) duration, ~20 m.y. (beginning in the Givetian, or late Middle Devonian); (2) episodicity, comprising at least eight separate episodes of extinction (House, 1985); and (3) selectivity, disproportionately eliminating tropical marine benthos (Bambach, 1985; Sepkoski, 1986). Extinctions were particularly severe among the middle Paleozoic reef community, dominated by stromatoporoids and corals (Fig. 2A; James, 1983), whereas high-latitude and cold-water species were less affected (Copper, 1986). The two extinction maxima of widest taxonomic impact occurred at or near the Frasnian-Famennian (F-F) and Devonian-Carboniferous (D-C) boundaries and are known as the Kellwasser and Hangenberg events, respectively (Fig. 3A; Talent et al., 1993).

The origin of the Late Devonian biotic crisis has been the subject of considerable debate. Much recent research has sought evidence of a bolide impact, an idea stimulated by proposals for such a catastrophic mechanism at the Cretaceous-Tertiary (K-T) boundary (Alvarez et al., 1980). Although minor iridium anomalies (Geldsetzer et al., 1987; Wang et al., 1993) and small concentrations of microspherules (Wang, 1992; Claeys et al., 1992) have been identified close to the F-F and D-C boundaries at several locales, siderophile element ratios are incompatible with those of meteorites, and these anomalies have been interpreted as resulting from concentration of metals by cyanobacteria or changes in redox conditions (Playford et al., 1984; Wang et al., 1993). Other causes proposed for the Late Devonian biotic crisis include climate change associated with global tectonics (Copper, 1986), oceanic overturn (Geldsetzer et al., 1987), and sea-level elevation changes (McGhee, 1991), but none of these fully accounts for the duration, episodicity, and selectivity of the crisis.

The Late Devonian is also characterized by an unusual combination of major excursions or permanent shifts in a variety of sedimentologic and geochemical records. Laminated black shales indicate episodic development of widespread oceanic anoxia in many cratonic sequences during this interval (Fig. 3, B–D). Deposition of organic-rich shales and coals during the Devonian-Carboniferous transition sequestered large quantities of isotopically light carbon in the sedimentary reservoir, causing an enrichment of marine carbonate $\delta^{13}C$ values of about 4‰ (Fig. 2B; Lohmann, 1988; Berner, 1989). A combination of increased burial of organic carbon and enhanced silicate weathering by vascular plants drew down atmospheric CO_2 levels from ~12–16 present atmospheric level (PAL) in the early–middle Paleozoic to ~1 PAL in the Carboniferous and Permian (Fig. 2C; Berner, 1994). Evidence of lowered atmospheric CO_2 is provided by changes in soil carbonate $\delta^{13}C$ (Mora et al., 1991) and by a marked decline in dolomite abundance across the D-C boundary (Fig. 2D). Marine evaporites of this age exhibit a +8‰ to +10‰ $\delta^{34}S$ excursion as a consequence of large-scale bacterial reduction of dissolved sulfate in association with burial of organic carbon (Fig. 2E; Holser et al., 1989). Drawdown of atmospheric CO_2 initiated global cooling, recorded as a about +3‰ enrichment of abiotic marine carbonate $\delta^{18}O$ values across the D-C boundary (Fig. 2F; Lohmann, 1988), and resulted in continental glaciation by the late Famennian (Fig. 3E; Caputo, 1985).

Plants *continued on p. 64*

IN THIS ISSUE

GSA TODAY — *March 1995*
Vol. 5, No. 3

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

SUBSCRIPTIONS for 1995 calendar year: **Society Members:** *GSA Today* is provided as part of membership dues. Contact Membership Services at (800) 472-1988 or (303) 447-2020 for membership information. **Nonmembers & Institutions:** Free with paid subscription to both *GSA Bulletin* and *Geology*, otherwise $45 for U.S., Canada, and Mexico; $55 elsewhere. Contact Subscription Services. **Single copies** may be requested from Publication Sales. Also available on an annual CD-ROM, (with *GSA Bulletin, Geology, GSA Data Repository,* and an Electronic Retrospective Index from 1972-to-current) for $89 to members, $125 to others; and in an annual, hardbound, library edition for $45. Order from Membership Services. **Claims:** For nonreceipt or for damaged copies, members contact Membership Services; all others contact Subscription Services. Claims are honored for one year; please allow sufficient delivery time for overseas copies.

This publication is included on GSA's annual CD-ROM, *GSA Journals on Compact Disc,* and also is available in an annual, hardbound, archival edition. Call GSA Publication Sales for details.

Printed with pure soy inks on recyclable paper in the U.S.A.

International Division Sponsors Geopals Program

L. Lynn Chyi, Geopal Program Coordinator of the GSA International Divison

In his report in *GSA Today* (October 1991, p. 220), Brian Skinner, former president of the International Division, discussed the International Division Student Committee's first major activity, the Geopals program. The program was continued with gifts from Gail Ashley, Maria Crawford, Mark Holmes, Peter Isaacson, Brian Skinner, and Lynn Chyi, supporting Student Associate memberships. The students nominated were from the University of Akron, the University of Cincinnati, Iowa State University, the University of Tehran, and Tabriz University.

An important aspect of the program is that GSA sponsors are encouraged to communicate with their Geopals, seeking to reinforce the department's educational efforts while they study in North America, and taking an interest in their professional development. We believe that Geopals will play an important role in helping to build professional and personal bridges to geoscientists in other countries.

The program consists of two separate but related parts, that of nominating and that of sponsoring a foreign student.

How to Nominate a Geopal

The Student Committee welcomes nominations of foreign graduate students, preferably those with strong credentials who otherwise wouldn't be able to afford GSA membership fees. We request that the sponsor and the student be from different departments, as an additional means of building bridges within North America on this collaborative project. A nominator or sponsor need not be a member of the International Division of GSA, but priority will generally be given to International Division members' nominations. An additional reason that we encourage you to join the International Division is so that you may help to provide guidance and may participate actively in some of its varied programs.

How to Sponsor a Geopal

The procedures for becoming a sponsor of a foreign student are as follows.

1. If you are on a university campus, tell the chair or GSA Campus Representative that you want to be a sponsor. If you are not on a campus or if you do not have a Campus Representative, call or write to Jim Skehan, who will send a sponsor's form and a student application form to the designated chair or Campus Representative in the student's department. You may also contact Skehan if you wish to sponsor and be paired with a nominated student on the committee's list.

2. When the forms are completed and signed by the chair or Campus Representative in the student's department, they will be sent to the sponsor, who will enclose a check as a tax-deductible contribution, made payable to GSA Foundation—Geopals. The sponsor will check one of two boxes:

Level of commitment:
- ☐ $40—dues and *Geology*
- ☐ $55—dues, *Bulletin,* and *Geology*

Length of commitment:
- ☐ 1995 dues, one year only
- ☐ 1995 dues and subsequent years as a student.

The sponsor then sends the package to: Geopals Program, c/o Membership Services, Geological Society of America, P.O. Box 9140, Boulder, CO 80301. If the intended supporting level is different from the above, sponsors can send their donations directly to the International Division Fund, GSA Foundation.

Two Programs for Foreign and American Exchange

If the student committee of the International Committee can be helpful in facilitating other contacts in international student-oriented projects, contact L. Lynn Chyi, Geopals Program Coordinator, Student Committee, Geological Society of America, Department of Geology, University of Akron, Akron, OH 44325-4101, (216) 972-7635, fax 216-972-6990. ■

CALL FOR NOMINATIONS REMINDERS

Materials and supporting information for any of the following nominations may be sent to GSA Executive Director, Geological Society of America, P.O. Box 9140, Boulder, CO 80301. For more detailed information about the nomination procedures, refer to the October 1994 issue of GSA Today, or call headquarters at (303) 447-2020, extension 136.

John C. Frye Environmental Geology Award

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 1995 award will be presented at the autumn AASG meeting to be held during the GSA Annual Meeting in New Orleans.

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 1995 is **MARCH 31, 1995.**

National Awards

The deadline is **APRIL 30, 1995,** for submitting nominations for these four awards: William T. Pecora Award, National Medal of Science, Vannevar Bush Award, Alan T. Waterman Award.

GSA ON THE WEB

What's new on the GSA home page on the World Wide Web? If you haven't yet connected to the Web, the Universal Resource Locator (URL) is **http://www.aescon.com/geosociety/index.html.**

For current information on any of the GSA Section meetings, go to **Meetings** and choose the Section you want to know about. This month has all the information about the Cordilleran Section meeting in Alaska.

See the **Section and Division** area for newsletters, meetings, and other news.

If you want to know more about the GSA Employment Service or about becoming a GSA Campus Representative, check the **Membership** section, which also has information on nominating a member to fellowship and on obtaining forms for applying to become a GSA Member or Student Associate.

See the **Geoscience Calendar** section for a listing of meetings of general geological interest.

The **Publications** section has a monthly table of contents and abstracts of articles for the *GSA Bulletin* and *Geology.* Also in this section is a guide for authors preparing manuscripts for submission to GSA publications.

USGS and the "Contract with America"

As reported by AGI (*Geotimes*, January 1995) and the news media elsewhere, the U.S. Geological Survey and the U.S. Bureau of Mines are slated to be abolished under the "Contract with America." Interested individuals should immediately contact their congressional representative to express concern. (More information about the "Contract with America" will appear in Washington Report in the April 1995 issue of *GSA Today.*)

In Memoriam

Donald A. Beaudry
Kingwood, Texas
December 9, 1994

Francis S. Birch
Durham, New Hampshire

Robert R. Coats
Aptos, California
January 12, 1995

Gilbert Corwin
Arlington, Virginia
December 5, 1994

H. W. Fairbairn
Watertown, Massachusetts
December 21, 1994

Phillip W. Ray
Boulder, Colorado
October 25, 1994

Ahti J. Simonen
Espoo, Finland
November 4, 1994

William L. Stokes
Salt Lake City, Utah

WASHINGTON REPORT

Bruce F. Molnia

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

Education and Employment Trends for Earth Scientists

Late last year, the Geological Society of America, in conjunction with the National Research Council's Board on Earth Sciences and Resources (BESR) and the American Geological Institute (AGI) sponsored a forum, "Education and Employment Trends for Earth Scientists." The meeting, hosted by the BESR at the National Academy of Sciences in Washington, D.C., was attended by more than 80 federal, private sector, and academic earth scientists, including the presidents and executive directors of 30 earth science societies. The purpose of the forum was to discuss the adequacy of college and university curricula for preparing students for earth science careers in the next decade and to assess present and future earth science employment opportunities.

The forum consisted of more than 20 presentations, organized into three themes: private-sector employment, government and research opportunities, and trends in education—universities and societies. The forum also featured a keynote address by U.S. Geological Survey (USGS) director Gordon Eaton, a distinguished lecture in geoscience policy by William Fisher (University of Texas, Austin), and a special address by Marguerite Kingston of the USGS.

USGS Director Eaton described "a new and different kind of earth science revolution that should be requiring all of us to rethink the way we approach our missions." With respect to the future of earth science education, he stated, "We need, therefore, to address how geoscience fits into the realities of today and then ask what implications there may be here for a redesign of the emphasis of our educational curricula." He added that "in the process of defining relevance and flexibility we must not lose sight of the critical need for technology training. Technology must be imbedded at all levels of education."

Marguerite Kingston described her experience working at the Office of Science and Technology Policy (OSTP), especially as it related to the formulation of President Clinton's new science policy statement, "Science in the National Interest" (see October 1994 Washington Report). She stated, "We as working scientists must explain to the American people why they as taxpayers should support world class science including fundamental research." With respect to the lack of visibility of the earth science community, she stated, "The president's science advisor John Gibbons and OSTP receive lots of mail from the scientific community, and not just requests for more funding, often suggestions on current science policy, reports of major scientific breakthroughs, or other science related issues including education and employment trends. But very, very rarely was there any mail from the community of earth scientists. That was so surprising considering the important work that geologists perform in strategic areas...."

The forum schedule included large periods of time for audience participation, time for full consideration of each topic and presentation, and time for feedback. Marilyn Suiter, AGI's director of education and human resources and a convener of the forum, stated, "Issues concerning education programs were vigorously discussed and reflected a variety of dimensions. These included the relationship between educational preparation and employment; appropriate and useful curriculum design; K–12 educational issues, including teacher preparation; and the potential role of professional societies." Suiter also reported that the discussion included the suggestion "that more interdisciplinary studies would improve students' abilities in creative thinking and problem solving; skills deemed critical for today's workplace needs." She said, "Several employers noted the need for a strong geoscience core curriculum, accompanied by training in other science disciplines, mathematics, computers, and communications, to prepare students for the professional demands they will face." These types of recommendations and conclusions are not unique to this forum. Suiter pointed out that "many of these points were supported by the commentary presented at recent conferences on geoscience education: the AGU Chapman Conference, 'Scrutiny of Undergraduate Geoscience Education,' held in September 1994, and the SEPM/IAS workshop, '21st Century Applications of Sedimentary and Paleontology Geology,' held in October 1994."

With respect to present and future earth science employment, speakers from industry, government, and academia presented sobering insights on employment opportunities. One industry representative suggested that the competition for the very few jobs available in the minerals industry was and would be so intense that only candidates with numerous years of experience could seriously expect to be considered for employment. Rosalind Helz of the USGS commented that she was struck by the lack of opportunities in many disciplines that she thought had more optimistic outlooks. She said that "the employment picture appears bleak across the board."

The following paragraphs, slightly modified from the summary released by BESR, expand upon the observations presented above and provide additional

Trends *continued on p. 64*

GeoTrip

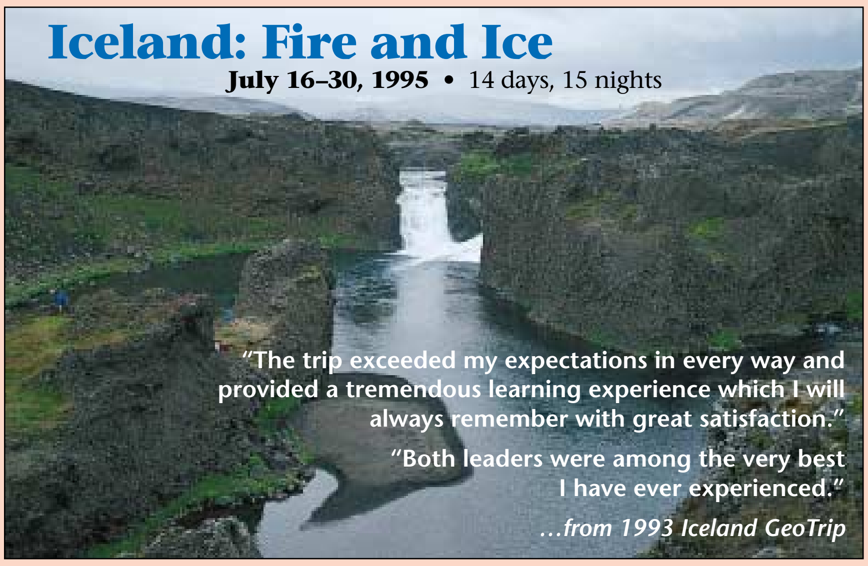
Scientific Leaders:
Haraldur Sigurdsson
Graduate School of Oceanography, University of Rhode Island
Haukur Johannesson
Natural History Institute, Reykjavik, Iceland

A native of Iceland and professor of oceanography, *Haraldur Sigurdsson* is a leading volcanologist with an international reputation for his research on many aspects of volcanism in Iceland, Italy, Mexico, Colombia, the United States, and Indonesia, among others. *Haukur Johannesson* has devoted most of his career to the geologic mapping of the uncharted volcanic regions of Iceland. He is an expert in the tectonic structure and origin of the Iceland basalt plateau and is also very knowledgeable about the natural history of Iceland in general.

Photo by Bob Grant

Iceland: Fire and Ice

July 16–30, 1995 • 14 days, 15 nights



This trip will reveal many unaltered and fresh geologic features that can be seen nowhere else on land. Expect to acquire a newly expanded understanding of volcanoes, hotspots, and rifts. There will be great views of steep-walled and flat-topped hyaloclastite ridges derived from subglacial eruption, young hyaloclastite islands produced by submarine eruptions, great explosion craters, tephra cones, calderas, blocky obsidian flows, waterfalls descending into the rift valley, and, of course, extraordinary glacial panoramas.

Lodging, Meals, Transportation. During most of the trip, the group will stay in country hotels (Edda hotels), rural secondary and high schools operated as simple but comfortable summer hotels. Food will be provided at all lodging locations, plus picnics during the day. Travel will be by four-wheel-drive mountain trail bus and by car ferry to the volcanic Westmann Islands.

Schedule

July 16, Sunday	Travel day from Baltimore or New York to Reykjavik, evening departure on Icelandic Air
July 17–30, Mon.–Sun.	Iceland GeoTrip
July 30, Sunday	Travel day from Reykjavik to next gateway

Air Transportation. The Baltimore gateway has the best connecting flights to most of North America. Round trip travel from Baltimore to Reykjavik will be on IcelandicAir. The current group round-trip fare is $748. Trip participants are required to travel on the group flight so that everyone can benefit from the advantages of a group reservation. You may use air mile coupons for your domestic flights, however. Travel arrangements are being handled by Volcano Tours—TR Consultants, which can help you with plans for your entire itinerary (1-800-923-7422, fax 401-247-0270). They will also offer a brief post-trip option to Greenland.

Included in the fee (see box) are all meals in Iceland; double-occupancy lodging; comfortable bus and ferry transportation; transfers and entrance fees; baggage handling; geologic road log; and field guidebook. ***Not included*** are airfare to and from Reykjavik, and hotel nights and meals, if any, in Baltimore.♦

1995 GeoVentures

GeoHostel

Geological History of Southwestern Montana

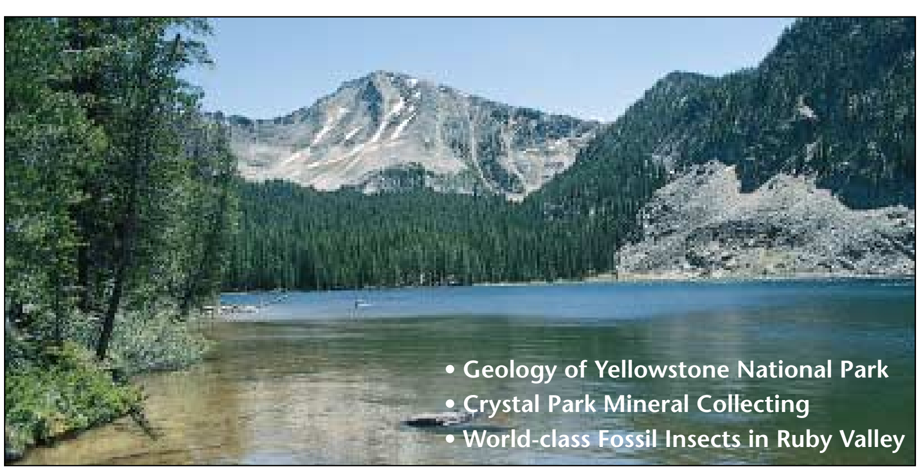


Photo by Rob Thomas.

June 17–22, 1995 • 6 days, 6 nights • Western Montana College, Dillon, Montana

Scientific Leader
Robert Thomas, Department of Geosciences, Western Montana College

Currently an assistant professor of geology at Western Montana College, Rob Thomas has been involved in geological field camps in the Dillon area since 1986. A graduate of the University of Washington, Rob has studied the patterns and processes of Cambrian mass extinctions, but his current research involves the origin and timing of extensional tectonism in southwestern Montana. Rob is an active member of the geological community in the northern Rocky Mountains, serving as the president of the Tobacco Root Geological Society and the Rocky Mountain Paleontological Society.

Schedule

June 17, Saturday	Welcoming get-together
June 18–22, Sun.–Thurs	Classes and field trips
June 20, Tuesday	Western Barbecue
June 22, Thursday	Farewell Party

The base for our trips will be the small college town of Dillon, best known for its abundant wildlife, trout streams, pioneer history, and spectacular geology. The GeoHostel will include field trips to the fold-and-thrust belt structure in the Beaverhead Valley, Cretaceous intrusions, ore mineralization and glaciation in the Pioneer Mountains, fossil insects and plants in the Ruby Valley, Cenozoic extensional tectonics along the northern edge of the Yellowstone hotspot tract, and thermal features in Yellowstone National Park. Trips will be both full and half-day. Plenty of leisure time will be available to enjoy the solitude of the "last best place" in America.

Lodging, Meals, Transportation. The group will be lodged for six nights at Western Montana College, Dillon, Montana, single-occupancy (or double for couples) dormitory–style rooms. Meals will include breakfast and a sack lunch daily through Thursday, western barbecue on Tuesday evening, a farewell dinner on Thursday evening, and breakfast on Friday before check-out. Field trip transportation will be in air-conditioned, 15-passenger rental vans.

Included in the fee (see box) are classroom programs and materials; field trip transportation; lodging for six nights; meals outlined above; welcoming and farewell events. ***Not included*** are air transportation to and from Dillon, Montana; transportation during hours outside class and field trips; meals and other expenses not specifically included.♦

GeoHostel

Scenic Geology of Northwestern Colorado and Dinosaur National Monument

June 24–29, 1995
6 days, 6 nights • Colorado Mountain College and Vernal, Utah

Scientific Leaders *Gregory Holden and Kenneth Kolm,*
Department of Geology and Geological Engineering, Colorado School of Mines

Ken Kolm and *Greg Holden* are among the brightest and most refreshing of the younger generation of geologists. Experienced GeoHostel Leaders, Ken and Greg received their doctoral degrees from the University of Wyoming, and both are currently associate professors at the Colorado School of Mines.

Schedule

June 24, Saturday	Welcoming get-together
June 25–29, Sunday through Thursday	Classes and field trips
June 29, Thursday	Farewell Party

Photo by Ken Kolm

Steamboat Springs, Colorado, in a high, green mountain valley, will be our base for two loop trips to explore the geology of northwestern Colorado, from Precambrian basement to Tertiary volcanic rocks. We'll also take a three-day trip west to see Dinosaur National Monument and the isolated back country that surrounds it. High points of the trip will be remote Brown's Hole (original hideout of Butch Cassidy's Wild Bunch), intimate views into and a raft trip through the deep canyons of Dinosaur National Monument, and a tour of the dinosaur quarry itself.

Lodging, Meals, Transportation. The group will stay on Saturday, Sunday, Wednesday, and Thursday at Colorado Mountain College, Steamboat Springs, in single rooms (doubles for couples). Lodging on Monday and Tuesday nights will be at the EconoLodge in Vernal, Utah, in double occupancy accommodations. Single rooms for Monday and Tuesday nights are available for the single-supplement fee of $50. Meals will include breakfast and a sack lunch on Sunday, Monday, and Thursday, lunch on Tuesday during the raft float trip or optional van trip, a farewell dinner on Thursday evening, and breakfast on Friday before checkout. Field trip transportation will be in air-conditioned, 15-passenger rental vans.

Included in the fee (see box) are classroom programs and materials; field trip transportation; lodging for six nights (single occupancy, or double for couples); meals outlined above; raft float trip (or optional van trip); welcoming and farewell events. ***Not included*** are air transportation to and from Steamboat Springs, Colorado; transportation during hours outside class and field trips; breakfast on Tuesday; breakfast and lunch on Wednesday; and other expenses not specifically included.♦

1995 GeoVentures Fee Schedule

Name	Grand Canyon	Montana	Colorado	Iceland
Type	GeoTrip	GeoHostel	GeoHostel	GeoTrip
Dates	April 21–28	June 17–22	June 24–29	July 16–30
No. of Days	8	6	6	14
Member Fee	$1450	$500	$520	$2780
Nonmember Fee	$1550	$550	$570	$2880
Deposit	$250	$100	$100	$250
Balance Due	March 1	April 15	April 15	April 15
100% Deposit refund date (less $20/$50 processing fee)	March 1	April 15	April 15	April 15

SOLD OUT

CALL TODAY!
HOLD A SPOT FOR YOURSELF AND FRIENDS.

We encourage you to make your decision as soon as possible. There is high interest in these trips, and many people have registered.

General Fee Information: If you have been with us previously on a GeoTrip, the surcharge will be waived. Please remind us of this when you register. Sorry, there is no fee waiver for GeoHostels due to their low operation margin. However, if you attend both 1995 GeoHostels, you will receive a $50 discount.

Single/shared Accommodation: Some trip fees are based on double occupancy. If you wish single accommodations, a limited number of rooms are available at an extra cost on a first-come, first-served basis. In the case of double occupancies, we will do our best to help find a suitable roommate, but if none is found, the single rate will apply. Please read the lodging information.

Age Limitations: In general, the age limit is 21.

Health: You must be in good physical and mental health. Any physical condition requiring special attention, diet, or treatment must be reported in writing when the reservation is made. We reserve the right to decline any person as a member of a trip. We also reserve the right to require a person to withdraw from the trip at any time when such action is determined to be in the best interests of the health, safety, and general welfare of the group.

Special Needs: We will do our best to accommodate special needs, including dietary requirements and physical disabilities. Please feel free to call and discuss your situation with us.

Air Travel: Arrangements are handled by the individual unless specified as group travel in the description. Cain Travel, GSA's official travel agency, is ready to help you find the least expensive routing to your destination. Call Cain at 1-800-346-4747 toll free, or (303) 443-2246 collect from outside the U.S., fax 303-443-4485. 8:30 a.m. to 5:30 p.m. MT, Monday through Friday.

Cancellation Processing Fee: Deposits and payments are refundable up to the cut-off time, less processing fees of $20 for GeoHostels and $50 for GeoTrips. Termination of a trip in progress for any reason will not result in a refund, and no refund will be made for unused parts of the trip.

Itineraries and Other Information: Detailed itineraries for each GeoVenture and helpful travel information are available from GSA. Feel free to call, fax, or E-mail: Edna Collis, GSA GeoVentures, P.O. Box 9140, Boulder, CO 80301; (303) 447-2020 or 1-800-472-1988, fax 303-447-0648, E-mail: ecollis@geosociety.org ♦

GEOVENTURES REGISTRATION FORM

If you would like to send a deposit to hold your reservation, please pay by check or credit card, which will be used only for this deposit. If all of your payments are by check, instead of credit card, you will receive a $25 refund at the end of the trip. You will receive further information and a confirmation of your registration within one week after we receive your reservation.

Name ______________________________

Institution/Employer ______________________________

Mailing Address ______________________________

City ____________ State ____ Country _________ ZIP _________

Phone: ( ) ____________ ( ) ____________
Business Home

Guest Name ______________________________

GSA Member # ______________

	Deposit Per Person	No. of Persons	Total Deposit
~~GT951—**Grand Canyon**~~ **SOLD OUT**	~~$250~~	_____	_____
GT952—**Iceland**	$250	_____	_____
GH953—**Southwestern Montana**	$100	_____	_____
GH954—**Northern Colorado**	$100	_____	_____

TOTAL DEPOSIT __________

☐ I've enclosed no deposit, but I'm interested. Please send more information.
☐ VISA ☐ MasterCard ☐ American Express

Credit Card # ______________________ Exp. Date ________

Signature ______________________________

Make checks payable to: **GSA 1995 GeoVentures**

Please mail Registration Form and check or credit card information to:
1995 GSA GeoVentures, GSA Meetings Department
P.O. Box 9140, Boulder, CO 80301
Phone: 1-800-472-1988 or (303) 447-2020: ext. 134 or 141
E-mail: ecollis@geosociety.org or mball@geosociety.org

Fax: 303-447-0648

PUBLICATIONS NEWS FROM GSA

BOOK NOOK

WATCH THIS COLUMN FOR NEWS ABOUT GSA PUBLICATIONS

RECENTLY RELEASED!

LARGE METEORITE IMPACTS AND PLANETARY EVOLUTION
edited by B. O. Dressler, R. A. F. Grieve, and V. L. Sharpton, 1994
Twenty-eight papers, organized in five chapters. Topics include impact cratering phenomena and processes, shock metamorphism, the origin of tektites, terrestrial and planetary impact structures, and paleontological extinctions. Six papers present new data on the origin and evolution of the Sudbury structure of northern Ontario. Information on nine other terrestrial impact structures also is presented. The six papers in the first section on Planetary Constraints and Perspectives are of special interest to the planetologist dealing with the origin of lunar multiring basins, impact structures on Venus, and impact melt production on the planets.
SPE293, 358 p., paperback, indexed, ISBN 0-8137-2293-4, $97.00

ELEMENTS OF PENNSYLVANIAN STRATIGRAPHY, CENTRAL APPALACHIAN BASIN
edited by Charles L. Rice, 1994
Nine papers synthesize the conclusions of ongoing paleontological studies of coal spores, macrofossils, and microfossils, including a preliminary zonation of Middle and Upper Pennsylvanian conodonts in the central Appalachian basin, and establish a new Pennsylvanian stratigraphic framework for the basin. The papers name new stratigraphic units, reconcile old stratigraphic problems, and demonstrate the correlation and continuity of key basinal biostratigraphic horizons. Cross-referenced glossary of both formal and informal stratigraphic terms
SPE294, 160 p., ISBN 0-8137-2294-2, $40.00

PERMIAN-TRIASSIC PANGEAN BASINS AND FOLDBELTS ALONG THE PANTHALASSAN MARGIN OF GONDWANALAND
edited by J. J. Veevers and C. McA. Powell, 1994
After reconstructing Permian-Triassic Gondwanaland, authors writing on South America, South Africa, Antarctica, and Australia profusely illustrate the relevant geology of each sector in maps and time-space diagrams underpinned by robust biostratigraphic and radiometric dating. The work is then drawn together in a stratigraphic-tectonic synthesis, which features the specifically Gondwanan glaciogene and coal facies, the Early and Middle Triassic coal gap, and the interplay of Pangean and Panthalassan tectonics.
MWR184, 372 p., hardbound, ISBN 0-8137-1184-3, $100.00

LATE CENOZOIC LAVA DAMS IN THE WESTERN GRAND CANYON
by W. K. Hamblin, 1994
Describes and documents the spectacular interplay of volcanism, fluvial erosion, and tectonic uplift in a unique area where this interplay can be seen in three dimensions.
MWR183, 144 p., hardbound, w/4 pocket-plates, ISBN 0-8137-1183-5, $85.00

THE GEOLOGY OF ALASKA
edited by G. Plafker and H. C. Berg, 1994
Get a comprehensive overview of the geology, tectonic evolution, and mineral resources of Alaska and adjacent areas of the continental margin. Plates include statewide maps showing geology, physiography, lithotectonic terranes, metamorphic rocks, igneous rocks, sedimentary basins, isotopic age data, neotectonics, isostatic gravity, magnetics, and metallic mineral deposits.
GNA-G1, 1,066 p., hardbound, w/14 plates in slipcase, 1 microfiche card, indexed, ISBN 0-8137-5219-1, $135.00

PHANEROZOIC EVOLUTION, NORTH AMERICAN CONTINENT-OCEAN TRANSITIONS
edited by R. C. Speed, 1994
CTV001, 514 p., indexed, hardbound, ISBN 0-8137-5305-8, $75.00

1-800-472-1988
The Geological Society of America
GSA PUBLICATION SALES
P.O. Box 9140, Boulder, CO 80301
303-447-2020 or fax 303-447-1133
Prepayment required. Major credit cards accepted.

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 November 6–9 for the 1995 GSA Annual Meeting in New Orleans, Louisiana. 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 must receive your material no later than September 15, 1995. 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 November. 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: tmorelan@ geosociety.org.

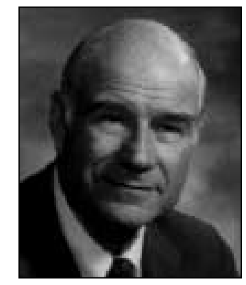
Looking for a New Employee?

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 1995, the cost of a printout of one or two specialty codes is $150. (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. 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 New Orleans, Louisiana, November 6–9). 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: tmorelan@geosociety.org. ■

GSAF UPDATE

Robert L. Fuchs

Davidson and Otte Appointed to Foundation Board of Trustees



Claire Davidson **Carel Otte**

At the Seattle meeting, the trustees approved enlarging the Foundation board from nine trustees to ten, an expansion necessitated by the added Foundation fund-raising work load due to the Second Century Fund campaign. This increase, combined with the retirement of Bill Heroy, created two vacancies. Two new trustees were appointed by the Board from a list of candidates approved by the GSA Council.

Claire B. Davidson enjoyed her entire career with the U.S. Geological Survey that spanned some 40 years and included positions within the Geology Division and the Water Resources Division, in Washington, Reston, and Denver. Her professional career began with the Geologic Names Committee, in a job that included investigating and approving rock-stratigraphic nomenclature and classifications, often working in the field to resolve stratigraphic problems. Subsequent assignments were field work and photogeologic mapping of the Colorado Plateau and uranium exploration in the Powder River basin. During the 1960s Claire was assigned to the Geochemical Exploration Branch, where she was Project Chief for assembling material on worldwide geochemical exploration techniques for subsequent publication by the USGS. During the early 1970s Claire worked in international resource analysis. She joined the Water Resources Division in 1973, remaining there until retirement in 1989. Her work again entailed rock-stratigraphic and hydrogeologic nomenclature and classification used in reports of the division. Subsequent to retirement and as an annuitant, Claire was retained by the USGS to compile a database for the Regional Aquifer System Analysis program, a project that she completed recently.

Claire Davidson's awards include USGS Outstanding Performance awards and the Superior Service Award from the Department of the Interior. In 1991 she was presented with the GSA Hydrogeology Division's Distinguished Service award. She served that division as an officer and as editor of *The Hydrogeologist*. She is a fellow of GSA, and a member of AGU, AAAS, Colorado Scientific Society, and Geological Society of Washington.

Educated at Mount Holyoke College in Massachusetts (B.A. in geology) and at the University of Colorado in Boulder (M.A. in geology), Claire has in recent years been very active and successful in fund-raising work for her undergraduate school. She has brought this valuable experience to the Second Century Fund Committee, where she is a campaign advisor.

Carel Otte was schooled in the Netherlands, an education interrupted by World War II. Following an eventful service in the Mediterranean and Middle East theaters, he came to the United States, to enroll in graduate school at Cal Tech in 1948, and received Master's and Doctor's degrees prior to being hired by Shell in 1954. Carel left Shell for Unocal in 1957, where he spent the balance of his formal career. He started Unocal's geothermal business and retired in 1989 as president of the Geothermal Division. The most notable accomplishment of that division under Carel Otte's leadership was the discovery and development of The Geysers field in Sonoma County, California, the world's largest producer of geothermal energy. Unocal also discovered two fields on Luzon Island in the Philippines, and a major geothermal resource is now being developed in Indonesia. These professional accomplishments were duly recognized by national organizations such as the National Society of Professional Engineers, the Institute for the Advancement of Engineering, the Geothermal Resources Association, and California Institute of Technology, all of which have cited Carel Otte for distinguished and outstanding scientific and engineering achievements. Carel was named as a lecturer for the Distinguished Lecture Series for the Society of Petroleum Engineers.

Retirement from Unocal marked the start of more active, *pro bono* involvement in national scientific groups. Carel was elected a member of the National Academy of Engineering and appointed to the Board of Earth Sciences and Resources of the National Academy of Sciences. In 1993 he was appointed chair of the Committee on Earth Resources of the BESR. For the past five years Carel has devoted considerable time and attention to the financial affairs of GSA. He joined the Committee on Investments in 1990 and became its chair in 1993. He has assisted the Second Century Fund Committee and the Foundation in the development of major corporate gifts.

Former GSA President R. W. Bromery, who is chair of the Second Century Fund Committee, commented on these two appointments: "Both Claire and Carel strengthen the Foundation's organization, and I appreciate their commitment and personal contributions. The Second Century Fund is a major undertaking for GSA, and the experience of these two new trustees in similar campaigns, fund raising, and financial matters will give a significant boost to our chances for a successful conclusion." ■

Trustee Bill Heroy Retires

William B. Heroy, Jr., who has served GSA in a variety of roles for more than 30 years, completed his five-year term as a Foundation trustee at the Foundation's annual meeting in October in Seattle. Bill and Dorothy Heroy now live in a retirement community near Duke University in Durham, North Carolina, enjoying a slower pace after a lifetime spent in science, academia, business, and philanthropy.

Bill Heroy was treasurer of GSA from 1977 to 1982, and in addition performed other financial and management tasks for the Society, not the least of which was a 20-year stint on the Committee on Investments. Bill served on ten additional committees and task forces, as well as Executive Committee and Council. GSA was not alone in benefiting from the public service of Bill Heroy. He was president of AGI in 1969 and treasurer of AAPG from 1970 to 1972. His business career progressed from field geologist with Texaco to executive vice president of Teledyne, Inc., and in academia Bill was both a professor and vice president–treasurer of Southern Methodist University. He holds GSA's Distinguished Service Award and AGI's Campbell Medal.

Philanthropy has been a persistent trait in the Heroy family, and a number of institutions, such as Syracuse University and SMU, have been recipients of the family's generosity. In 1993 Bill and Dot established the Heroy Fund at the GSA Foundation, through a Second Century Fund deferred gift contribution to the GSA Pooled Income Fund. Income from the Heroy Fund will be applied to the student research grants program.

The GSA Council has issued a resolution of thanks in recognition of Bill Heroy's years of work for the Society. Foundation chair Charles Mankin, speaking on behalf of the board, said, "Few people have devoted more personal energy to GSA. Bill Heroy has been a contributor of time and money—both are needed to make GSA's programs succeed. The financial health of the Society today is due in no small part to his work, usually behind the scenes but always resulting in another step forward. We wish Bill and Dot a comfortable and enjoyable retirement, with the caveat that he now fill the role of senior geological statesman and share with us, from time to time, the fruits of his long experience." ■

Donors to the Foundation—December 1994

Antoinette Lierman Medlin Scholarship
C. S. Venable Barclay
C. Blaine Cecil
Aureal T. Cross
Joseph A. Dixon
Bruce R. Doe
Terry W. Offield

Biggs Excellence in Earth Science Education
Whitman Cross II
Mohamed Gheith
Douglas C. Pasley, Jr.*

Birdsall Fund
Susan J. Altman
Alfred Clebsch, Jr.
David M. Diodato
C. W. Fetter, Jr.
Marc Hinton
Larry A. Jackson
Alvin R. Leonard
Jeffrey W. Reynolds
William W. Simpkins
Jeffrey A. Sitler

Allan V. Cox Student Research
Harold E. Malde*
Tom Shoberg

*Century Plus Roster (gifts of $150 or more).

Doris M. Curtis Memorial
Irving G. Grossman

John T. Dillon Alaska Research Fund
Carl S. Benson
Steven C. Bergman*
John S. Ferguson
Roland D. Hall
Charles C. Mull
Douglas C. Pasley, Jr.*

Shirley J. Dreiss Memorial
P J Adam*
Paul J. Boison
John Bredehoeft
Kenneth L. Cameron*
Anne E. Carey
Stanley N. Davis*
Barbara J. Dutrow
Alan R. Dutton
Graham E. Fogg
William C. Haneberg
W. Berry Lyons
Gilbert Masters
Martin Reinhard
Michael B. Underwood
Tamie R. Weaver

Dwornik Planetary Geoscience Award
Edward J. Dwornik
Ted A. Maxwell

Engineering Geology Division Award
Duane A. Eversoll

John C. Frye Environmental Award
Alvin R. Leonard
Douglas C. Pasley, Jr.*
Thomas F. Rafter, Jr.

GEOSTAR
Bruce H. Bryant*
Lawrence R. Cann
Richard F. Hadley*
David G. Hardy
Calvin F. Miller
Douglas C. Pasley, Jr.*
James K. Roche
John L. Rosenfeld
Allan F. Schneider

History of Geology Division Award
Alan E. Leviton*

Hydrogeology Division Award
George T. Cardwell
Daryll T. Pederson
Joseph W. Troester
Leonard A. Wood

IEE
James O. Brown
Wendell A. Duffield
Gerald I. Eidenberg
Gretchen Luepke
Charles C. Rich
John F. Sutter
F. Michael Wahl*

J. Hoover Mackin Award
Anonymous
Victor R. Baker*
William W. Locke
Stephen G. Wells

Carol G. and John T. McGill Fund
Manuel G. Bonilla
Richard Lung

Memorial
Charles J. Hoke *(in memory of Charles W. Sternberg)*
Ronald K. Sorem *(in memory of Gyula Grasselly)*

Minority
Brian F. Atwater
Karen Chin
John E. Kaiser
Harold E. Malde*
Robert A. Matthews
William D. Rose, Jr.
Robert Schoen
Daniel P. Spangler

Penrose Conferences
Matthew J. Kramer

Publications
Richard A. Davis

Research Fund
Hans G. Avé Lallemant*
James W. Baxter
Donald W. Boyd*
Francis R. Boyd, Jr.
Brian J. Cooper
Clinton A. Cowan
Ralph K. Davis
Howard W. Day
David P. Dethier
Russell C. Evarts*
Lanny H. Fisk
Virginia S. Gillerman
David P. Gold
Jonathan H. Goodwin
Keith A. Howard
Michael J. Hozik
G. Randy Keller
Wayne Kemp
Dennis V. Kent
Yousif K. Kharaka
J. Richard Kyle
Maureen P. Leshendok
Jody V. Maliga
Walter L. Manger
Elizabeth L. Mathieson
Calvin F. Miller

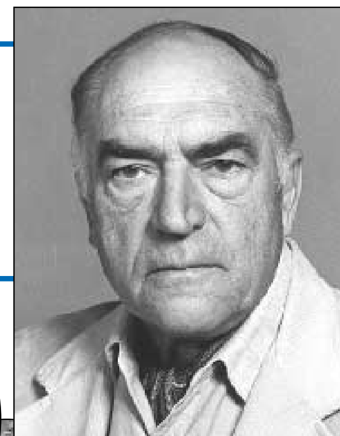
Donors *continued on p. 63*

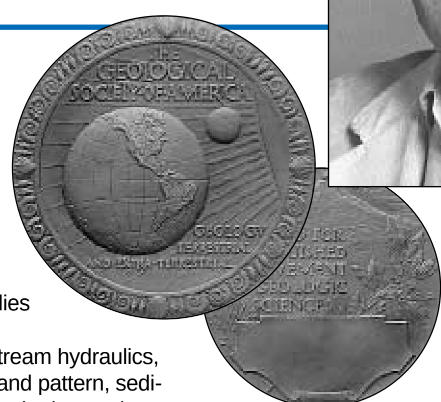
GEOLOGICAL SOCIETY OF AMERICA

MEDALS AND AWARDS

FOR 1994

Presentation of the PENROSE MEDAL to LUNA B. LEOPOLD





Citation by WILLIAM B. BULL

Luna Leopold's achievements in geological research, education, and environmental policy are a legacy with influence extending into the future. In recognition of that, he is the 1994 Penrose Medalist. Luna's pioneering and provocative work includes studies of early storm warning, rainfall frequency and drought, downstream flow-velocity changes, stream hydraulics, alluvial stratigraphy and stream-channel form and pattern, sediment transport, urban hydrology, landscape aesthetics, and channel response to base-level change. Luna's landscape ecology studies identify and analyze truly crucial interdisciplinary problems, and his dynamic leadership facilitates application of geomorphic research to land-management decisions. The short list of references selected by the nominating committee is representative of the breadth and depth of research done by Luna Leopold.

Luna's background is rooted in a New Mexico family with diverse interests. His comprehensive academic degrees are a B.S. in civil engineering at the University of Wisconsin, Madison, a Masters in physics-meteorology at the University of California, Los Angeles, and a Ph.D. in geology at Harvard University. As Chief Hydrologist for the U.S. Geological Survey (1956–1966), and later as a professor at the University of California at Berkeley (1972–1986), Luna Leopold established a new intellectual basis for water research programs. His bold innovative steps and exceptional research productivity served by example to convert the Water Resources Division of the U.S. Geological Survey into the world's leading hydrologic research institution; a truly major accomplishment. He fostered three generations of quantitative, interdisciplinary earth scientists by being an exceptional mentor for colleagues and especially young scientists.

Luna encourages scientists to set career objectives a little higher than they have yet imagined, just as he challenges himself in research and public policy matters. Continually testing bold new hypotheses, Luna has the courage to accept the risk of failure. The result is a bold, exceptionally innovative career that has created a continuing aura of excitement for a new fluvial geomorphology with a landscape ecology flavor. His mix of skill, dedication, personality, and zest for life revolutionized theoretical and applied fluvial geomorphology.

Luna has a flair for recognizing field settings that allow him to delve into how flowing water shapes landscapes, and how humans alter geomorphic processes. Many "river boys and girls" are fortunate to share field experiences with Luna. They find him to be forthright, dedicated, and formidable; yet flexible, highly considerate, and humorous. As a result of working with Luna, many scientists and engineers better appreciate the need for geomorphic concepts to be soundly based in field observations. They also share his enthusiasm for understanding more about geomorphic processes and landscape evolution, and the societal benefits of such studies.

Our debt to Luna is boundless; his inspiration enriches our geologic research endeavors. Geologists, ecologists, engineers, foresters, and policy makers have a different view of rivers, indeed a reverence for rivers, because of Luna Leopold.

Selected Publications of Luna B. Leopold

Leopold, L. B., 1943, Climatic character of the interval between the Jurassic and Cretaceous in New Mexico and Arizona: Journal of Geology, v. 51, p. 56–62.

Leopold, L. B., 1951, Rainfall frequency: An aspect of climatic variation: American Geophysical Union Transactions, v. 32, p. 347, 357.

Leopold, L. B., and Maddock, T., Jr., 1953, The hydraulic geometry of stream channels and some physiographic implications: U.S. Geological Survey Professional Paper 252, 56 p.

Leopold, L. B., 1953, Downstream change of velocity in rivers: American Journal of Science, v. 251, p. 606–624.

Leopold, L. B., and Maddock, T., Jr., 1954, The flood control controversy: New York, Ronald Press, 278 p.

Leopold, L. B., and Miller, J. P., 1956, Ephemeral streams: Hydraulic factors and their relation to drainage net: U.S. Geological Survey Professional Paper 282-A, 38 p.

Leopold, L. B., and Wolman, M. G., 1957, River channel patterns: Braided, meandering and straight: U.S. Geological Survey Professional Paper 282-B, 51 p.

Leopold, L. B., and Wolman, M. G., 1960, River meanders: Geological Society of America Bulletin, v. 71, p. 769–794.

Leopold, L. B., and Langbein, W. B., 1962, The concept of entropy in landscape evolution: U.S. Geological Survey Professional Paper 500-A, 20 p.

Leopold, L. B., Wolman, M. G., and Miller, J. P., 1964, Fluvial processes in geomorphology: San Francisco, W. H. Freeman, 522 p.

Langbein, W. B., and Leopold, L. B., 1968, River channel bars and dunes—Theory of kinematic waves: U.S. Geological Survey Professional Paper 422-L, 20 p.

Leopold, L.B., 1973, River Channel change with time—An example [Geological Society of America Presidential Address]: Geological Society of America Bulletin, v. 84, p. 1845–1860.

Dunne, T., and Leopold, L. B., 1978, Water in environmental planning, San Francisco, W. H. Freeman, 818 p.

Leopold, L. B., and Bull, W. B., 1979, Base level, aggradation and grade: American Philosophical Society Proceedings, v. 123, no. 3, p. 168–202.

Leopold, L. B., and Emmett, W. W., 1984, Bedload movement and its relation to scour, *in* River meandering: New Orleans, American Society of Civil Engineers, p. 640–649.

Leopold, L. B., 1990, Ethos, equity, and the water resource: Environment, v. 32, p. 16–20, 37–42.

Leopold, L. B., 1994, A view of the river: Cambridge, Massachusetts, Harvard University Press, 298 p.

Response by LUNA B. LEOPOLD

Just 105 years ago, the eminent geologist Sir Archibald Geikie addressed the Oxford University Scientific Club. In his paper he commented on the opportunity offered to, and by implication the responsibility of, the geologist to study the effects of humans on the physical environment.

"Prominent among these changes," he said, "has been the clearing of the dense woodlands that once covered so large a proportion of the surface.… But man's influence on the landscape has not consisted wholly in removing what he found to be obnoxious. He has introduced many forms of vegetation among those indigenous to the country. He has converted thousands of square miles of scrub, marsh, and woodland into gardens, parks, meadows, and corn-fields. He has replaced some parts of the primeval forest by plantations of a different type … (including) trees which seem to have had no place in the original flora."

Sir Archibald's thoughts strike a resonance in the current discussion of biodiversity, loss of species, desertification, and the tensions over the distribution of limited water supplies. The effect of human use on landscapes has been more far-reaching than Sir Archibald might have imagined. These changes have involved geomorphic, pedologic, biologic, chemical, and hydrologic functions—in other words, all aspects of ecology. The understanding of and possible amelioration of the effects of such influences is merely one part of the larger science of geology as we know it.

We face practical problems in land management that perhaps can be solved as we learn more about basic biophysical processes operating under a variety of conditions. To maintain the integrity of these natural systems we must develop the basic science that may underlie solutions. Let me mention samples of these practical problems.

The effects of the floods of 1993 and 1994 have prompted legislation that will govern how river valleys will function after even further regulation. National policy in which geologic aspects are not only prominent but essential is being formulated under our very noses. Yet as I read the technical material, geologists seem not included in discussions of alternative policies.

There is a need for evaluating the ecologic health of a piece of landscape. Management decisions continue to be made without a technical determination of the effects of such decisions on the ecosystem, many of which involve effects on soils, vegetation, water chemistry, erosion, and geomorphic stability. Managers struggle to find principles that underlie stability.

Consider the effect of massive logging of forests on stream morphology and chemistry, on landslides, erosion, and water availability. Despite a growing awareness of the advantages of maintaining biodiversity, it is ironic that the policy of the United States Government is to plant in clear-cut areas only one species of tree, leading as an end result to a monoculture of an even-age stand. The long-term effect of such a policy is within the scope of geomorphology, if that subscience is broadened to become a new and much-needed one that might be called biogeomorphology.

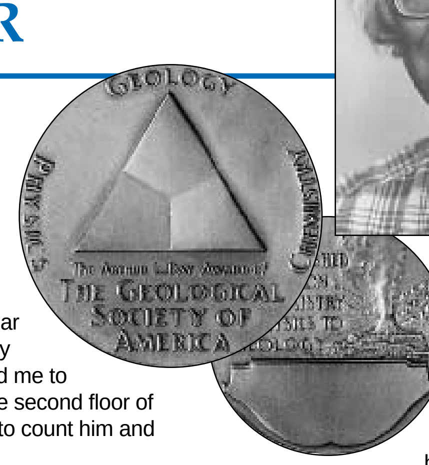
Though there are plenty of basic problems touching on our science, geology has allowed many parts of its core to be sloughed off to other disciplines only too eager to take over, but generally unprepared to do the job alone. Hydrology has been preempted by engineers. Climatology practically no longer exists, but its importance is ever more important as climatic change, an early concern of geologists, now is in the public mind. Soil erosion and its myriad aspects in pedology, hydrology, and sedimentology have been assimilated by agriculturists. After years of touting its importance, we still cannot compute satisfactorily the probable erosion rate of any segment of landscape larger than small fields of cropland.

The old idea of physiography or physical geography as a part of geology seems to have been gradually eroded. I draw the distinction between physiography as a combination of many scientific subdisciplines, and the separate units such as geomorphology. This combination has been replaced by greater specialization in which pure science points toward increasingly abstract problems, pursued through computer models and mathematical generalizations devoid of field observation.

In the earth sciences we cannot afford to close our eyes to the practical problems generated by human exploitation of natural systems on which we depend. Formulation of clear statements of the underlying nature of these practical problems will lead us to engage in innovative combinations of our basic sciences involving new interactions not heretofore contemplated.

Perhaps from the award of the Penrose Medal to a physiographer of the old school, our younger colleagues will see that physical geology has been, and again can be, the locus of intersecting ideas that affect many parts of a civilized society, and is central to many of the public policies of the nation.

Presentation of the DAY MEDAL to DAVID WALKER



Citation by EDWARD M. STOLPER

It is my pleasure to introduce David Walker, Professor of Geological Sciences at Columbia University, for the 1994 Arthur L. Day Medal. I have known Dave for 24 years, since I was a freshman and he was a third-year graduate student at Harvard. Although he may not remember it, it was he who first introduced me to scientific research, in the "Moon Room" on the second floor of Hoffman Lab at Harvard, and I am privileged to count him and his family among my closest friends.

Igneous petrology has evolved in recent decades from a discipline concerned primarily with origins of specific igneous rocks and associations to one that contributes vitally to understanding the large-scale evolution of the terrestrial planets. Through his innovative experimental and theoretical studies, Dave Walker has helped lead development of this modern discipline of igneous petrology.

Dave is what I would call an "elegant" scientist. He seems unconcerned with the hurly-burly of the crowd and chooses problems that interest him without regard for whether anyone else thinks they are important. He works at his own pace until he is satisfied with the results, writes usually a single paper that educates the rest of us on how to think about the problem and on how he has extracted unanticipated gems from the work, and then moves on without fanfare to the next mine. Via this style, he has managed to lead rather than follow, to surprise and often challenge the bulk of the community by the insights he pulls from work that is at a high angle to the mainstream, and to write more than his fair share of classic papers. I could give many examples of this style and the accomplishments to which it has led, but will cite just a few here.

1. Mid-ocean ridge basalts are the most voluminous igneous rock type on Earth. Though there had been much experimentation on them in the 1960s and early 1970s, by the mid-1970s there was still no systematic understanding of their crystallization behavior and of the processes leading to their diversity. In the mid-to-late 1970s, Dave carried out a series of experiments on the crystallization of mid-ocean ridge basalts at low pressures. No one would have thought there was much new or exciting to be learned. However, he devised a phase diagram (called by many the "Walker diagram") that systematized nearly all available data and transformed people's way of thinking about the evolution of basalts at low pressures. He demonstrated clearly the important role that magma mixing plays in the formation of these basalts and how this explains not only aspects of the compositions and phase equilibria, but also previously enigmatic aspects of their textures.

This work on mid-ocean ridge basalts repeated a style he had established previously in his work on the petrogenesis of lunar basalts. Although many experiments had been carried out by a distinguished group of investigators when he began his doctoral work on Fra Mauro basalts and his later work on mare basalts, he devised a simple phase diagram (also called the "Walker diagram," but luckily there is very little overlap between those scientists that use the lunar and terrestrial "Walker diagrams"!) from which he generalized to the larger problems of planetary evolution. This gave his work a much larger impact than that which had come before and started him on using igneous petrology as a firm quantitative basis for understanding planetary evolution and differentiation.

2. Since the publication of Bowen's classic work in the late 1920s, earth scientists had believed that the Soret effect (the development of a compositional gradient in response to a thermal gradient in a multicomponent system) was of no importance in geology. Dave guessed that this conventional wisdom might be wrong (I do not recall what interested him initially in this phenomenon), and he began to look for the Soret effect via experiments on molten silicates. To everyone's surprise, he demonstrated that the effect was very large and readily quantifiable. More significantly, with Chip Lesher he showed how the results of simple experiments in a thermal gradient could lead to surprising insights into the thermodynamics of silicate melts, that they could be generalized to determine crystal-liquid partition coefficients over a wide compositional range, and how partially molten systems in a temperature gradient would evolve texturally and compositionally. This latter insight may well have resolved the classical problem of the formation of adcumulate textures in layered intrusions. The key is that rather than working on the obvious, Dave struck out in a completely new direction, to great effect. Moreover, rather than simply observing the phenomenon, he related it to fundamental thermochemical properties of geologic materials and used it as a basis for developing hypotheses to explain classical geological observations.

3. There has been growing interest over the past several years in the densities of magmas at pressures of several tens to hundreds of kilobars. This stems partly from the suggestion that melts might actually become denser than coexisting crystalline silicates at upper mantle pressures—i.e., that magmas at great depth might go down rather than up. Dave has pursued this suggestion in a number of different ways in the dozen or so years since it was first made. First, he published several theoretical papers that laid the groundwork for relating phase equilibrium measurements to density relations and for understanding the significance of complex phase relations in terms of liquid volumes. Second, he set out with his student Carl Agee to measure directly the densities of ultrabasic melts to pressures of 60–70 kilobars using olivine float-sink relations; these were difficult and clever experiments. Finally, he considered the consequences of neutral buoyancy of olivine for the development of chemical stratification in a crystallizing terrestrial magma ocean (harking back to earlier work he had done on the evolution of a lunar magma ocean) and developed the concept that accumulation of neutrally buoyant olivine deep in the magma ocean would have had a significant effect on the physical and chemical evolution of the mantle. We see again the pattern: a novel insight or idea that leads to unique experiments; these are related back to fundamental properties (e.g., the equation of state of silicate melt at ultrahigh pressures) and then imaginatively applied to the solution of classical geological problems (in this case, the origin of chemical stratification in the mantle and the apparent enrichment of the upper mantle in olivine).

A side benefit of Dave's efforts to do experiments at ever higher pressures to measure melt densities was that it led him to try to simplify existing multianvil technology. Pioneered by the Japanese, available apparatuses were large, expensive, and cumbersome to use. It appeared that it was going to be necessary to move to a central facilities mode of operation in order to make this kind of experimentation at 50–250 kilobars available to American earth scientists. Dave saw that a new design could simplify these apparatuses and make them much smaller, easier to use, and inexpensive. The experts scoffed: "Walker may be a good experimental petrologist, but innovation at the cutting edge of high-pressure technology should be left to us," they said. Suffice it to say that Dave's design worked and has demystified multianvil research. His design is to multianvil experimentation what the Model T was to cars: it brings it within reach of a very large number of researchers. Many predict that this will usher in a revolution in our understanding of phase equilibria and planetary processes in the >50 kilobar range, just as the piston cylinder apparatus opened up a new era of experimentation in the 5–40 kilobar range that revolutionized our understanding of magma genesis in the upper mantle. Dave and his coworkers, including Harry Green and Marie Johnson, are helping to lead the way with new discoveries such as the hydroxyl-rich nature of β-Mg_2SiO_4, the nature of "anticracks" in phase transformations and the rheology of mantle minerals, and the breakdown of hydrous phases and the equation of state of water to 150 kilobars.

I hope this introduction gives some sense of what a special scientist Dave Walker is. He is arguably one of the leading petrologists in the world. This leadership comes via his taste in problems, from his ability to go off in unexpected directions and surprise us with elegant experiments, deep insights, and novel explanations for geologic phenomena, and through his unassuming manner. And besides all this, he is a wonderful, warm, and generous friend and human being. Only in his 40s, he has already accomplished a great deal, but has so much promise for the future that he is, in my opinion, an ideal choice to fulfill Day's intent through this award "to recognize outstanding achievement and inspire further effort."

Response by DAVID WALKER

I was minding my own business one Saturday night last May. Bill Dickinson called me up to tell me I had been selected as the Day Medalist. I thought it was a crank call—you know, Candid Camera or something. I certainly knew Bill Dickinson's name and pedigree, but not his voice. So it was a rather sobering experience to receive an official notification on GSA letterhead a couple of days later. I'm glad the couple of drinks I'd had suppressed my penchant for rude repartee during the phone call. The call was a big surprise because it was rather unclear that I deserved this signal honor. The Day Medal is supposed to be for the application of physics and chemistry to solving geological problems. I have never claimed to know any physics, nor have I ever been contradicted in this denial. I can recall more than one occasion in which people have stood in line to tell me how little chemistry I know. Perhaps more depressing with regard to the solution of geological problems is the thought that I believe I had a clearer picture of how Earth works when I was a graduate student than I do now. This is not just a failing memory. It reflects the feeling that the more you know, the less you actually understand because so much happens beyond your current specialty. Is it any wonder then that I do feel the need to wander around a lot from problem to problem?

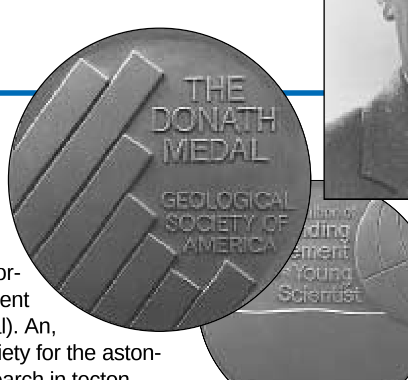
My memory is not so bad that I have forgotten what a fabulous place for petrological research Harvard was in the early 70s, or your place in it, Ed. It was a great thing for both of us that you were able to engage in significant research as an undergraduate just as I had been given the research opportunity before you when I was at Oberlin with Bill Skinner and Jim Powell. It is unlikely that every generation of undergraduate or graduate students can be immersed in a project as exciting as the first look at new lunar samples, but it is an encouraging development that many major research universities seem to be trying to take their undergraduate programs a bit more seriously these days. We both have Jim Hays, Harvard, and NASA to thank for our involvement in that most exciting enterprise.

Actually, I have a long list of additional people who should be thanked. In the last 25 years, I have published more than 100 papers, only two of which I have solely authored (and they weren't much, at that). That is an important measure of my debt to others—my collaborators must share in this honor in a very important sense. You, Ed, Jim Hays, Jim Kirkpatrick from Harvard days, Steve Delong, John Longhi, Tim Grove, Chip Lesher, Richard Sack, Ian Carmichael from Oberlin, Harvard, and Columbia days. And my Columbia-era colleagues: Carl Agee, Youxue Zhang, John Jones, Marie Johnson, Bruce Watson, Harry Green, Bruce Scott, and Charlie Langmuir. With friends like these, who needs to think for yourself! I also wish to thank Lamont and Columbia for giving me the supportive environment to continue petrological research, and my wife Celia and our children for giving me the time and understanding to pursue it.

You are correct, Ed, to characterize a fair amount of my research as orthogonal to the mainstream. One potential explanation for this, which we might be best served to quickly pass over, is that I am simply too lazy or inept to discover where the mainstream is. But, I guess I have always been a little disappointed that our mutual efforts in lunar and planetary differentiation have not become more "mainstream." As you correctly note, there is a fairly conspicuous non-overlap of the planetary and terrestrial communities. I suppose that is what we must expect when we let the Senator Proxmires of the world set our research agendas for us. On the other hand, I think Chip Lesher and I have always been secretly relieved that the Soret business has not become mainstream. Can you imagine what a circus it would have been if Ted Ringwood, rest his soul, had retracted his early disdain and decided that Soret was the flavor of the month after all? I must also thank my patrons at the NSF and DOE: Don Heinrichs, Bruce Malfait, John Snyder, Maryellen Cameron, Dan Weill, George Kolstad, and Bill Luth for exercising a certain amount of enlightened judgment in supporting stuff that clearly was out of the mainstream, and for showing a relaxed managerial attitude toward changes of project in midgrant to allow new opportunities to be pursued. Very little of the work honored today, or the equipment development that has gone in parallel with it, would have been possible without the flexibility of their support. In keeping with the Day philosophy, I hope they will be inspired to continue support of this sort.

I am particularly pleased to accept the Day Medal because it indicates that petrological research is still valued within the world's premier geological society. As global environmental perspectives add important new emphasis to our discipline, it is reassuring to remember that Earth does have some solid bits that are still worth studying! I hope that I and those who will follow me in years to come will continue contributing to our understanding of Earth as much as previous Day Medalists. Thank you very much. I am deeply honored.

Presentation of the YOUNG SCIENTIST AWARD (DONATH MEDAL) to AN YIN



Citation by GREGORY A. DAVIS

It is with the greatest of pleasure that I present to you An Yin of the University of California at Los Angeles — the Society's 1994 recipient of its Young Scientist Award (the Donath Medal). An, a native of China, is honored today by the Society for the astonishing diversity, scope, and success of his research in tectonics. It is fitting at an annual meeting with the theme of "The Leading Edge" that An's award stems from the exceptional melding of earth science disciplines learned on opposite sides of the narrowing Pacific Ocean. A native of Harbin in northeastern China, An was admitted to highly regarded Peking (Beijing) University in 1978, where he acquired skills in mathematics and geomechanics. In the fall of 1983, one year after receiving his B.S. degree in geomechanics, he entered the University of Southern California where among other studies he recognized the importance of field recognition, mapping, and interpretation of the kinds of structures he had analyzed theoretically in Beijing. The amalgamation, to use a plate tectonics term, of these diverse quantitative and qualitative skills largely occurred at UCLA, where as an assistant professor An Yin fell under the benevolent and supportive influences of the faculty there, especially Mark Harrison. As a consequence of these diverse academic experiences, An has become a truly exceptional young scientist. He is one of the very few tectonics practitioners on the continent today who can begin a research project with mapboard and hammer in hand, and complete it with original, insightful analyses of the kinematics and mechanics of the structures he has encountered.

I can recall some of the circumstances of An's coming to the United States for graduate study. In his 1982 letter of application to USC he stated that he had become interested in the theory of plate tectonics in his middle school and that was why he had undertaken a major in geology at Peking University. He assured our chairman that if he was admitted to the graduate program, "you will find out that I am 100 percent good student." Upon later learning that he had been admitted to USC he responded by writing, "I think I am the luckiest fellow in the world." I remember being touched by that verbal expression of happiness—it was the kind of heartfelt, sincere sentiment that no American applicant to any grad school would ever express, and it carried with it the promise that here was someone who would make the most of his forthcoming academic opportunities in the United States. We were not to be disappointed.

An's graduate tenure at USC was characterized by levels of motivation, hard work, and inquisitiveness that I had not seen before, and have not seen since. In the summer of 1984, he began mapping part of the famed Lewis thrust system in Glacier National Park, Montana. As one of several USC participants in a USGS-sponsored project to prepare an updated geologic map of the park, An quickly demonstrated a remarkable deftness for field observation and mapping (skills that do not always come easily to students from "third world" countries where the importance of field mapping is sometimes downplayed). I remember both my surprise and delight, upon field-checking his grizzly bear–infested map area at the end of the 1984 field season, that I could find no errors in either his mapping or interpretations of the complex temporal and spatial relationships within the thrust system. His experiences in rugged Glacier Park, both geologic and logistic, were to prove vital to his later and still ongoing field research in remote areas of eastern Asia.

An's selection as the 1994 Donath Medalist comes not from contributions in a specialized or narrow field of research, but rather for the impressive diversity, scope, and productivity of his scholarly efforts. His work has led to new kinematic and dynamic models for the formation of contractional duplex and fault-bend fold systems and for the coeval development of normal faults within active thrust wedges. He was a leader in developing mechanical models for the initiation and subsequent dome-basin folding of low-angle normal (detachment) faults associated with metamorphic core complexes—efforts contributing to the current interest in elastic and viscoelastic solutions for studying the origin of these enigmatic structures. More recently, An and his coworkers have contributed fresh ideas to our understanding of Himalayan and Qinling collisional tectonics in eastern Asia, the origin of the Tan-Lu transform fault of China, the geometry and kinematics of the controversial Lewis and Clark line in Montana and Idaho, evolution of the Whipple Mountains detachment system, and the nature of Laramide intraplate deformation in the Cordillera.

An's major contributions to Cordilleran and Asian tectonics and to our understanding of fault mechanics are all the more impressive given the very short time since the completion of his graduate studies. From Brunton to computer, An has established himself as an exemplar of "The Compleat Tectonician," and an eminently worthy recipient of the Donath Medal. Does he still consider himself the "luckiest fellow in the world"? I don't know because I haven't asked him, but An Yin is a shining example of how persons can make their own good luck by setting their sights very high and making the very most of opportunities afforded them.

Response by AN YIN

Dr. Stephenson, President Dickinson, Dr. and Mrs. Donath, ladies and gentlemen:

I was overwhelmed when Bill Dickinson informed me that I was the recipient of this year's Donath Medal. I am immensely honored, because it allows me to share this award with people who were heroes of mine when I was a graduate student. A ceremony such as this gives me the opportunity to thank those who helped me during the growth of my career. I felt fortunate when I was admitted to Beijing University in 1978 immediately after the Cultural Revolution, where I learned continuum mechanics from Professor Wang Ren and global tectonics from Professor Xianglin Qian. With generous financial support from my uncle and aunt (Mr. Pan Feong Tai and Mrs. Tjhin Liong Piet) and great uncle and great aunt (Mr. Tjong Tjhit Ton and Mrs. Jong Wai Wa) in Indonesia, I was able to come to study in the United States in 1983. They paid tuition and living expenses for my first two years of study at the University of Southern California.

At USC I was honored that Greg Davis took me as his student. Greg not only taught me how to map in the field but also showed me how to design and test a tectonic hypothesis through field investigations. Greg convinced me that mapping is the most important and fundamental aspect of geologic research. This philosophy has firmly shaped my research. I am grateful to Greg not only for his impact on my scientific career, but for his friendship during all these years. At USC I had the opportunity to interact with Kei Aki and Dick Walcott, who was on sabbatical from the University of Wellington in 1985 and 1986. They inspired me to approach tectonic problems quantitatively. In addition, interactions with Doug Burbank, Tom Henyey, Bob Osborne, and Charlie Sammis have influenced my later research.

My life would not have been complete at USC without my classmates Jay Jackson, Tom Kelty, Jack Dunn, Susan Roberts, George Steward, Kelly Ahlschwede, Sue Orell, Mary Droser, Lilly Metzger, Kathi Beratan, Louis Teng, and extended USC friends, through the Carleton College connection, Christine Smith and Norm Brown. With the guidance of those classmates at USC, my English vocabulary expanded rapidly (especially those words that cannot be found in a standard dictionary). I wish Kelly Ahlschwede were here this evening to share the moment. She passed away a year ago after losing her courageous fight against leukemia. However, her spirit accompanied me whenever I faced a challenge.

My years of geologic mapping in Glacier National Park were exciting. I enjoyed observing one of the most spectacular thrusts in the world, the Lewis thrust, as well as dealing with grizzly bears on a daily basis. I am extremely grateful to my field assistant Anthony Allen, who endured hardship in the park for five summers with little or no pay. His great sense of humor and ability to locate the best huckleberries helped make my field mapping nothing but a joy.

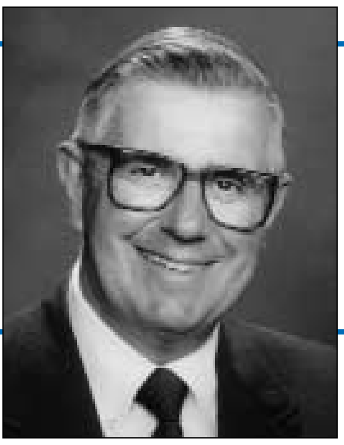
One of the reasons I am standing here this evening is because I have many wonderful colleagues at UCLA, who have provided a stimulating and supportive environment for a young scientist. Among them, I would like to especially thank Mark Harrison for introducing me to the fascinating problems of the Himalayas and Tibetan plateau. Mark has been a mentor, friend, and reliable running partner. Running with Mark is not only physically demanding, but mentally exhausting as well, because Mark enjoys arguing about almost everything at any time. Fortunately, we run together only once a day! I would also like to thank other colleagues of mine at UCLA: John Christie, Ray Ingersoll, Ron Shreve, and Shangyou Nie for sharing scientific thoughts; Gerhard Oertel for teaching me tensor analysis as well as hosting the famous "Oertel Afternoon Coffee Break"; and former and current chairs of the department Margie Kivelson, Art Montana, and Paul Davis for their support and encouragement. My gratitude also goes to my students: Christian Zarn, Earnie Paylor, Jeff Fillipone, Tom Kelty, Adam Norris, Liz Forshee, and Mike Murphy, from whom I learned more than I taught. I thank Brad Hacker, Rick Ryerson, Jim Sample, and George Gehrels for successful collaborations. I would like to thank my friend Donna J. Young, who proofread many of my manuscripts and proposals. I thank Dr. and Mrs. Allen and Mr. and Mrs. Kelty for treating me like a son since I came to the U.S.

Although I am grateful to many friends and colleagues who helped me during the growth of my scientific career, the people I owe the most to are my parents, who have been a constant source of support and motivation through the years.

Every scientist has his or her own style of conducting research. My approach has been to use field mapping to establish the geologic history of a region. I then use the regional history as the basis for designing a quantitative physical model. Finally, the model is used to explore physical mechanisms that cannot be observed directly in the field. Above all, field mapping and establishing regional geologic history are the foundations of my research.

Ten years of my life during the Cultural Revolution were wasted by studying Chairman Mao's Little Red Book and working in the countryside and factories. In contrast, the last ten years of my life in the United States have been rewarding, rich, and fulfilling. I have found that only in this environment could I best express myself and best develop into a scientist. For that, I want to thank the Geological Society of America for giving me this prestigious award.

Presentation of the GSA DISTINGUISHED SERVICE AWARD to F. MICHAEL WAHL



Citation by WILLIAM R. DICKINSON

The Distinguished Service Award is given for exceptional service to GSA as an institution. The recipient this year was your Executive Director for twelve intense years of growth in membership and expansion of programs. Two-thirds of the current membership first affiliated with GSA during his tenure in Boulder. But no one gets a medal just for doing his job professionally and conscientiously, and Mike is no exception. The essential extra ingredient in his performance was true dedication to the goals and purposes of GSA. He was one of us before he went to work for us and he is one of us still. To underscore that point, Mike went from the status of salaried employee to being a regular unpaid member of our crucial Investments Committee on consecutive days last summer.

Many things that now lie at the heart of the GSA enterprise originated as just gleams in Mike's eye. The publication *GSA Today,* which has become the prime vehicle for communication among GSA members, was his concept and bears the name he bestowed. The building addition was nurtured into reality primarily through his patient maneuvers. On his watch, publication volume quadrupled and publication revenues increased fivefold, to over a million dollars annually. DNAG ran its course, and a host of new initiatives were launched with his help and guidance. SAGE and IEE and Geoventures and Geotrips and Annual Meeting Short Courses are a few key examples.

The splendid contributions of F. Michael Wahl will not be forgotten, and will have a positive impact on GSA affairs for many years to come.

Response by F. MICHAEL WAHL

Receiving this award certainly has to be the highlight of my 12 years as Executive Director of GSA. I remember when I arrived to interview for the position, the president of the Society said "Michael, we would like to ask you some questions," and my response was, "That's fine—but I have two pages of questions to ask you about the Society, what it is doing, and where it is going!" We started with my list.

Most of the changes in the Society and the new programs that have occurred over the past twelve years were on that list. Bill has mentioned some of those changes and new initiatives, but there are a few others that I am proud to have been a part of, namely the addition of six new associated societies whose members now meet with us regularly at the annual meeting, the formation of three new GSA divisions, and the establishment of the Young Scientist Award (Donath Medal). Another highlight was the Centennial Celebration in Denver in 1988. Of course, when Denver was selected as the meeting site for this important meeting, we were assured that by 1988 the city would have a new convention center and a new airport. We had neither, but we survived, and the meeting was a huge success!

My greatest satisfaction over these 12 years was having had the opportunity to revitalize the Society and its programs, so that you the members may take pride in being part of GSA. Also gratifying has been the opportunity to work with so many many of you who have served on committees and participated in the programs of the Society. A very special thanks goes to my dedicated headquarters staff, without whose efforts I certainly would not be here today. To the Section secretaries, to the 12 presidents during my tenure, and to the other officers and many councilors with whom I have been privileged to serve, I thank you all for your support!

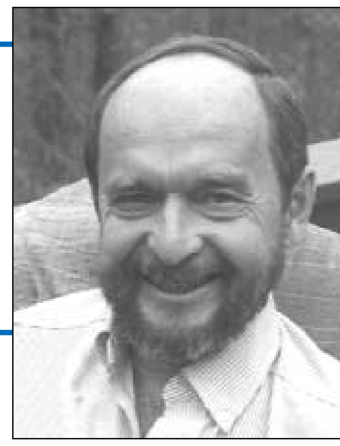
Finally, and most important, my heartfelt thanks to my wife Dottie for your patience, encouragement, and support. We both will always remember the past 12 years as a highlight of our lives. Thank you very much.

Presentation of the

RIP RAPP ARCHAEOLOGICAL GEOLOGY AWARD

to

JACK DONAHUE



Citation by JULIE STEIN

Jack Donahue's life changed in 1973. Before that time he was happily working as a well-respected petrologist and reconstructor of depositional environments. He had published his research on the laboratory growth of pisolite grains in 1965, and completed his dissertation, at Columbia University in 1967, on the Salem Limestone of south-central Indiana. Jack dabbled in the scanning electron imagery of sand-grain surface textures in 1968 while a lecturer and assistant professor at Queens College, and while continuing his interest in limestones branched out into burrow morphology when he joined the University of Pittsburgh in 1970 as an assistant professor. During the next few years, Jack began his collaboration with Bud Rollins, examining marine transgressive-regressive sequences and paleoecological reconstructions. All of this was traditional research for a promising sedimentary petrologist. But he never suspected what was to come from meeting a colleague at the University of Pittsburgh, a young archaeologist named Jim Adovasio.

Adovasio had found a rock shelter in Pennsylvania, located in a sandstone outcrop. He asked local petrologists to "come on out to the site and take a look." Yes, it was sandstone, so Jack decided to poke around and help out a little. From 1975 to 1994 Jack Donahue has published or co-published 20 articles about Meadowcroft rock shelter (and that does not include contract reports or papers at conferences). Little did Jack know that the simple act of answering the phone that day would lead not only to so many publications but also a new career.

With the work at Meadowcroft came a new direction to Jack's life. He began to explore this new interdisciplinary relationship with archaeology on many different fronts. His first big enterprise was the Dead Sea Archaeological Expedition in Jordan, where he investigated the geoarchaeological aspects of Early Bronze Age sites in 1977 to 1981. He combined this Old World experience with work in the Western Hemisphere. He and his students worked on the Little Platte River from 1978 to 1980; Moche and Chimu sites in northern Peru in 1981; Antigua, Barbuda, and Montserrat sites in 1984, Danger Cave, Utah, in 1986; southern Peru in 1987; China in 1988; Rio Jama and Rio de la Plata in Ecuador and Colombia in 1991; and Yautepec, Mexico, in 1993.

Throughout these wanderings, as he reconstructed depositional environments and paleogeography, modeled terrace sequences, and analyzed alluvial and coastal settings, Jack continued to ply his trade as a petrologist. The subjects of his petrographic examination had changed. They were now ceramics, not rocks. He examined Bronze Age sherds in Jordan, Woodland sherds from the eastern United States, sherds from St. Catherine's Island, Georgia, and from the northern Lesser Antilles. He used his skills to further the field of ceramic petrography, and he has published extensively on this subject.

Another research area that Jack pioneered was within the arena of geoarchaeological applications to cultural resource management. Jack was the staff geoarchaeologist at the Center for Cultural Resources Management Program at the University of Pittsburgh from 1976 to 1990, and he continues this tradition at the Center for Cultural Resources Research, since 1991, within the Department of Anthropology. In this capacity, he has produced hundreds of reports to contracting agencies and has even acted as an expert witness in two important cases involving the theft of artifacts from public lands. Jack's ability to team up with cultural resource managers has been a model for many of us who have taken up the effort in the years following his work.

All of us owe a debt of gratitude not only to Jack, but to Jim Adovasio for diverting Jack Donahue's interest from traditional petrology toward geoarchaeology. Not only did Jack conduct all the valuable research I have just mentioned, but he also did a tremendous amount of service for the new, growing field of geoarchaeology. In 1978 Jack ran the first field trip sponsored by the newest division of GSA, the Archaeological Geology Division. The division was officially recognized by GSA in 1977, and for this trip Jack took everyone to see (what else) Meadowcroft Rockshelter. He followed the field trip by becoming the vice chair and chair of the division in 1979 and 1980. These were the first years of the division, a time when everyone was wondering if the infant discipline would survive. Jack was one of those who nursed it to health nearly 20 years ago.

Perhaps Jack's greatest contribution in the area of service was to create the first journal devoted exclusively to the subject of geoarchaeology, *The International Journal of Geoarchaeology,* published by John Wiley. He was its sole editor from 1985 until he passed the baton to Paul Goldberg and Ofer Bar Yosef this year. We are all grateful for the work that he did in his ten years as editor. In this same vein, Jack became one of the editors of the DNAG (Decade of North American Geology) volume entitled *The Archaeological Geology of North America,* published in 1990. Jack and Norm Lasca created a volume of 35 chapters that still constitutes the largest single source of references about geoarchaeology, thus establishing geoarchaeology as one of the respected research areas within the Geological Society of America.

Not all of us attended or participated in the birth of geoarchaeology in the early 1970s or are aware that in Pennsylvania a young archaeologist was cajoling a young petrologist to come over and take a look at a sandstone rockshelter. But from that moment, the discipline of geoarchaeology was forever changed.

Response by JACK DONAHUE

I am both surprised and pleased to receive the Rip Rapp Archaeological Geology Division award. I would like to outline the evolution of my career, and talk about the events and people who helped me become a geoarchaeologist. In thinking back through the past, I feel that both people and ideas influenced the route I chose to travel. I want to thank up front all the archaeologists with whom I have collaborated, for, without their contributions, I would not have developed the diversity of research topics that enriched my career as a geoarchaeologist.

My parents, Ruth and Len, were the first to influence me by their strong interest in nature and the outdoors. They have inquiring minds and often asked me to think about the "how" or "why" of natural phenomena. We took family camping vacations in the 1950s in the Colorado, Montana, and Canadian Rockies, showing me at an early age the splendor of the mountains. This was quite an awakening, as I was growing up on the flat, Pleistocene plains of Illinois.

I attended the University of Illinois as an undergraduate, and with my first course in physical geology, I knew I had found my life's work, and I declared geology as my major. Two people stand out in my memory from my years at Illinois. The first was F. Michael Wahl, a young Ph.D. who taught an excellent course in mineralogy. He kindled such excitement with his dynamic lectures I was seriously considering mineralogy or geochemistry as a research area. The second person who strongly influenced me was F. H. T. Rhodes, a visiting professor of paleontology from Swansea, Wales. He introduced me to the delights of paleontology and paleoecology and suggested I attend graduate school at Columbia University, where I could study with John Imbrie, one of the leading researchers in paleoecology. As I was a recipient of a National Science Foundation fellowship, I was able to go to Columbia, where the big city changed my life forever! At Columbia, I completed a Ph.D. dissertation on the depositional environments of the Salem Limestone, a Mississippian-age limestone in southern Indiana used extensively for building stone. One of my locations was the rather large quarry from which the stone had come to build the window sills for the Empire State Building. The study of the Salem gave me a thorough grounding in reconstruction of depositional environments and thin-section petrography, both of which have carried over into my geoarchaeological research. At Columbia, I met a fellow graduate student, in marine geology. Jessie and I were married while in graduate school. Considering that we will celebrate our 30th wedding anniversary in January 1995, we have managed to season a happy marriage with a lot of spicy geological discussion. She has helped me throughout my career with encouragement and discussions of research topics. She has also participated in geoarchaeolgic field work and continually challenged me intellectually.

I left New York City in 1970 to accept a teaching position in the geology department at the University of Pittsburgh. A friend and fellow colleague from Columbia had preceded me there, and we were excited to continue together some research directions he had started. Bud Rollins and I worked quite a few years on the paleoecology and depositional environments of the thin marine limestones intercalated in the largely nonmarine fluvial coal measures that are the exposed bedrock in western Pennsylvania.

In 1973, a graduate student in anthropology, Joel Gunn, approached one of our graduate students, Lilo DeGasparis, to see if anyone in the geology department would be interested in some cooperative research. Jim Adovasio, with the Department of Anthropology at Pittsburgh, was conducting the summer field school in a large, sandstone rock shelter near Meadowcroft Village. I agreed to take a look at the site, as I am always interested in new research topics. I met Jim Adovasio at the shelter and took four sediment samples from the colluvial slope beneath the rock shelter. I wrote a short summary of my findings and went back to work on the real rocks, my Pennsylvanian limestones. Several months later, a very excited Jim Adovasio called me to say that the radiocarbon dates from the deepest part of the excavation, at that time about two meters, were coming back at 8000–9000 years B.P. Because I was working on limestones that were 250 to 260 million years old, the full import of his statement did not register.

However, Meadowcroft did not go away. Jim needed more information about the geology, and because some radiocarbon dates from deeper parts of the excavation proved to be in excess of 10,000 years B.P., the site was beginning to emerge as a very important one. By this time, I had learned more about archaeology and recognized the significance of the older dates. I became a regular visitor at the site and collaborated with Jim for many years. My work at Meadowcroft revealed a great deal about mechanisms of sedimentation in sandstone rock shelters and was even more fascinating than Pennsylvanian limestones. From that point on, I never looked back.

In conjunction with the archaeological mitigation program at Pitt, I also investigated sandstone rock shelters in eastern Kentucky and northeastern Mississippi. My studies of sandstone rock shelters were largely completed by 1986 and have, I hope, expanded our understanding of the erosional and depositional dynamics of sandstone rock shelters.

Concurrently with my research at Meadowcroft, I was invited in 1977 by Tom Shaub, a biblical archaeologist at Indiana University of Pennsylvania, to join an ongoing excavation in the Dead Sea rift in Jordan. The Southeast Dead Sea Archaeological Expedition had been working on some Early Bronze sites and was interested in learning more about the past landscapes and climates. This started a long collaboration among Tom Shaub, Walt Rast (another biblical archaeologist), and myself. I spent time in the field in Jordan in 1977, 1979, 1981, and 1989. This research direction was new for me and involved landscape reconstruction in a tectonically active area and an arid climate. I also began a petrographic study of thin sections of Early Bronze potsherds. This study continues today as a Ph.D. dissertation by one of my students.

In 1982, Jim Richardson, of the Department of Anthropology at Pitt, asked me to do some field work in Peru. He was collaborating with Mike Moseley, an archaeologist now at the University of Florida. Bud Rollins and I visited Moche and Chemu sites in northern Peru. I was struck by the similarity of the desert environment with that of the Dead Sea and realized that the occupants of the sites in both Peru and Jordan had used similar construction and water management techniques. I don't know if this constitutes the field of paleoethnogeoarchaeology or not.

The late 1970s were the time when I realized that I had become a geoarchaeologist. Peter Storck of the Royal Ontario Museum and I organized and led one of the first field trips for the Archaeological Geology Division at the joint GSA-GAC meeting in Toronto, and I served as vice chair and chair for the division in 1979 and 1980. In 1979 I also began a joint appointment in geology and anthropology at Pitt, a position that I still hold.

In 1983, at the Atlanta GSA meeting, I met Rhodes Fairbridge who asked me if I was interested in founding and editing a journal dealing with geoarchaeology. As usual, I was interested in trying something new and said yes. We met with a publisher who was interested in the project. Two publishers and three years later, the first issue of *Geoarchaeology* appeared. The journal began as a quarterly solidly in the red, went into the black in the fifth year of publication and expanded to a bimonthly with the seventh volume. After serving as editor for ten years, I knew that I was "burning out" and am very happy that Paul Goldberg and Ofer Bar-Yosef have taken over as co-editors for volume ten. Also during the early 1980s, I made the mistake of agreeing to organize and edit the GSA DNAG Centennial Special Volume on archaeological geology. Since editing geoarchaeology and drawing together manuscripts for the Centennial volume were relatively small efforts at this time, I thought I could manage both. I had received a letter from Norm Lasca, University of Wisconsin, Milwaukee, saying he would be interested in co-editing the volume. As both projects grew in size, I contacted Norm to ask for his help. I will always be grateful to Norm because he is the person who drew together and finalized the editing of the DNAG volume.

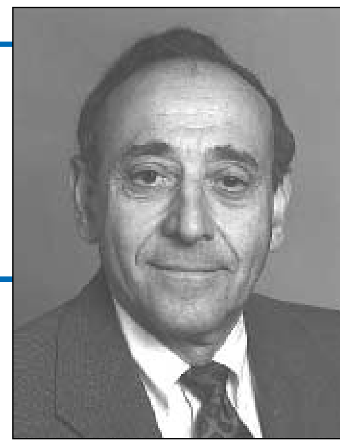
Beginning in the early 1980s, I began shifting my field studies to Central and South America, both to look at the younger sites in the Western Hemisphere and to see different environmental settings.

In 1984, Dave Watters asked me to work with him on the island of Barbuda, a small, remote island in the Northern Lesser Antilles near Antigua. Dave is an archaeologist with the Carnegie Museum in Pittsburgh, and had already put in several years work on Barbuda. I made several field visits to the island and looked at old strand lines on a carbonate platform. I also became interested in petrographic studies of Barbudan potsherds. The temper in the ceramics was volcanic, and as the island is all carbonate, the ceramics had to have come from another island. What fun this research is, like a detective game! The volcanic inclusions and temper offer the potential for fingerprinting sherds in order to track trade and exchange routes through the islands.

In 1992, I began a study in coastal Ecuador with Jim Zeidler and John Issachson, both at the University of Illinois. My work has concentrated on fluvial sequences containing Valdivia sites. All the sedimentary sequences are aggradational in nature, beginning with point bar sands and gravels and working up to floodplain sediments containing paleosols. We are now plotting the stratigraphic sections at a number of localities on a time rather than a sediment-thickness axis. Because we have several dated volcanic ashes in the sections, this is a relatively easy task and one we feel is worth pursuing, because it will add an important time perspective to a stratigraphic section, showing how long any environmental setting was available for human occupation.

I want to close with three comments. The first is that in the past 20 years, the Archaeological Geology Division has certainly become my home at GSA meetings. Second, I want to emphasize that my work over the past 20 years has been aided and abetted by a long list of archaeologists, all of whom I thank, for without them I would not have arrived at where I am today. Third, I originally defined geoarchaeology as an interface between geology and archaeology. Ideally, though more difficult to achieve, geoarchaeology is the interactive or synergistic interface where contributions from a geologist and archaeologist create a final

Presentation of the
GILBERT H. CADY AWARD
to
HAL GLUSKOTER



Citation by
ROBERT B. FINKELMAN

Few people have had as far-reaching and profound an impact on the field of coal geology as Hal Gluskoter has. For almost 30 years, first as a researcher and then as an administrator, Hal has left an indelible imprint on coal geology in North America and abroad.

One of his first publications concerned the application of an electronic low-temperature ashing device to coal. This simple procedure allowed coal scientists, for the first time, to efficiently remove minerals from macerals without thermal alteration, and thereby revolutionized coal geochemistry. Today, all serious coal-research laboratories in this country and in many foreign countries have low-temperature ashing units. Countless papers, dissertations, theses, reports, and presentations have been based on data derived by using Hal's visionary application.

Hal Gluskoter's impressive list of publications, dealing chiefly with the inorganic geochemistry of coal, quickly established him as one of the world's leading coal scientists. His pioneering work on the minerals and elements in coal are still widely cited in the literature. Hal's geochemical research culminated in a landmark publication on trace elements in coal: Illinois State Geological Survey Circular 499 . This publication is still a classic against which subsequent coal chemistry publications are measured.

Hal's scientific accomplishments were followed by equally impressive administrative accomplishments. He was appointed head of the Coal Section at the Illinois State Geological Survey, where he ably directed this group through difficult economic times. Under his guidance, the Illinois State Geological Survey maintained its position as one of the world's preeminent coal research organizations.

In 1978, Hal took his talents to industry, where he established a coal and oil-shale research program for Exxon Production Research Company. In a few short years, much first-rate coal science was accomplished under Hal's guidance. As a result of shifts in the world energy picture and changes in global economics, the Exxon coal-research group was disbanded. Hal's versatility allowed him to take on the important responsibility of supervising the company's training program.

Hal returned to coal geology in 1985 as the chief of the U.S. Geological Survey's branch of Coal Geology, where he provided an environment for creative and productive research. I believe that under Hal Gluskoter the Coal Geology Branch produced some of its best research.

In addition to his research and administrative accomplishments, Hal has served the coal-science community in many other ways. He has been an active member of the GSA Coal Geology Division for nearly three decades. He served as chairman in 1980 and has continued to work hard for the betterment of the division. Hal has been widely sought as a speaker on a variety of coal-related topics and has served on national panels and commissions dealing with coal science. Hal was the 1992 recipient of the Gordon H. Wood, Jr., Memorial Award from the Energy Mineral Division of AAPG in recognition of his significant contributions to coal geology.

Hal's impressive accomplishments as a researcher, as an administrator, and as an advocate and representative of our discipline are rivaled by his impact as a teacher, mentor, and friend. The list of those who have worked for, and learned from, Hal reads like a Who's Who of recent coal geology. I cannot think of anyone who embodies the spirit of the Gilbert H. Cady Award, or anyone who more richly deserves it, than Harold J. Gluskoter.

Response by
HAL GLUSKOTER

I would like to express my most sincere gratitude to the Coal Geology Division of the Geological Society of America. You have just awarded to me the single most meaningful recognition that I could possibly receive—the Gilbert H. Cady Award.

I was fortunate to have the opportunity to become fairly well acquainted with Doc Cady. (Everyone called him Doc, and in nearly every photograph of him that you will see, he sported his trademark bow tie.) Although Doc officially retired in 1951, he came to his office at the Illinois State Geological Survey almost daily (and worked all day long) until a very few weeks prior to his death in 1970. Thus, I was able to have frequent contact with him during my first eight years at the ISGS.

Having examined the list of the 13 previous recipients of the Cady Award, I am even more convinced of the honor of being added to this august group. I have had the privilege of knowing them all personally, and all 13 are greatly to be admired and their actions emulated. Some on that list are among my heroes, including the first two recipients, Jim Schopf and Jack Simon.

Jim Schopf on occasion would send me essays—thought pieces—that he had written and would ask for my comments. I especially remember one piece on sulfur in coal that sent me scurrying through the literature in order to respond properly. His material had no references and no attribution—but it was full of ideas. My task then became to do all the legwork and, of course, to learn as I did so.

If a young geologist just getting started could have one wish granted, it should be for a mentor just like Jack Simon. What Jack had learned from his mentor, Doc Cady, he practiced with his colleagues, always with a deep, warm personal regard for all with whom he came in contact. Jack was the one person most directly responsible for my entry into coal geology, and he provided valuable and welcome guidance for the first two decades of my career. What a fortunate piece of luck that was for me!

In geology, and in life in general, as established for us by John Donne, no person is an island. We, as scientists, usually add incrementally to knowledge built up by our predecessors and colleagues. My work is no exception, and I owe much thanks to many people, including many here today. I will not list them all individually; there is not sufficient time and I would doubtless inadvertently omit someone important. Rather, I thank all who have made coal geology stimulating and enjoyable for me for the past 32 years, and those who continue to do so.

We are celebrating the 14th Cady Award ceremony. If we accept that nothing will go on forever and that the number of such awards is finite, how many more such awards can we expect to celebrate? (I have a distinct impression that not many here today have lost sleep while pondering this particular question.) Because the Cady Award honors contributions to coal geology, the question can be restated as, "How long will coal geology as a subdivision of fossil fuel science be around?" This restatement reveals a deeper issue.

In order to answer this question, we have to succumb to the temptation to peer into the future. Not very long ago we predicted everything as it would transpire in the year 2000. That might have been a challenge 40 or 50 years ago, but now it is really rather straightforward. Six short years from now, in that very year 2000, energy utilization in the United States (and worldwide) will be very similar to energy utilization today. Power plants currently producing electricity will continue to do so, and mines producing coal will, for the most part, still be operating. The next six years are easy to predict, but what about 50 or 100 years hence?

The earth currently holds 5.5 billion people. Its population is projected to double during the 50–100-year time frame we have defined for our look into the future. Population growth will not come from the developed countries, however, but from the underdeveloped and developing ones. Certain factors could limit that growth, and some salient ones appear in the Book of Revelations: famine, war, pestilence, and death. If we humans are to avoid or, at least, alleviate the effects of the Four Horsemen of the Apocalypse, the world's energy consumption, especially that of the developing countries, must greatly increase.

Nearly all factors influencing quality of life, such as infant mortality, life expectancy, literacy, and availability of clean water and adequate medical care, correlate with energy consumption and also with income. Those countries wherein both income and energy consumption per capita are lowest in the world are the most polluted in regard to water and indoor air. Poverty is the world's worst pollutant.

Modern economists have long used a rule of thumb whereby a 1% increase in the Gross Domestic Product (GDP) will be accompanied by a 1% increase in per capita energy consumption. Increased efficiencies in energy production coupled with energy conservation may cause the rate of increase in energy consumption to decline, but total consumption will undoubtedly continue to increase as countries develop. As the least developed countries begin to utilize increased amounts of fossil fuels, their contributions to some aspects of air and water pollution will increase; recent studies have shown this to be taking place. However, once the GDP (or the GNP) exceeds $5000 per capita, the pollution decreases markedly; the country becomes able to afford technologies for cleanup and prevention.

What will be the source of the increased energy needed to support a growing world population—we hope a better fed, healthier, and better educated population? In the near term, the energy source must be fossil fuels, or nuclear fuel. For thousands of years humankind subsisted using traditional fuels, especially wood and dung. In the Industrial Revolution, coal replaced wood as the dominant fuel. As that revolution expanded and accelerated, oil and gas took their place as the dominant energy source. Still later, nuclear energy made its appearance and acquired a significant, although minor, share of the world's primary energy mix.

Earth's most abundant fossil fuel is coal. It is widely distributed geographically, and it is relatively easy to develop and produce. As such, it is a likely resource for developing nations to use as an indigenous source of energy, thereby reserving hard currency for capital goods that they must import. Moreover, the methods for utilizing coal are well known, and they are not so technologically sophisticated that their use by developing nations is precluded or feared.

As the foregoing comments suggest, the near-term future of coal is a positive one. However, coal development and use are not without problems. Coal extraction can scar the earth, and inefficient coal utilization can produce pollutants. The world has become increasingly concerned as to the potential effects of global warming due to increase of greenhouse gases. Carbon dioxide from the combustion of fossil fuel has been targeted as a significant biogenic contributor to the greenhouse effect. The burning of coal produces significantly more CO_2 per unit of energy than do natural gas or petroleum.

Nations do have choices—and are making them—about the source of energy they will use to produce electricity. France has opted for nuclear energy. The People's Republic of China uses coal almost exclusively. The United States employs a broader energy mix; coal's current share is approximately 55%.

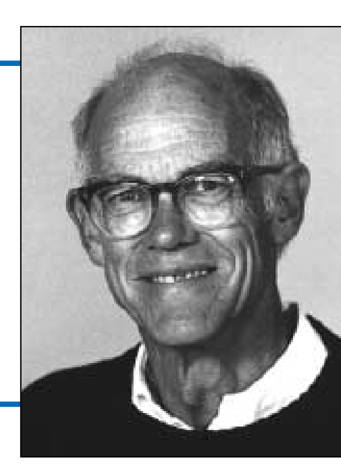
Because of coal's lower cost relative to other fossil fuels, its ease of use, and its widespread availability, the world will be able to increase its use of coal for decades to come. In truth, however, fossil fuels are present on Earth in finite amounts, and both societal pressure and necessity will at some point push us to wean ourselves from the use of stored forms of the Sun's energy and to develop methods of using that energy more directly. More direct solar, fusion, or some major technological breakthrough that I have not the wisdom to foretell will eventually replace the use of fossil fuels as our primary energy sources.

Looking as much as 100 years into the future is nearly impossible for most of us. Imagine yourself living in 1894, trying to predict life in the 1990s! Could you have predicted major technological developments such as satellites and global positioning systems (GPS)—or even karaoke? My prediction for 2094, and of this I can assure you, is that humankind will not be using fossil fuels as sources of energy. That being the case, we will then need to redefine the criteria for which the Cady Award is given.

Returning again to the spirit of the award, I am reminded of the memorial to Gilbert Haven Cady written by Jack Simon and published by GSA. This excerpt best expresses my personal memories of Doc Cady: "His frequent gruff manner could not conceal his deep personal concern for all with whom he was associated. The few stormy professional issues in which he was involved never resulted in a loss of respect on either side. He was frequently a keen professional adversary regarding new ideas but was receptive to presentation of sound scientific data. And what a joy it was to colleagues who did battle with him in a scientific discussion to receive his approval."

Receiving this award and thereby linking my name with that of Doc Cady is truly an exceptional honor.

Presentation of the
STRUCTURAL GEOLOGY AND TECTONICS DIVISION CAREER CONTRIBUTION AWARD
to
RICHARD P. NICKELSEN



Citation by
STEVEN E. BOYER

Richard P. Nickelsen, variously known to his friends and colleagues as Nick or Dick, has greatly influenced undergraduate education in the earth sciences. Throughout his career Nick has exhibited a concern for majors and nonmajors alike. His students have graduated to fill positions in industry and academia. But of equal or greater importance, over a period of 40 years he has instilled in nonmajors an appreciation for their earth, their environment, and science in general.

Nick is best known for his work in the Plateau and Valley and Ridge provinces of the central Appalachians. Therefore, it was fitting that he was honored by a symposium and dinner at the 1991 meeting of the combined Northeast and Southeast Sections, held in Baltimore. However, Nick also deserves recognition at the national level, as he has exemplified the best qualities of teacher, mentor, and trusted colleague.

In nominating Nick for this award, his friends and associates most frequently cited devotion to teaching *and* sound creative research as his most significant career contributions. Nick began his teaching career as an Assistant Professor at Penn State in 1953 and continued from 1959 at Bucknell University, where he served as chairman from 1959 to 1976. He has been professor emeritus since 1992.

Nick's defining characteristics as a teacher can be summarized in a few words—enthusiasm, patience, persistence, and dedication: enthusiasm for the earth sciences and the simple joy of learning; patience for students slow to accept the high standards he expected of them; persistence in establishing the fundamentals; and dedication to the concept of a liberal education.

The qualities that make him a great teacher are also exhibited by Nick in the conduct of his research. Nick's research accomplishments are many and have provided important insights into the style of deformation and distribution of strain across orogenic belts.

Nick's persistence and thoroughness are well-known to all who have been in the field with him. Nick's mapping skills were developed while working in the Blue Ridge of northern Virginia and eastern West Virginia. The mapping and field observations were part of his Ph.D. dissertation conducted under Ernst Cloos at the Johns Hopkins University, published in a 1956 GSA *Bulletin* article. He further honed those skills with over 40 years of fieldwork in the central Pennsylvania Appalachians, Norwegian Caledonides, Rocky Mountain foreland, and Colorado Plateau.

Nick's work in the Valley and Ridge and Plateau provinces of Pennsylvania, published in a number of papers during the 1960s and early 1970s, demonstrated the roles played by pressure solution and regional fracturing as early responses to tectonic stresses. This work also established that the deformation front extended far into the foreland to the front of the prominent fold and thrust front.

Anyone who knows Nick is aware of his love affair with the Bear Valley strip mine at Shamokin, Pennsylvania. Stripped of overlying coal measures, a fully exposed anticline and adjacent synclines display beautiful small-scale structures. This open-pit anthracite mine served as a focal field trip of both physical and structural geology classes at Bucknell. Over many visits to the mine, Nick meticulously unraveled the sequence of deformational features: regional joints, cleavage, wrench faults, out-of-the-syncline thrusts, forelimb extensional grabens, and fold-related fractures. The result was a classic paper on small-scale structures and sequential deformation, published in 1979 in the *American Journal of Science*.

A 1986 *Journal of Structural Geology* article established the concept of the "cleavage duplex." Careful mapping, the results of which were published in GSA Special Paper 222, demonstrated the significance of small-scale duplexes in absorbing strain within thrust belts. This work has implications for the kinematics, the construction of balanced cross sections, and the partitioning of shortening, not only within the Appalachian Valley and Ridge, but within thrust belts in general.

Six articles, written by Nick and various collaborators, contributed significantly to understanding the stratigraphy, structure, and tectonic evolution of the southern Norwegian Caledonides.

Never one to rest on his laurels, Nick, in collaboration with Olivier Merle, George Davis, and Pierre Gourlay, has now ventured onto the Colorado Plateau to study cleavages and thrust faults, generated by gravitational spreading of the Marysville volcanic center.

As many of my colleagues became aware that Nick was to receive this award, they came forward to offer their thoughts. A number of these individuals teach at small liberal arts institutions, and they noted that Nick had served as their role model, demonstrating that not only are good undergraduate teaching and significant scientific research compatible, but that each is essential to the other. In that vein, I close with some words from Win Means: "Dick is one of my heroes …, for his gentle yet passionate inquisitiveness, his careful and imaginative mapping, and for his influence on so many of us, students and professors alike."

Response by RICHARD P. NICKELSEN

You, Steve, and others who started geology as my undergraduate students, and have achieved so much, have made my teaching life complete. This Structural Geology and Tectonics Division award is a great honor, because I stand before you and many other former students and colleagues who know me best and have shared my pleasure and enthusiasm for doing structural geology in beautiful places these many years. But before continuing with that, I first want to pay tribute to Cindy my wife of 44 years, and to three fine children, Abby, Bruce, and Jill, two of whom are here, for their support and patience with my weekend field trips and evening work—Dad's tapping typewriter as they dozed off—and all of those roadside stops and geological detours. Cindy shared the heat of Virginia summertime attic apartments, a distant-from-everywhere trailer in Wyoming's Shirley Basin, and rainy days in Norwegian huts amongst cloud-draped mountains, to sustain present family as I studied ancient geologic history. Before all of you I want to thank them.

A few pivotal moments in my career provide a suggestion of what influences are worth preserving in our educational and mentoring system. First, I found geology, a discipline I'd never heard of, at a predominantly undergraduate liberal arts college staffed by dedicated professionals who were also devoted teachers—the Dartmouth College of Stoiber, Lyons, McNair, Goldthwaite, and others. I didn't have to choose a major before I arrived on campus, but when I did I was wonderfully encouraged and supported by these teachers and a flock of outdoor-oriented student peers.

Second, during the course of that education we were exposed to lectures by a few geological giants. In the post-war 1940s Hans Cloos came—a dynamic presence that I can still visualize, and that settled whether I would pursue graduate work in structure or glacial geology. And, of course, I chose Johns Hopkins, where his brother Ernst Cloos taught. Third, Ernst was an inspiration, through his skill at teaching field observation and interpretation of structures, his realistic clay deformation demonstrations, and the example of his careful incorporation of strain data from the many small, oriented specimens of his beloved oolites into the finest regional strain map in existence.

Fourth, following seven educational years on the hard rocks of New England and the structures of the Piedmont and Blue Ridge, I arrived to teach at Penn State, where it was suggested that I pursue geological study of the good strip-mine exposures in horizontal bituminous coal measures of the Appalachian Plateau. Not too willingly, I encountered a new world of geology where I fortunately could find tectonic overprinting of regional joints and penetrative strain features not previously observed that far into the foreland. These observations had a profound influence upon my geological thinking and future research on the regional extent and sequential development of different stages of deformation within the Alleghany orogeny. I tell this story to encourage the acceptance of challenges that are apparently far from your training, experience, or what you think you like to do.

Fifth, I found another geological environment in the Pennsylvania Valley and Ridge that was good for teaching undergraduates, because of its accessible Paleozoic stratigraphy, its magnificent structures and their related geomorphic features, its environmental problems, its nice transitions from simple to more difficult geology, and, of course, its several excellent structural localities, all close by. Bucknell's environment has directed and enhanced my teaching and that of my colleagues. It afforded geologic mapping for each student in a first geology course, and provided historical and modern perspectives that led into appropriate land use opinions. For majors there were opportunities for projects or geologic field studies in diverse fields, culminating in a senior thesis, which, since 1967, has been completed by most students. I would have been less effective elsewhere, so I owe much of what I am to good colleagues and the place where I have been fortunate enough to live and work.

Chance encounters or invitations to participate in the research programs of others have influenced my research directions or enhanced the product. John Prucha and Shell Development Company invited me to study Rocky Mountain geology. Knut Bjørlykke helped me negotiate the Norwegian countryside and provided critical reviews of my stratigraphic revisions. I met Jake Hossack also in Norway in the late 1960s, and we shared ten years of geologic study in the magnificent Caledonide thrust belt. Rodger Faill of the Pennsylvania Survey discussed my evolving notions about the sequence of stages of the Alleghany orogeny in Pennsylvania, and George Davis provided a capstone by inviting me to participate in a study of High Plateaus geology in Utah. To these and all of the others that I can't take time to mention, I send my thanks.

My hopes for the future are (1) that we can do a better job of educating the general public about their geological environment; (2) that geologists can more successfully occupy their rightful place in environmental decision making; and (3) that careful geologic mapping of well-exposed structural units like the Weverton, Bloomsburg, Claron, Valdres, or Tuscarora shall not perish from this earth as other data-gathering systems proliferate.

As I viewed the list of prior recipients of this award, the four awesome Johns—Handin, Rodgers, Ramsey, and Crowell—as well as Clint Dahlstrom and Ben Page, I could only conclude that the award decision was influenced by the writings of Harvard biologist E. O. Wilson on biodiversity. Thank you for preserving geologic diversity.

Presentation of the O. E. MEINZER AWARD to STEVEN GORELICK

Citation by IRWIN REMSON

In 1974, the Stanford University Geology Department received an application for graduate admission from a young man attending New College in Florida. He had a good scientific background but his main accomplishment appeared to be a period mixing cement for futurist Paolo Solari, at Arcosante in the Arizona desert.

We gambled on the young man and offered him admission. Almost immediately, I received a letter expressing his desire to start on his Ph.D. research. I told him to slow down because he had a lot to learn before starting on such research. Little did I know that he could have completed a successful research project at that time because the man was Steven M. Gorelick. Incidentally, New College never survived Steve and went belly up shortly after he attended.

Besides his brilliance, two things have impressed me most over the 20 years that I have known Steve as my student and colleague. The first is his moral concern and his desire to solve environmental problems. The second is his innovativeness, and this must be a trait of the Gorelick family. His father neglected his dental practice so that he could use his X-ray machine to study ancient engraved Sumerian artifacts. His mother is a successful modern artist and his sister Deputy Attorney General of the United States. His lovely teenage daughter Alyssa is preparing for an acting career.

Between his stints as a student and faculty member at Stanford University, Steve did research for eight years at the U.S. Geological Survey. He has been a good citizen and supporter of his profession. He is recognized both nationally and internationally. He is a Fellow of both the Geological Society of America and the American Geophysical Union. His honors include a Presidential Young Investigator Award and the James B. Macelwane Medal of the American Geophysical Union.

It is hard to understand how the Meinzer Award Committee was able to select only four publications from Steve's list of 50 publications and books. Despite their diverse thrusts, his publications show his ability to find problems that are scientifically and socially important, his ability to implement innovative solutions, and his ability to work productively with colleagues and students. The papers are

Gailey, R. M., and Gorelick, S. M., 1993, Design of optimal, reliable plume capture schemes: Application to the Gloucester landfill groundwater contamination problem: Ground Water, v. 31, p. 107–114.

Koltermann, C., and Gorelick, S.M., 1992, Paleoclimatic signature in terrestrial flood deposits: Science, v. 256, p. 1775–1782.

Tiedeman, C., and Gorelick, S. M., 1993, Analysis of uncertainty in optimal groundwater contaminant capture design: Water Resources Research, v. 29, p. 2139–2153.

Wagner, B. J., and Gorelick, S. M., 1989, Reliable aquifer remediation in the presence of spatially variable hydraulic conductivity: From data to design: Water Resources Research, v. 25, p. 2221–2225.

It is noteworthy that the senior authors of the papers cited for this award are his students.

Steve's first major scientific thrust arose from our work with distributed parameter ground-water management models in the late 1970s. He wanted to do his doctoral research on the creation of contaminant optimization models. I urged Steve to be more cautious and restrict his research to hydraulic models, where we already had some success. However, Steve successfully developed pollutant optimization technology and extended it to source and parameter identification, to aquifer reclamation, to conjunctive use, and to the incorporation of economic and social policy objectives. A remarkable achievement was the 1984 Water Resources Research paper with the Operations Research Group at Stanford on the use of nonlinear programming to jointly optimize quality and hydraulics in aquifer reclamation design.

The papers cited for this award deal with one of Steve's current research thrusts, the quantification and tracking of uncertainty through the computational process, extending from parameter estimation to simulation to optimal contaminant management.

Steve's recent work varies from the development of a patented air-lift pumping method for in situ remediation to the design of multiple contaminant remediation methods for contamination that is controlled by rate-limited mass transfer. On a basin scale, his work with Christine Koltermann uses sedimentary simulation models to improve the hydrogeologic characterization of sedimentary terranes. His paper "Paleoclimatic Signature in Terrestrial Flood Deposits" appeared in *Science* in 1992.

On a pore scale, Steve's work with Haim Gvirtzman published in *Nature* in 1991 successfully modeled the effects of anion exclusion during infiltration. It is apparent that Steve's productivity has remained strong.

For these many reasons, it is an honor to present the recipient of the O. E. Meinzer Award for 1994, Steven M. Gorelick.

Response by STEVEN GORELICK

Professor Remson, fellow GSA members, and friends, I thank you for this award, which came as a complete and wonderful surprise. I knew there was a good reason why I asked Irwin Remson to serve as the citationist, but it wasn't until after the beginning of his citation that I remembered what that reason was. For years, I have survived Irwin's ridicule and pranks, and I would like to take this opportunity to return the favor. As you all know, there is a unit of measure of hydraulic conductivity known as a "Meinzer," who is the same individual for which the O. E. Meinzer Award is named. A Meinzer is defined as a gallon per day per square foot. However, few know that there is also a volume unit of measure known as a "Remson." As defined by our colleague Ken Belitz at Dartmouth, and used as a measure throughout the world, a "Remson" is that quantity of water sufficient to kill one acre of broccoli. On a serious note, I truly thank Irwin for his kind words, years of tutelage, sage advice, and his true friendship. Both I and the hydrogeologic community owe him a great deal.

It is an immense pleasure to give this acceptance speech because I can say thanks to so many. First, I thank my students. All of the cited papers are ones that I coauthored with my students, and for which I am indeed the last author. I gratefully share this award with my former students, both previously mentioned and others, who clearly did the lion's share of the work, from whom I have constantly learned, and whose contributions will be noted for years to come. As a Remson student, I learned to always put my students first, and if we are successful in academia we should produce students who know more and are better scientists than us. Second, I thank those senior scientists who during my early career didn't know me, but provided terrific opportunities and opened many doors. I can't tell you how much the unsolicited support of Al Freeze, Jared Cohon, George Pinder, Roger Wolff, John Bredehoeft, Jacob Rubin, Don Nielsen, Steve Burgess, Uri Shamir, and Bill Yeh meant to me. That tradition, in which I now follow, of encouragement and promotion of other's activities and careers is the life-breath of our future in the hydrogeologic research community. Third, I am grateful to my colleagues at the USGS. I was very fortunate to have spent my initial career working with a collection of first-class research scientists in the Water Resources Division. The environment that they created was one of excitement, research freedom, and generous collaboration. My decision to leave was very difficult, and I miss our day-to-day working relationship. Finally, I was going to especially thank Lenny Konikow for our memorable years together at the USGS and our continued friendship, but he told me to keep my speech short. Sorry Lenny, I'm out of time.

I am really touched to be named the recipient of the 1994 O. E. Meinzer Award.

Thank you.

Presentation of the GEORGE P. WOOLLARD AWARD to CHARLOTTE E. KEEN

Citation by RON M. CLOWES

I have the pleasure and privilege of presenting the citation, on behalf of the GSA's Geophysics Division, for Charlotte Keen as the 1994 recipient of the George P. Woollard Award. My pleasure is twofold. First and foremost, Charlotte is a highly deserving recipient who has spent her scientific career applying in a most effective way the principles and techniques of geophysics to the solution of geological problems. She is very much a geophysicist but has never wavered from the principle of improving our understanding of earth structure and the geotectonic processes that developed that structure. The double pleasure is this opportunity to acknowledge the second Canadian to receive the Woollard Award.

Charlotte is a native Haligonian (for those of you on the west coast, that's a person born and raised in Halifax, Nova Scotia), who took her Bachelor's and Master's degrees at Dalhousie University in Halifax and then continued on to Cambridge University in the U.K. where she received her Ph.D. in geophysics in 1970. Even at the undergraduate level there was a portent of scientific contributions to come. Her very first paper was published while she was still an undergraduate; it provided the first detailed analysis of modern turbidites and was published in *Nature,* no less. As a graduate student, she received four separate scholarships to carry out her studies, so I assume her academic record was exceptional, and I know her science since then certainly has been. One example is her Ph.D. research, which included the first detailed seismic refraction experiment near a ridge, in this case the Mid-Atlantic Ridge, and provided important new data on its crustal structure.

Immediately following her Ph.D. at Cambridge, Charlotte joined the Atlantic Oceanography Lab of Energy, Mines and Resources in Dartmouth, Nova Scotia, as a research scientist. The following year in 1971 she became a research scientist at the Geological Survey of Canada in its Atlantic Geoscience Centre, still in Dartmouth, where she has remained active ever since. Today she holds the highest level of scientific appointment within the GSC.

While most of Charlotte's career has been concerned with diverse geophysical studies of the rifted continental margins and sedimentary basins of the Atlantic, one early pivotal study, undertaken with Don Barrett, was in the Pacific. This was shortly after the plate tectonic revolution, suggestions of alignment of olivine in the flow direction, and determination of the anisotropy of olivine. Keen and Barrett designed and carried out a special refraction experiment that demonstrated seismic anisotropy in the uppermost mantle and showed that the directions of maximum and minimum velocity were consistent with seafloor spreading directions.

I think I've already indicated that Charlotte is a keen (pun intended) and thoughtful scientist who approaches geological problems in a very direct way and has done so throughout her career. Early in that career, she was planning to carry out one of her experiments on the Mid-Atlantic Ridge and needed ship time to do so, probably on the order of three weeks. In those days (1970–1971) women weren't allowed on Canadian research ships, so this posed a problem. Her boss backed her all the way and argued that she must be allowed to go to sea to carry out her research. This caused a great kafuffle and uproar that ended up in Ottawa in the deputy minister's office. The thoughtful bureaucrats considered this problem and gave their decision: *she could do her research on the ship but she would have to get off it each night!* Finally her cruise was okayed, with the proviso that there be a doctor on board. At that time, this was normal on a research ship, so Charlotte went out and collected her data.

In the space allotted, I could not begin to summarize the very many and significant contributions that Charlotte has made, from Baffin Bay in the Arctic to the eastern seaboard of the U.S. and in the Atlantic Ocean. Her work is characterized by careful application of all applicable methods of geophysics—not just the refraction I've already mentioned—to studies of sediment accumulation, basins, rifted margins, the crust, and the upper mantle. As one illustration of her appropriateness for the Woollard Award, in one study she used biostratigraphic and organic metamorphism data from deep exploratory wells off Nova Scotia and Labrador. With these data she showed that subsidence of basement, after removing sediment-loading effects, followed a depth-age curve similar to that for the oceanic lithosphere. For at least the past 15 years, and in addition to her seismic studies, Charlotte has been heavily involved in the development of thermal-mechanical models and their application to the rifted Atlantic continental margins. She has published extensively on this work, in sole-author papers and in collaboration with others, both at the Atlantic Geoscience Centre and elsewhere. Two papers representative of her recent work with colleagues at AGC are one on the effects of rifting and subsidence on thermal evolution of sediments in Canada's east coast basins, and one on a comparison of model predictions for decompression melting at rifted margins with the distribution of igneous rocks along the eastern Canadian margin.

But Charlotte is more than a scientist. She is very interested in music, sailing, and skiing, and she is very generous as a friend and as a colleague. My personal experience with the latter goes back to my plans when I first arrived at the University of British Columbia to set up a marine seismic program, even though I had never been to sea. I received some very useful and important information then and for some years thereafter that helped bring my ideas to fruition. Charlotte even made it clear that her key engineer would assist me in any way possible and, needless to say, I took advantage of her generosity.

I can't let this opportunity pass without a few words on Charlotte's contributions to the establishment of Lithoprobe as Canada's national geoscience research project. As the chairperson of CANDEL, Canada's representative group for the International Lithosphere Program, and as a motivated scientist, Charlotte put her tremendous energies into furthering the concept of Lithoprobe at a time when there was no assurance we would be successful. She prepared the first published paper on the concept and was a key member of the steering committee that got the project rolling. Once that had been achieved, she remained a valuable member of the advisory scientific committee for four years. Charlotte, thank you for your many contributions to the establishment of Lithoprobe. You helped me get a really interesting job!

As you might imagine, all of this activity has garnered Charlotte a fair number of awards. I'll only mention three of at least seven: in 1980 she was elected a Fellow of the Royal Society of Canada, our equivalent to the Academy of Sciences; in 1986 she was made a Fellow of the American Geophysical Union; and last year she was the second recipient of the Geological Association of Canada's Michael J. Keen Medal in Marine Geoscience. This year she can add GSA's George P. Woollard Award to her other honors.

Response by CHARLOTTE E. KEEN

It is a very great honor to be a recipient of the Woollard Award by the Geological Society of America. The celebration of the symbiotic relationship between geology and geophysics is an important contribution to our scientific community. Like any marriage, the bond is sometimes strained, mostly by poor communications, but these days it is most often a happy and productive union. Also, as a Canadian and a woman, both of which attributes remove me a little from the archetypal GSA member, I sincerely appreciate the recognition.

I had the good fortune to enter marine geophysics at a very exciting time and to work with a number of excellent teachers. At Dalhousie University in Halifax, where I did my M.Sc. work, seismic studies of the crust had only been underway for a couple of years, under the guidance of Michael Keen and my supervisor, J. E. Blanchard. Across the harbor, the new Bedford Institute of Oceanography had just been established, and Bosko Loncarevic had hung out his shingle there. So there was lots of excitement and enthusiasm about the future, but not a whole lot of expertise in marine studies. We graduate students were guinea pigs, as we all learned from our successes and failures. My early sea-going experience with "sealing wax and string" instruments, most of which dissolved and sank on contact with water, seem almost ridiculous by today's standards of technology, but I learned a lot that way.

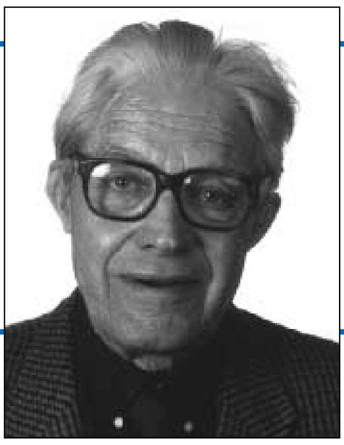
As a Ph.D. student at Cambridge University, my eyes were opened to the ferment of the plate tectonic revolution. I had the honor of working with Drum Matthews at Cambridge, the co-discoverer of sea-floor spreading, and himself a former recipient of the Woollard Award, as well as with my supervisor Dai Davies and with Sir Edward Bullard, the head of the laboratory. Cambridge was also a place where students rubbed shoulders with a great many brilliant people. I was one of the first two women to be admitted as a Ph.D. student to our department, and I became friends with the other woman, Monica, who came from a Cambridge family. She invited me to come home with her for dinner, and I met her father, the Nobel prize winner in physics, P. A. M. Dirac. At some point she and her mother left me alone at the table with him. Was I ever intimidated and tongue-tied! But as I cast about for something to say to him, I realized that he was even more shy than I was. Scientists, even famous ones, became more human through this kind of contact, and science itself became more personal and interesting.

My years at the Bedford Institute of Oceanography have also been stimulating and fun, and I have worked with some wonderful people. The continental margins provided a ready-made laboratory off our coast in which to study geological questions of global importance. The years have not been without struggle, however, as women have worked hard to overcome many biases since the early 1970s, particularly sea-going women, as Ron has indicated. I was lucky to have Michael Keen as my mentor, friend, and colleague. Without his support I would probably not have stayed in science. Also in the early years at BIO I worked very closely with Don Barrett, who saved many of our cruises with his genius for instrumentation. Bosko Loncarevic, the first director of the Atlantic Geoscience Centre, and David Ross, the head of the geophysics group when I began at BIO, were important in giving me their support and encouragement.

I came into earth sciences from physics with a somewhat theoretical background. Marine research, on the other hand, is relentlessly practical. It keeps us firmly rooted in reality whether we want to be or not. Combining the two requires that a balance be found between theory and experiment, between the practical and the abstract. It is hard to keep that balance, but the effort is very rewarding. Modeling becomes more realistic, and experimental work is based on a more solid foundation of basic understanding. The Canadian Lithoprobe project is a prime example of what can come from such a balance on a large scale. The future of our science lies in a fruitful mixing of disciplines and approaches as epitomized by that project.

It's usual when awards are given to go back over the scientist's career and list what the recipient has done for science, but I would like to reflect briefly about the opposite—about what science has done for me. In many ways, the scientist and the science can never be totally separated; one influences the other. Doing science has always fed my sense of the excitement of discovery, of mystery, of a bigger world being out there than the one I normally inhabit. On the other hand, I find science difficult, and doing science has meant hard work, long hours, discipline, and concentration. Bringing the sense of mystery together with the hard technical work is what doing good science is all about. It is not about grantmanship or government policy or being a good team member, although these things may be important or valuable for other reasons. I am very grateful to the Geological Survey of Canada that I have had an opportunity to participate in the "mystery of science," and I thank all my teachers and colleagues for the wonderful times and opportunities they have provided.

Presentation of the HISTORY OF GEOLOGY DIVISION AWARD to FRANÇOIS ELLENBERGER



Citation by KENNETH L. TAYLOR

If you visit François Ellenberger at his home in the town of Bures-sur-Yvette, south of Paris, you find that he and his wife Hélène live in what amounts to a small alpine enclave set on the rim of the Yvette valley. Their house is a comfortable alpine chalet, and the garden is a riot of diverse shrubs and trees and flowers, many of them wild plants adapted to these surroundings. François' main hobby is botany, an interest he has pursued since his youth. He remembers with evident pleasure his first scientific distinction, a "medal of encouragement" won at age 14 for his dedication to botany.

I imagine that this somewhat improbable alpine domestic setting, on the fringe of the Paris suburbs, reflects François' enduring preference for mountain scenes, and his keen esthetic sensitivity to his natural environment. To this day he recalls with particular pleasure the postwar years he spent drawing up the detailed geological map of the Vanoise region for his doctoral thesis. He invokes words like "exalting" and "intoxicating" in describing the pleasures of physical and intellectual exhaustion experienced in his solitary geological explorations.

François Ellenberger was born in 1915 in southern Africa, at Lealui in what is now Zambia. His early education, in Lesotho, was overseen by his parents, who were evangelical missionaries; he had no schooling outside the family before he was 11. Following a course of studies in the natural sciences, he received a degree from the Ecole Normale Supérieure in 1937 and was mobilized as an artillery officer, serving eight years. For five of those years he was a prisoner of war in an officers' camp at Edelbach in Austria. One gains some understanding of François' tenacious and determined character from the way he occupied himself during those five years. He participated in the invention and operation of a prison-camp university, complete with disciplinary curricula and degrees. In addition to his teaching, he organized a group for geological research of the camp site. This led in 1948 to publication of a collaborative monograph, chiefly petrographical and paleobotanical, under François' leadership, an astonishing piece of work called by Eugène Wegmann, in his preface, "a truly heroic effort."

François Ellenberger is a double awardee in 1994: he has also been named an Honorary Fellow of GSA. But I limit my remarks here mainly to his historical scholarship concerning geology.

François' monumental doctoral thesis on the Vanoise completed, he was named maître de conférences (senior lecturer) of the University of Paris science faculty and embarked on researches over a long period in stratigraphy, paleontology, and applied geology, in France and overseas, notably in South Africa and Norway. From 1962 on, he held a chair in regional and structural geology, and directorship of a laboratory soon relocated at the new suburban campus of the University of Paris at Orsay. As a teacher, Professor Ellenberger conducted field courses in geological mapping and also led groups of more advanced students in studies of European structural geology. He has consistently urged students to confront natural phenomena in a spirit of openness to nature's complexity and of suspicion regarding doctrines and orthodoxies. Among the distinctions he has earned have been two prizes conferred by the Société Géologique de France, the Prix Viquesnel and the Prix Wegmann. He served the French Geological Society as president in 1972. He is an Honorary Member of the Geological Society of London, and he won that Society's Sue Tyler Friedman Medal.

Starting from use of history of geology as a pedagogical tool in his courses, François rapidly expanded his involvement in this field in the early 1970s. Right away he demonstrated one of the most important of his scholarly perceptions: he knew the necessity of going directly to original historical sources. Even among aficionados of James Hutton, the reading of *An Investigation of the Principles of Knowledge* must be rare. François studied this three-volume work and also prepared a translation, with commentary, of Hutton's medical thesis. François' voluminous historical publications over the past 20-odd years are marked by a characteristic determination to find and utilize relevant historical sources, including sources that may once have been obscure or little known to other researchers.

Sometimes, as in his treatment of Gautier or Goropius, Ellenberger's historical analysis has been based on materials he to all intents rescued from oblivion. In other cases the materials he has mined are sources by no means unknown, but nonetheless all too seldom read—rather, mentioned in histories written on the basis of other histories. Read François' own greatest effort at synthesis, his two-volume *Histoire de la géologie* from antiquity to the early nineteenth century, and you will never see him submit passively to historical authorities. The greatest single attribute of his work is its authenticity: it reflects his own judgments based on personal encounters with the writings of his scientific forebears.

Many of the sources with which François has been most fascinated are francophone, especially from the eighteenth century and the first part of the nineteenth century: Bourguet, Boulanger, Rouelle, Guettard, de Sauvages, Giraud Soulavie, Deluc, Cordier, and many others. One of his motivations, clearly, has been to illuminate the frequently undervalued roles of French scientific figures in the development of the geological sciences. But his perspective is nonetheless admirably international. As a historical scholar he is, himself, a model of intercultural understanding, taking special pains to examine the writings of historical characters in various languages, ancient and modern.

François Ellenberger's use of historical materials bearing on the history of the geological sciences displays also his typical insistence on scientific exactness and rigor in the effort to establish historical truth. Finally, readers of Ellenberger's researches in the history of geology know of his keen originality and independence of thought in reinterpreting geology's past.

For those who know François Ellenberger and his work, the merit of his published writings hardly looms larger in their estimation than his tireless efforts to promote a cooperative and interdisciplinary study of geology's history by scientists and historians alike. He was the principal founder and animating spirit of the *Comité Français d'Histoire de la Géologie,* which since its beginnings in 1976 has greatly raised the profile within France of historical studies about the earth sciences. COFRHIGEO now has a substantial international membership. Under François' continual guidance COFRHIGEO has grown into one of the world's most active groups in the field, and its *Travaux* regularly publish articles and notes of high caliber.

In the future, when people concerned with the history of geology look back on the work done in this field by scientists and scholars during the last third of the 20th century, I believe that François Ellenberger's name will stand out as among the handful who contributed most to its advancement. He will be seen as having advocated and practiced methods of research and writing according to high critical standards—subjecting conventionally accepted ideas to analytical scrutiny and searching vigorously for little-known or unstudied documents to shed light on significant historical problems. He will be recognized as the author of a large number of original-minded publications, many of which have broken new ground. And he will be recalled as a cultivated, humane, and successful promoter of a previously underdeveloped field, many of whose practitioners profited from his generous encouragement and wise guidance.

I do not wish to end without a few final words on François' versatility. To those who have had occasion to be with him out of doors, a familiar Ellenbergerian posture is hunched over, aiming a camera close range at some plant. In 1991 he published an original, self-proclaimedly amateur monograph—but no less technical for being amateur—on *phyllotaxia,* or leaf arrangement. At certain junctures, notably while geologizing in southern Africa, he has given some of his time to ethnomusicology and ethnology. And not least impressive, in 1947 he published a prize-winning book based on introspective psychological self-study carried out during wartime imprisonment, *The Mystery of Memory.* All of this was accomplished on the side, as it were, by a man mainly occupied by geology and in due course by its history.

I think the scope of François' interests and abilities is quite relevant to the achievements for which he is recognized here today. He is a man of extraordinary breadth, intellectually and personally. To the synthetic enterprise of historical investigation concerning what I believe to be the most integrative and complex of natural sciences, he brings his seemingly inexhaustible energy and curiosity, his richly cultivated mind, and his capacity for unfeigned wonder. He is an altogether remarkable man. It is a great privilege for me to take part in presentation of the Geological Society of America's 1994 History of Geology Award to François Ellenberger.

Response by FRANÇOIS ELLENBERGER

[François Ellenberger, recovering from a stroke, was unable to travel from France to attend the GSA Annual Meeting. His response was presented in his absence by Kennard B. Bork.]

I dare say that the citationist has gone a little too far in his laudatory words! Whatever my alleged merits, the support of all my friends has greatly contributed to my achievements, and I address to them a very warm "Merci!" In what follows, my duty, I suppose, is to talk egocentrically about myself.

Last May, I received a letter that filled me with both joy and distress: I was informed, to my great surprise, that the illustrious Geological Society of America had bestowed a very great honor on me (indeed, a double one!). It was only too evident that I would not be able to attend your meeting: I was then still struggling to recover from an inopportune attack of hemiplegia.

In my peaceful hospital bed, I knew that my first duty was, at whatever cost, to keep my poor brain working; thus, I tried to recall some algebraic formulae, but found more reward in turning to recollect my golden childhood at Leribe. This name fills me with ineffaceable warmth and happiness. Leribe was a mission station in Lesotho, South Africa, of which my parents were in charge, among quite friendly natives. The scenery was magnificent, and the vault of the night sky showed an incredible display of countless glittering stars. The large mission garden was my Eden (with occasional huge vipers!). I trotted around barefoot, climbed trees, and tried all sorts of naive experiments. I learned the very expressive native language, plus some crude English. Above all, I was a most fortunate boy, who did not sit on a school bench before he was 11 years old! My dear parents were both highly cultured; my mother managed to find time to instruct her rather disobedient pupil (who was quick to jump out of the window!) in all basic subjects. She loved literature and history, and she would recall for us children the feats of our Huguenot forefathers, who endured martyrdom for the sake of liberty of belief and thought. My father added Latin lessons. But perhaps the greatest benefits of this unorthodox tuition lay elsewhere. Through my mother, I learnt a deep regard for history. My father taught us how fascinating it was to scrutinize every object found outdoors. Each trip with him into the countryside was full of discoveries: insects, birds, shrubs, stones, perhaps even fossil bones, or the huge birdlike footprints you could find upside down, in low relief, on the bottom surface of some protruding beds in the sandstone cliffs. He was a born naturalist (I took this trait fully from him), though his academic education in the sciences was poor; he admitted his ignorance—a most salutary example, compared to the "everything is known" attitude that now too often prevails. I developed an almost universal curiosity, a passionate and jealous love of nature, lasting to this day. (My wife and I consider the current worldwide extermination of wildlife to be a sacrilegious offense against the mysterious Creator of our evolving universe. From early childhood, I studied the Bible, and I still do, but have now discarded any fundamentalism, in the free light of modern exegesis.)

Missionary families have to endure the ordeal of separation. Aged 14, I was put in a Protestant boarding school in Montauban, in southern France. I was a rather brilliant student in both humanities and mathematics, but wild nature was my main solace. I went on enriching my large herbarium. In those pre-pesticide days, our countryside still offered a profusion of wild flowers. (Recently, my lasting taste for botany has led me into rather deep researches in phyllotaxis.) I also became fascinated by the casual discovery of fossil marine shells. The Scout movement taught me to take full responsibility for decisions and initiatives, both for myself and for those younger.

At 18 I felt a call to teach the wonders of nature and creation to children, and I decided to graduate in natural sciences. In the Faculty of Science at Toulouse, a whole new world was opened to me, thanks to the lectures of some men of exceptional stature, especially in zoology and botany. In geology, the main courses were dull, but the lecturer in charge of practical exercises, Gaston Astre, was an unduly modest man, who was dedicated to research. And not just his own research; he provided generous help to authors, mainly amateurs, including the printing of their work in a provincial journal of which he was the untiring editor. With great kindness, he encouraged me to undertake my own research directly in the field: a decisive start. I have never forgotten his sound advice. For example, one must read thoroughly all the literature, however old, pertaining to the subject of research. He also taught me to be boldly disrespectful on scientific grounds—not to persons, but to opinions. Such principles later inspired my whole scientific career.

(I believe this generation should be earnestly reminded of these precepts.) Thanks to Astre, how proud I was to see my first geological work (mainly on local unrecognized thrusts) printed! I was just 22.

In the famed Ecole Normale Supérieure in Paris, I acquired the full qualifications for teaching or writing a doctorate, after spending one year in the army. But then a certain Mister Hitler shattered all my expectations. I spent the next eight years in the uniform of an artillery lieutenant: first, three years lost in low-I.Q. routine activities; then, after June 1940, five full years as a prisoner of war, in the Spartan comfort of a large camp for officers.

But this period of total seclusion in Oflag XVII A was crucial in my life. Among many hardships, one could also gain immense benefits, both moral and intellectual. Some 4500 persons, many of them highly cultivated in technology, science, humanities, music, entertainment, and fine arts, were packed together in a space of open land 400 meters on a side, located on the Austrian part of the Bohemian massif. One could find there unique opportunities to cultivate one's mind and soul through daily contacts with many fine personalities. Thus, guided by a renowned philosopher, I went deeply into introspective psychology. The arduous book I then wrote on the phenomena of reminiscence won me a prize and was published in 1947.

Very soon after our arrival, lectures for a "general public" began with great success (including mine, on astronomy for beginners). A whole program of university-level courses was soon instituted, covering a wide range. (Not to mention a certain course in Chinese, which proved just a pleasant hoax, as the "teachers" knew not a single word of the subject! Humor helped to overcome gloom.)

The courses of geology at Oflag XVII A were a more serious affair. I joined the teaching team, bravely promoting myself to assistant professor, and lectured on various subjects, including geomorphology. To teach, I had first to learn, at the rate that long-awaited packages of books (and pedagogic samples) arrived from France. Thus, I think I became pretty well read in some fields of the earth sciences. We brought up several comrades to *licence* level, which was officially acknowledged on our return to France. Our Oflag could be compared to some sort of extremely busy (and noisy) monastery, set aside from the turmoil of war and its horrors (including the Shoah, and the bombing of so many beautiful cities).

But as year after year elapsed, a general feeling of discouragement spread. As others did in their own fields, I decided to launch a program of research, to be pursued at any cost, with a daring and juvenile enthusiasm that I think survives in me even today. Three years of continuous tramping had completely laid bare the soil of what had been meadows; running water had dug erosion furrows. Thus, we could collect and study a great number of stones and other objects, including some prehistoric and protohistoric artifacts and large pieces of silicified wood. We could get a precise idea of the structure of the top subsoil, which cropped out in the ditches: coarse gravels lying on the crystalline basement (catazonal schists, plus strange hydrothermal silicifications, both offering fine examples of metasomatic processes). Under my guidance, a handful of volunteers, all amateurs, began to work, in spite of some general scepticism. Meticulous observations were conducted in the "field" (right under the eyes of our suspicious guards); we started the crucial job of cutting thin sections. We had no saws, no machine, nothing but chips of stones to be patiently worn down by hand and stuck onto bits of window glass with a mixture of violinist's colophane and sardine oil. Pinches of precious carborundum powder were begged from the workshop of the telescope mirror grinders (who sprouted from our local Astronomical Society). Each slide was scrutinized with the utmost care on a makeshift microscope. In some respects, our endeavor had a genuinely patriotic side: it was our way of being French *résistants,* as it were, to thumb our noses at our enemies. All in all, our work was of sufficient quality to find easy publication, on our return to France, in the form of a collective illustrated memoir of 180 pages. My chief personal results were to confirm the synkinematic nature of regional metamorphism (contrary to the doctrine then prevailing in France), and show that in this case lineation lay parallel to the transport, then a heretical assertion.

Amid great post-war difficulties, I married Hélène, my marvelous wife, in 1947, and she gave me three adorable and loving children. I started working for my D.Sc. degree and undertook the ambitious task of unraveling the extremely intricate geology of the Vanoise massif in the Alps of Savoie: a grand aim indeed. It fulfilled all the dreams of wild rambles that had obsessed my mind in the seclusion of Oflag XVII A. It also satisfied my inclination to pluridisciplinarity: an exciting necessity in high mountains where you happened to find ammonites transfixed by glaucophane needles! Truly, the job was exhausting, both for body and mind, and the funding was miserable; but I enjoyed an incredible freedom in my work. In those blessed ages, research had not yet fallen under the iron grip of prejudiced and short-sighted bureaucrats. I got my D.Sc. degree in 1954 and was lucky enough to see my work published in 1958 (actually that work produced many advances in alpine tectonics). A significant byproduct was the Introduction, in which I briefly traced the succession of conflicting doctrines about alpine metamorphism, from 1830 on. This was my first essay in the history of geology.

In 1957 I was appointed assistant professor, with the main duty of initiating whole classes of beginners in the art of geologic mapping in the field. Hundreds of future geologists were thus my pupils, and I well remember our unforgettable open-air sessions. I pity all those people who now despise such activities as outmoded; they seriously overlook the true nature of geology, which is as much a craft as a science. I say to them: *Tant pis pour vous!* They deprive themselves of great pleasures, and, even more damaging, they endanger geoscience by forcing it to be deductive, so that truth is supposed to come from the top. In the light of one simple scheme, you must interpret all observed facts—as poor old Werner had done! But history testifies with great clarity that the progress of the earth sciences has been impelled fundamentally by induction, involving a thorough knowledge of all already recorded data—the Baconian approach. I recall with great happiness those weeks of convivial life in small villages, with teams of young, cheerful students. We struggled together to decipher the structure and sequence, largely hidden under detritus and thorny bushes. The most difficult part was to make the students conscious of the fact that rock units *do* continue *inside* hills, and then to induce by reason what their invisible underground forms may be. Is this not exactly the laborious path taken by nascent geology, after the great Steno had formulated his key principles? Such a personal practice will certainly enhance, in the historian, sentiments of understanding and of high esteem toward the early pioneers in earth science.

In geological research, many subjects interested me. One topic, however, was central: comparative tectonogenesis—comparison both between different mountain belts and within one definite belt (laterally, or linked to depth). I took a special interest in two opposed types of structures: clean-cut low-angle thrusts and very deep seated recumbent folds. In the latter, all foliations became parallel, from the reworked granite-gneiss core to the enveloping sedimentary schists. Such is the case in parts of the Swiss Alps and Norway; but also, so it seems, in the Saxon Erzgebirge (this fact in part explains Werner's vision of one single sequence of conformable deposits). With doctoral students, we pursued studies in the Alps, Spain, central France, the Pyrennean belt, and, more extensively, in the Caledonides of Norway. The tectonic style of this latter belt differs widely from any received model, with its huge, paper-thin crystalline nappes. I am sorry to say that this challenges the blind "plate-tectonics-can-explain-everything" credo: faced with the multifarious problems of tectonic reality, the word "collision" is void of sense. The same with the enigmas of epeirogenesis, about which I wrote an extensive analytic paper. Experience and the lessons of history have made me wary of systems and dogmas.

I shall say only one more thing of my many other activities as practicing geologist (digging dinosaurs, etc.). We know that the history of geology is pursued in parallel by professional historians and by geologists. The latter sometimes may doubt if the former really understand the problems at stake. But mind! The range of topics involved is extremely wide, out of reach of somebody too specialized. Therefore, I am grateful to have meddled in many disciplines of "grandpa's geology" (as they call it today, looking at you scornfully over their computer screens). But I ask: Who, then, in the future, will have the ability to write about the general history of that dying discipline, true geology? A tidal wave of abyssal ignorance is sweeping away the wealth of patiently gathered data on the natural world.

In 1962 I was given a professorship of regional and structural geology at the University of Paris at Orsay, which I kept until my retirement in 1983. In my lectures, partly centered on the structure of Europe, I introduced, for the sake of pedagogy, some glimpses of the history of geology (as did a colleague). At that time, the approach of the Russian school was to lay stress on the subdivision of the uppermost crust, in superimposed major units, disposed in a standard order from the basement up. On the other hand, the Western school put the emphasis on orogenesis and the subdivision of mountain belts in longitudinal zones of different ages and types (according to the geosynclinal doctrine). I told the students that this first, static vision was in one sense rooted in the Wernerian geognosy of two centuries ago. The second, which insisted on transformation, was typically Huttonian in its spirit. "Now, let us talk a bit about these fellows!" I would say, to make things lively.

My interest in history thus aroused, I wanted to learn more than I had picked up in Geikie's classic book. Taking it for granted that Hutton was the father of modern geology, a scientific hero, I threw myself into serious study of his books. I traveled to London, translated his medical thesis from Latin, and went in search of possible sources, or forerunners. So it was that, through Louis Bourguet, I discovered Henri Gautier (1660–1737)—my first significant find, with his surprisingly modern intuition of the geostrophic cycle. In the meantime, I felt more and more concerned about the neglect by historians, notably in my own country, of early Continental geological literature. I started to photocopy original texts anywhere I had the chance. In the great medical library of Montpellier, I was allowed to explore the venerable treasures hoarded on long, dusty shelves: a most exciting privilege indeed! Thus, I gathered in my home a large collection of primary sources. With the same eagerness as in the past when I collected plants, day after day I enriched my boxes of classified large cards covered with excerpts: my "bibliographic herbarium" (but all historians do the same). Now, texts are useless if left unread. If one desires old authors to become one's real concern, one must listen to them with great attention, and in their own language. Many will recoil from the great effort involved. But how great a happiness you enjoy when you become able at last to read them in their own words: Hooke in English, Arduino in Italian, Füchsel in Latin, Werner in German, and even Strabo in Greek!

Among the papers I published, I mention here only two, which are of more general interest. One discusses the influence of the physical environment on general concepts; in northern France, agents still in operation *do not* account for both landforms and recent deposits (we now know them to be a periglacial heritage). Diluvialism was thus a logical last resort after all. In another paper (with Gabriel Gohau), the despised Jean-André Deluc was shown to have actually been an important pioneer in stratigraphical paleontology and even transformism. Apparently, no historian had condescended to read his prolix writings. Indeed, from ancient ages right to the present, ignorance of the literature must be stigmatized as a major hindrance to the progress of knowledge and science.

I was co-opted by INHIGEO (International Commission on History of the Geological Sciences) in 1972, at a time when very few people in France felt concerned by the history of even their own geology. In 1976, I reacted by founding the French Committee for the History of Geology, which turned out to be a lasting success. It also happened that in 1987 a publisher asked me to write a short(!) history of geology. Like a perfect fool, I accepted, vastly underestimating the amount of labor it would demand. Some of the better years of my terrestrial autumn I spent chained to this task. My reward will be if people consult or read my book with real pleasure, not as another tedious duty! Life is short, we should all have some fun in our most serious endeavors. So I have tried to live since childhood. And I recollect what the deeply regretted Reijer Hooykaas told us, in a moving lecture, about the great delight given to the historian when he can identify himself fully, as it were, in an intimacy with past geologists and with their own joys of discovery. I have indeed been able to experience that!

Presentation of the E. B. BURWELL, JR., AWARD to J. DAVID ROGERS

Citation by C. MICHAEL SCULLIN

The E. B. Burwell, Jr., Award is presented for a published work of distinction which advances knowledge concerning principles of engineering geology. It is a memorial to E. B. Burwell, Jr., a pioneer in the practice of engineering geology and the first Chief Geologist for the U.S. Army Corps of Engineers, the largest engineering organization in the world. The 1994 recipient of this honor is J. David Rogers.

His article "Reassessment of the St. Francis Dam Failure" in Engineering Geology Practice in Southern California, published by the Association of Engineering Geologists, strongly advances the knowledge concerning the principles and the practice of engineering geology and the related fields of soil and rock mechanics where the role of geology is emphasized. It is a perfect example of the critical importance of soliciting sound engineering geologic input from more than one expert source. It is also a prime example of why public safety and welfare has to be assured through detailed engineering geologic investigation and evaluation prior to development and throughout the construction stages. The St. Francis Dam failure is a particularly poignant case history to reexamine, inasmuch as it represents a major milestone in the appreciation of engineering geologic input for major civil works projects. The practice of American engineering geology basically began with the St. Francis disaster, the greatest man-made civil engineering tragedy in this century.

The Rogers paper brings forth several key points previously overlooked by the engineering geological and civil engineering professions. Primary among these is the recognition that inclusion of one or two engineering geologists in the planning of such a major project does not insulate such structures from catastrophe. Literally hundreds of engineering geologists have investigated, visited, or viewed the site over the past 65 years without ascertaining that the entirety of the left abutment, or eastern side of the canyon, was covered by an enormous paleolandslide.

Rogers also questioned the basic premise that dam engineer Bill Mulholland did not appreciate geology nor incorporate geologic input—that if he had, the failure would not have occurred. After digging deeper into the matter, he found that Mulholland had consulted at least one eminent geologist, who visited the site and concurred on the dam's siting. Rogers also revealed that it was Mulholland's actual appreciation of geology which led him to build the St. Francis Dam; in order to provide a year's supply of water to Los Angeles in case the San Andreas fault ruptured their Owens River aqueduct.

Last, you may not see many other papers that cross so many subdisciplines: forensic reconstruction of events, geomorphology, rock mechanics, keyblock theory, structural engineering, dam engineering, uplift theory, channel hydraulics, sediment transport, and historical research are all treated in this paper. This sort of multidisciplinary narrative is exactly the sort of geology and civil engineering we need to see and appreciate. The excellent pictorial representations clearly present his keyblock analysis, an area of engineering geology little appreciated in today's academic curricula.

J. David Rogers is experiencing a distinguished career in engineering geology and geotechnical engineering as a practitioner, teacher, leader, and author of numerous practical publications. Rogers was born and raised in the San Gabriel Valley east of Los Angeles at a time when southern California boomed with development. He attended Mt. San Antonio Community College and California Polytechnic University in Pomona, where he was named outstanding graduating senior in geology in 1976. He attended graduate school at Cal Berkeley to work under the tutelage of Richard E. Goodman, a previous recipient of this award. He never received a scholarship, but worked his way through six years of broad-based graduate study in civil engineering, geology, seismology, geophysics, structural engineering, and hydrology. I am told that he wrote the longest Master's thesis and Ph.D. dissertation in the history of the geotechnical engineering program at Cal.

Rogers is a teacher at heart. I think he chose consulting because it was the only way he could have the autonomy to pursue his wide-ranging research interests and have enough office space to house his voluminous libraries. He is most known within his firm as a benefactor of used-book sellers. He maintains a library of over 5000 volumes, some 70,000 slides, and more than 12,000 prints. He seems to maintain files on everything, past citations and responses for the Burwell Award, and a file on just about every American engineering geologist or geotechnical engineer of any stature.

Rogers is keenly interested in the roots of our profession. He corresponds with an enormous circle of professionals, generating five to ten letters a week. He is a man who seeks out and appreciates the wisdom of his predecessors. He also seems to always find the time to work with senior members of our profession. I met him in 1985 when he sought me out to interview me on the standard of care of grading and excavating. This was not a trivial sort of encounter—he had to get on a plane and fly 500 miles just to see me. It was his natural curiosity that brought him. Since that time, we have taught, as a team, a series of courses on grading and excavating all over the western States. I wish all of you could have the pleasure of listening to his ever-evolving lecture on the history of grading, which runs something like a PBS documentary.

Tireless in his pursuit of quality education, he routinely grants interviews for local news media professionals, never pushing his own credentials or firm name. He's even made a movie for PBS on geologic time as seen on a raft trip through the Grand Canyon that he still sends out free of charge to anyone who asks for it. When he attends professional meetings, he's usually sitting quietly in the front row taking detailed notes. You'd never tell from looking at his office, but just ask him about a particular presentation ten years earlier and he'll usually be able to lay his hands on the published abstract and his notes of the presentation within five minutes, complete with sketches of all the charts and key figures presented.

Very few of his colleagues are aware that he also had a distinguished career in naval intelligence, which included serving in an active-duty flag-staff intelligence billet for five years while concurrently running a consulting company. This dual career allowed him to travel 50,000 miles per year and afforded him many an extended stay in Panama, where he has spent days sifting through the myriad of construction files of the building of the Panama Canal. His library on the canal is extensive, and few of his lectures pass without at least a few breath-taking views of the enormous landslides that project fostered. He will soon retire from the Navy as one of the most decorated reserve intelligence officers in the post–World War II era, being the first intelligence officer in the Pacific Command to earn Navy wings as well as ten different medals.

He has taught in numerous university extension programs, and whenever we travel to far-away cities to give our ICBO grading course, he will call ahead and avail himself to nearby colleges for guest lectures. He demands excellence in his lectures, putting in enormous preparations for each presentation, and constantly upgrading his lectures with new and better information or rare photographs. Recently he decided to affiliate with the faculty in civil engineering at U.C. Berkeley, where he teaches engineering geology.

If we were to present to students a model character for an engineering geologist, we might do well to hold up the example of J. David Rogers. He was cross-trained with degrees in both geology and civil engineering; cross-registered in civil engineering, geotechnical engineering, geology, and engineering geology; and suitably well published in both civil engineering and geology, and so his opinions command respect. If you want to see a geologist who can scare the heck out of engineers, convincingly, he's your man.

Dave Rogers's resume does not do justice to him, and reading it, you would not glean something of the essence of the man, whom I believe to be a scholar and a gentleman. He has almost 100 publications to his credit at mid-career, and I am confident that we will see the best of his efforts in the years to come. On behalf of the Geological Society of America and the engineering geology profession, I take great pleasure in presenting the E. B. Burwell, Jr., Award to J. David Rogers. He has amply and meritoriously earned this honor.

Response by J. DAVID ROGERS

Mentors, Failures, and the Future of Engineering Geology

Luna Leopold

One of the most important determiners of success is the encouragement we receive from mentors. While I was attending graduate school in geological engineering at U.C. Berkeley, one of the giants of the scientific method, Luna B. Leopold, sat quietly in the northwest corner of the Earth Sciences Building, where he shared a split university appointment in geology and landscape architecture. Leopold was a scholar of the old school, and he believed in giving much of his time to each of his students. As a consequence, he consistently refrained from ever taking on more than just a few students, so he was never able to construct an academic empire like many of his younger colleagues. But for those of us who shared his time, it was a gift beyond comparison.

Leopold taught me how to study things. In the mold of Louis Agassiz, he taught one to become an astute observer of nature. We learned how to make measurements, how to collect large volumes of data, how to synthesize such data, and how to write it up. Leopold had studied under Kirk Bryan, and he passed on every aspect of Bryan's life and methods of operation that you can imagine, much like a native tribesman passes down the fables of his ancestors to his children. Leopold didn't believe in "salami science," as John Costa so aptly puts it, wherein faculty of the modern era publish regurgitated versions of the same piddly work in as many journals or conference proceedings as possible. No, Leopold would study a phenomena for 5, 10, 20 years or more before publishing a word on it. This was the example laid for us by our predecessors, by people like G. K. Gilbert, William Morris Davis, Kirk Bryan, and Charlie Hunt. They would study something for a decade or more before writing what was usually a definitive contribution on any particular subject.

Leopold also taught us how to tell a story with figures. Assemble figures to tell the story. Create figures to illustrate the key points. Remember that people who do not speak English as their primary tongue will be reading your papers! Carefully select the figures that tell your story, then write the captions. A reader should grasp the essence of one's work by quickly viewing the figures and reading the captions. Like National Geographic, if the figures and the captions are enticing, one may even break down and read the contents of the article!

Do we demean science by making it more palpable? I don't think so. When you adopt this methodology you're going to have to do a whole lot of work in preparing each paper, and therefore you'll be incapable of writing so many smaller articles. The essence of an article's scientific contribution should be sifted out in detailed peer review, review that we solicit from our brethren scientists BEFORE submitting it for publication. I've been deeply disappointed by the lack of in-depth understanding evidenced in the few official peer reviews my work has been subjected to. Too many junior faculty personnel, devoid of any practical experience and seemingly always in a hurry, seem to provide the bulk of reviewing manpower. As a consequence, many practitioners feel that little of the published literature is relevant, and a general disdain for participating in published work has developed within the mainstream of the consulting community. This trend suggests that our centers of education and research are having less and less impact on what's happening in the real world of solving problems, where the constraints of time, budget, legal concerns, and political correctness oftentimes crowd out technical considerations.

Leopold maintained, and I agree, that it is the authors who are often too lazy or feel incapable of producing good, high-quality figures to illustrate their papers. Sometimes this means hiring an artist, or chartering a plane to take key oblique photos, or, perish the thought, drawing some of the figures yourself! How we present our data is critical to their being properly understood, especially by those students who may be most influenced by our efforts.

St. Francis Dam

Inspired by Luna Leopold, I began to keep files on a multitude of subjects. I undertook work on multiyear projects, most of which I am collecting data on to this day. I have published very little of this collecting. One day in the fall of 1991, I heard that Dick Proctor and Barny Pipkin were going to republish a classic two-page article by former USC professor Tom Clements on the 1928 failure of the St. Francis Dam. I was panicked! I had been working on St. Francis for over 15 years as one of my "Leopold projects." My research, both within libraries, as well as out at the dam site, suggested a dramatically different conclusion than the one that had been reached by the Governor's Board of Inquiry in 1928. F. Leslie Ransome and George Louderback were the geologists on that panel. They visited the dam site for a day, convened for another four, and issued their conclusions on the sixth day. They concluded that the dam had likely failed via piping along a fault in the right abutment, and that the dam's designer, William Mulholland, had not appreciated the importance of engineering geology. None of the conveners was experienced in forensic investigations, none had engaged in any manner of independent measurements or assessments, and the public demanded to know "who was to blame." The panel's conclusions had come to pass as gospel to all students of geology in southern California: we all made the obligatory pilgrimage to the dam site and learned what a buffoon Mulholland was not to appreciate the detrimental effects of a fault crossing his dam's foundation.

Oh, that life and its lessons could be so simple. Several sage old geologists had questioned the conventional wisdom, however. In separate conversations with the late Dick Jahns, Jim Slosson, and the late Jerome Raphael, a professor of structural engineering at Berkeley who had spent his entire career in concrete gravity dams, I was informed that it wasn't likely a gravity dam could fail on two abutments of differing geology simultaneously. The die was cast, and like anyone who's found himself obsessed with a mystery, I was hopelessly hooked.

Time doesn't permit me to recount the many exciting details of my ongoing quest to unravel the St. Francis mystery, but suffice it to say, it was one of the greatest learning experiences of my life. I learned that one must sift through everything possible, lifting stones and turning them over, never knowing what will be found. It's what the old-timers like Leopold called "science," and it is an addictive process. One thing always led to many others, and new puzzles revealed themselves at almost every turn. What I did learn was what Leopold has prophesied: that one will use EVERY bit of technical training and knowledge one possesses at some time in life. I was using water chemistry, channel hydraulics, debris flow mechanics, structural engineering, rock mechanics, hydrology, terrestrial photogrammetry, cement chemistry, shock wave seismology, sedimentology, petrology; it just went on and on. It was the kind of project that keeps one tied up at the office till all hours of the morning, not wanting to sleep for fear of missing something.

Surprising Conclusions

In the end I learned just how much we can learn from our predecessors. Mulholland was no fool. In fact, he probably appreciated geology more than most of his contemporaries did. I found that he built the reservoir to retain a one-year supply of water for Los Angeles on the southern side of the San Andreas fault, cognizant of the effects that a repeat of the January 1857 Ft. Tejon earthquake would have on his recently completed Owens River aqueduct. Mulholland had brought Stanford geology professor John Branner out to the dam site to see if he concurred on the location. You couldn't have done much better than Branner in California in 1922. One of Branner's colleagues, by then retired, was former geology professor Bailey Willis. Willis was one of the first true engineering geologists, with degrees in both civil engineering and geology well before the turn of the century. After the dam's failure Willis had correctly asserted that the left abutment had been the real culprit, being composed of a series of ancient megalandslides developed within the Pelona schist.

Despite my many forays to the dam site, Willis's insights seemed amazing, and it wasn't long after reading them that I went out to the site again and looked at the evidence he presented. Too many of us had been held hostage by the omnipresent San Francisquito fault, forgetting to look at the bigger picture. Few people had listened to Willis, likely because he was working for the plaintiffs (flood victims) and he was something of a character. (A few years later Willis drew sides against Berkeley mining and geology professor Andrew Lawson on the foundation conditions to be encountered on the Golden Gate Bridge; his views were subsequently proven wrong and his career permanently tarnished.) His views on the St. Francis failure were published only in the obscure *Western Construction News,* a journal it took me two years to find (I finally located it at the Los Angeles Department of Water and Power, the owners of the ill-fated dam!).

The lesson of St. Francis is very simple. There are geologists and there are geologists: engineering geology is a tremendously subjective art. Put three geologists in a room and you'll likely elicit three answers. This disparity of opinion does not mean that engineering geologists are technically incompetent or don't know what they are doing. Like interpreting geophysics, one of those geologists may be correct! The problem inherent in our practice is that the simple inclusion of engineering geologic input is, in and of itself, no guarantor of not experiencing disaster. It simply depends on the experience and training of the geologist you hire. John Branner was one of the biggest names in geology when he blessed the St. Francis site. His professional colleague Willis visited that same site and drew a dramatically different conclusion. In another important case study, Willis was proved to have been wrong.

I see this manner of professional disparity every day of my practice, and it has almost driven me to desperation. I'll map an ancient landslide somewhere, and the other geologist doesn't see any evidence whatsoever for any landslides. So, it may not come down to whether or not we retained a "geologist," but to what geologist we retained and who that individual was lucky enough to have studied under. In this world of ever-increasing competition, one geologist is oftentimes seen by clients as "as good as another," and they accordingly hire the less expensive one. For those of us who make our living going around investigating engineering geologic failures, the future looks bright:

there appears to be no end in sight of geologic disasters in the making due to the economic forces shaping the way our culture "does business." I just hope another 600 people won't be paying the price for a geologist's oversight.

Becoming Mindful of Our Past and Our Own Limitations

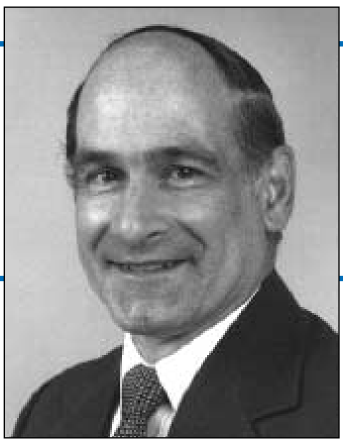
We must endeavor to know what has occurred in the past: who the players were, what constraints they operated under, and what assumptions were necessary in the design decisions. How much did economic and political factors control the outcome of the projects they worked on?

I feel that the profession of engineering geology is exceedingly more complex than it appears on the surface. It is one of the most subjective sciences known to mankind, and the development of sound professional judgment would appear to be based, more than on any other single factor, on whom our mentors were and the training they passed on to us. Those geologists fortunate enough to have received quality training from competent and experienced individuals are the only people who have a chance to develop the type of professional judgment necessary to guide the development of critical structures in the ground. This recognition of competency lineage is nothing new; Karl Terzaghi discussed it in some detail back in 1944 in the ASCE Symposia on Highway Geology.

We now live in the video age of time bites, libraries with reduced hours and holdings, and ever-increasing rules, regulations, paperwork, and societal diversions. Time for continuing education, literature review, library research, professional society activities, and communication with our federal scientist counterparts has all but disappeared from our professional routine. Some are calling this a lack of "professional growth." No matter what it's called, we are quickly losing our heritage, the experience our forebears have to offer, and the lessons learned from their failures.

As engineering geologists we must learn to network more with our brethren scientists. This means actively soliciting information and anecdotes from others as well as making oneself available to others. We must also learn to be persistent. Whenever asked, attorneys will generally deny access to anything interesting on the grounds that someone (usually another attorney) will use the information to defame an agency, owner, or project that had some sort of interesting problem. The St. Francis riddle was solved only because the City of Los Angeles finally gave access to their files, due to persistence. Many before me had made attempts to get this information and failed. I believe that second efforts, some degree of eternal optimism, and a lot of sweat are what make a good scientist or engineering geologist. I don't believe that brains and brilliance alone will carry any of us to make contributions that are significant. There's a plethora of brilliant people out there who will have no appreciable influence on society if they are not willing to work hard. Good forensics is simply hard work. Like Luna Leopold in the stream looking for his painted rocks after a flood, we have to develop both the patience and tenacity to pick up each of the rocks and look at them with an unbiased eye if we are to set about truly solving a problem.

Presentation of the KIRK BRYAN AWARD to ARTHUR N. PALMER



Citation by JAMES F. QUINLAN

No one within the field of cave and karst studies is more highly respected by his peers than Art Palmer. Few speleological names are as well known to professionals outside of this field.

Much of the respect for Art has been earned because of the cogency, clarity, and comprehensiveness of his writings, his presentations, and his unpublished research that he gladly shares with others. These include five books, ten book chapters, more than 20 journal articles, about 20 nonrefereed articles, more than 20 reviews, and ten computer programs. He has given more than 30 papers at national and international meetings and 50 invited lectures in the U.S. and Europe.

Most of Art's writings have been concerned with the origin and development of caves, chiefly in limestone, and it is for his grand, original, and definitive synthesis on this topic that we honor him with the Kirk Bryan Award. But Art has worked on much more than speleogenesis. He has also made original and significant interpretations of paleokarst, landform development, stratigraphy, geochronology, and petrology. All of them have been based on extensive field work with his wife Peg, complemented by their laboratory studies. Most of this work has been supported by the nonexistent Palmer Foundation.

Much of Art's research has been done in national parks, especially Mammoth Cave, Wind Cave, Carlsbad Caverns National Parks, and Jewel Cave National Monument. At all these places, the National Park Service has asked him to prepare interpretive materials for the park staff and for visitors. He is an expert in successfully communicating complex ideas in terms understandable to the public.

The paper for which we honor Art is "Origin and Morphology of Limestone Caves," which was published in the January 1991 GSA *Bulletin,* volume 103, pages 1–21. This unique paper is the first in the 36-year history of the Kirk Bryan Award to be concerned with caves or karst. So relevant is this paper to ground-water hydrology, however, and so significant is it to that discipline as well, that several people nominated it for GSA's Meinzer Award. I've never heard of a GSA grand slam, but if there is such a thing, Art, perhaps you might get it.

Caves have been interpreted by various specialists in terms of ground-water chemistry, geomorphic setting, lithology, aquifer type, geologic structure, potential fields, hydraulics, and solution kinetics. Art synthesized much of this but focused on the origin of the basic cave patterns and the rates of cave enlargement. Much of the paper is analytical and based on computer-aided calculations, but its conclusions are also based on extensive, arduous, and sometimes tedious field work in about 500 caves in various geomorphic, structural, and hydrologic settings throughout the U.S. and parts of Europe.

In support of his analyses and conclusions, Art describes and explains the results of processes governing cave morphology, epigenic and hypogenic origin, rates of limestone dissolution, evolution of passage size and geometry, control of cave patterns by ground-water recharge, origin of branching caves, origin and modification of caves by floodwaters, origin of maze caves by diffuse recharge, and the inability of artesian flow alone to form maze caves. He gives a succinct but sound mathematical analysis of these topics that is supplemented by numerous original graphs clearly showing complex relationships between various chemical and hydraulic parameters. It is truly a *tour de force,* and it reads well.

When I tried to summarize more of Art's paper in the limited time and space available to me, I was reminded of Richard Feynman. When he was asked by a reporter in 1965 to tell in a few words what he had done to get the Nobel Prize for physics, he replied, with a twinkle in his eye, "Listen, buddy, if I could tell you in a minute what I did, it wouldn't be worth the Nobel Prize." So it is with Art's paper. Read it if you want to get an understanding of significant insights. Surprisingly often, you will be saying to yourself, "That's neat!"

Where does Art's paper fit into the overall scheme of our understanding of cave development and hydrology? I suspect that modesty might make Art say it's merely a first approximation, but most people familiar with the field would say that it is a monumental, original analysis and synthesis and that only a few others have done so much, each in a different way, to so greatly advance our understanding of karst hydrology and geomorphology during the past 20 years. Each of them is an original thinker, but each would readily admit that he stood on the shoulders of giants. I believe Art's paper will remain definitive for many years to come.

Art can be rightly proud of his publications, the merits of which are measured by how often they are cited by others. But I think he is proudest of the results of his teaching, as measured by the accomplishments of his students, who are well trained. In 1980 he initiated the Water Resources Program at State University of New York at Oneonta, a school that stresses quality teaching rather than the importance of research. This was one of the first undergraduate programs of its kind in the country, and it has always been one of the largest. The most recent recognition of Art's teaching abilities came this year, when he was awarded a Distinguished Teaching Professorship.

I've spoken about Art's work and his numerous accomplishments. Let me close with a few words about the man himself. He is a gentleman and a gentle man who has always graciously shared his many insights with others. He has always been a role model for his students. His unique qualities and talents, and how he has applied them, have made the world a better place.

Response by ARTHUR N. PALMER

Many thanks to all of you who were on hand to share in one of the grandest surprises of my life. This award is a surprise for several reasons. First, although geomorphology is one of my earliest and most enduring passions, I am not a geomorphologist. However, my geomorphic roots can be traced back through Bill Thornbury to Clyde Malott, one of the pioneers of American karst studies. Since we're in the Who's Who section of this response, I also want to acknowledge the training and encouragement given me by Bill Fox at Williams College and by the hydrology-geophysics team at Indiana University: Allen Agnew, Judson Mead, Burke Maxey, Pat Domenico, and Yaron Sternberg. Dick Powell of the Indiana Geological Survey showed me the power of simple geomorphic field tools such as the hand level. Most of all, I want to give a cheer for my wife Peg—not only a constant field companion, but an equal and even leading partner in many of our research projects.

Geomorphology has played a pivotal role in my social development. It was on a geomorphology field trip led by Bill Thornbury that I first met Peg. Professor Thornbury was, of course, an accomplished author and lecturer, but he had the good sense to minimize his comments over the bus loudspeaker. "Where's Miss Olson? I want to 'esker' what this hill is up ahead" was an abnormally lengthy comment. Meanwhile, as a graduate student, I felt it was my duty to sit next to this bright young undergraduate to convey to her the subtle details of the passing landscape. "There goes a 'possum," Professor Thornbury informed us over the PA. I eagerly pointed out my dissertation field area. I later learned that Peg felt sorry for me for having to spend my summers in such a dull place. But ever since then geomorphology has taken second place on my love list.

The second reason for my surprise is that I am a faculty member at a school that emphasizes teaching rather than research. And yet, as much as we gripe about limited equipment and support for research, we have more opportunity to pursue research in the grand nineteenth century manner, driven by personal interest. I had the luxury of spending about 20 years preparing the GSA *Bulletin* article that led to this award. Such a leisurely pace would be the death knell to anyone on a grant.

Third, the paper is about limestone caves. Perhaps no other topic in geology is regarded with less enthusiasm by other scientists. Many of them consider cave studies to be mere sport. Also, it's difficult to maintain one's dignity while crawling through mud. However, I think the main reason is as follows.

During the early decades of this century, cave origin was pursued by several of the most outstanding geologists in the history of the field, including William Morris Davis and J Harlan Bretz. Near the end of that golden age, organized cave exploring got underway in America, and the scientists among the ranks of cavers went their own way, publishing mainly in specialized journals of limited readership. Every so often a cave-related article would appear in a mainstream journal, but the results seemed to puzzle rather than enlighten other scientists. To make an impact on others, your ideas must be slightly different from theirs—but not *too* different. People are most impressed when they already know most of what you tell them. Karst concepts are not difficult to grasp, but few readers had a personal involvement with them.

Until recently, that is. Within the past 10 or 15 years, karst has become a hot topic among the nonkarst community: stratigraphers, carbonate sedimentologists, economic geologists, petroleum geologists, structural engineers—all have found karst to be a vast new field of importance to them. Karst concepts can be used as a tool to solve many of their problems. Now the subject connects on a personal level. The gap in perspective has narrowed, and just as when two charged poles are gradually brought close together, sparks are now able to leap the gap.

There is one conspicuous exception to the list of those who have embraced karst studies—my own colleagues, the ground-water hydrologists. Most of them view karst with emotions that range from indifference to open hostility. Why?

Ground-water hydrology has one solid rock that serves as its quantitative foundation: Darcy's Law. It is valid only for laminar flow. And along come people who say that Darcy's Law does not apply to karst aquifers. There are turbulent-flow equations that apply to the movement of water through cave passages, and they interfinger quite nicely with those for laminar flow. Although they are foreign to most ground-water hydrologists, they do not pose any great conceptual hurdle. However, ground-water hydrologists gain the majority of their knowledge of aquifer behavior from pumping tests and piezometer measurements, and most such tests reveal aquifer characteristics similar to those in fractured nonkarst aquifers. One reason is that turbulent flow can often be misinterpreted as mere heterogeneity within laminar-flow systems. Another is that most of the volume of a karst aquifer is indeed typified by laminar flow.

The direct underground observations of karst researchers is limited to turbulent-flow conduits, few of us having waistlines sufficiently thin to explore laminar-flow fissures. Tracer studies show mean water velocities in conduits on the order of hundreds or thousands of meters per day. Tracers and water chemistry provide ample evidence for the surrounding laminar flow, but conduits dominate our thinking. This difference in viewpoint is not an academic issue. If one were concerned solely with water-well yield, there would be little penalty for failing to recognize the presence of cavernous voids. However, today's big issues include contaminant transport and monitoring of waste facilities. The laminar flow so commonly detected by well tests is tributary to conduits that convey water and contaminants at high velocity to springs. Unless monitor wells intercept these conduits, contaminants can pass right between them without the slightest chance of detection. Recognizing the existence and pattern of conduits is crucial. Furthermore, any attempt to apply numerical methods to the modeling of karst aquifers, particularly contaminant transport, is doomed to failure unless the exact pattern of turbulent-flow conduits is known. It never is.

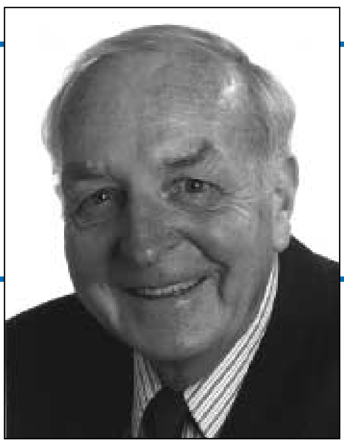
So the problem is twofold: hydrologists rarely see the effect of karst on their well tests, while karst researchers tell them they are all wrong. No wonder karst studies have not been greeted enthusiastically by hydrologists. The two poles have not come close together enough for sparks to bridge the gap.

Finally, I should say a few words about how the paper “Origin and Morphology of Limestone Caves” materialized, because it is a good example of how one's geomorphic thinking can evolve over the years. It started with a passion for cave exploring, which might be considered the essence of science: wondering what is there and seeking the answer. Ever since grade school I've also enjoyed maps and mapping. I still find the geologic mapping of caves to be a fascinating occupation. It has provided a large database on caves and what controls their pattern. From this it was easy to formulate general ideas about their origin.

My hydrology training led me to explain cave morphology simply in hydraulic terms. The basic ideas in the GSA paper were in place as early as 1970. Chemistry and chemical kinetics came rather late in the game, but they made a perfect fit. By 1980 the concepts for the GSA paper were nearly complete. As a further test, I engaged in finite-difference analysis of karst flow systems, combining hydraulics and chemical kinetics to show how solution conduits originate and grow with time, and revealing functional relationships whose validity was confirmed by further field observation. These relationships were then verified analytically, although the results appeared in an earlier paper.

I am greatly touched by your support. But papers like this, which presumptuously try to sum up and supersede all previous work on a subject, attract attention at the expense of a great deal of excellent but more specialized work. There are other people whose lifetime achievement in karst studies is greater than mine. To them, and to all those who pour their hearts into their work without recognition: I want to share this honor with you.

Presentation of the
G. K. GILBERT AWARD
to
STUART ROSS TAYLOR



Citation by ROBIN BRETT

Ross Taylor is the intellectual grandson of V. M. Goldschmidt, because his scientific father is Brian Mason, who worked with Goldschmidt. This is quite a remarkable coincidence because Ross and Brian both grew up in New Zealand (which we of Australian origin regard as the end of the world). Taylor resembles Goldschmidt because of his exceptional scientific breadth.

Ross grew up on a farm in New Zealand, some 20 miles from Bill Fyfe. The air in New Zealand must be special for producing outstanding geologists (Taylor, Fyfe, Doug Coombs, and Francis Turner, to name but a few). This is somewhat of a generalization—one must not forget Rutherford and others.

Taylor did his undergraduate work followed by his M.Sc. at the University of New Zealand (which no longer exists in name), where he was exposed to Mason's energy and intellect. He followed Mason to Indiana University, where he did a Ph.D. thesis on the petrogenesis of some New Zealand metamorphic rocks, using elemental analyses. He took some 30 years to publish part of this. Thankfully, his publications have been more rapid in recent years; otherwise, he might still be publishing pre-Apollo ideas. Taylor first used the optical emission spectrograph for some of his analyses, which stood him in good stead in later life.

In 1954, Ross moved to Oxford, a far cry from the dignified atmosphere of Indiana University. Optical emission spectroscopy was the main trace elemental analytical technique, of which the master was Louis Ahrens, with whom Taylor worked closely. Among other things he showed that trilobite skeletons are high in Cs—but why? Having done important work mainly on igneous rocks (Wager and Malcolm Brown were at Oxford at that time), he followed Ahrens to Cape Town in 1958. During his time in Cape Town, he helped Ahrens prepare the seminal textbook on optical emission spectroscopy and among other things developed a life-long interest in objects of interest to planetary geology—tektites. His first paper on these objects of so much controversy was published in 1962 and said it all: “a lunar origin is not compatible with the geochemical evidence.” His many additional papers on this subject have added further nails to that coffin. Taylor's work in this field sounded the death knell for a lunar origin, although others have filled in important pieces.

In 1961, Ross moved to Australian National University and has been there ever since, except for many forays into the outside world. In Canberra he joined one of the most creative departments in the world, although in later years his life there was not without stress, which often happens when faculty members overlap in fields. He became a master of spark-source mass spectrometry, which can measure in one analysis nearly all mass numbers. He continued his work on tektites, began his seminal work on the growth and origin of continents, and studied the geochemistry and petrogenesis of many felsic and intermediate igneous rocks.

I first met Ross in 1967 during an 8-month sojourn at ANU, and we became fast friends. He visited the U.S. in 1969, when I was chief of the Geochemistry Branch at NASA in Houston. During preliminary examination of the lunar rocks, newer geochemical techniques were not allowed; the analyses were to be done by optical emission spectroscopy, so as not to perturb the principal investigators all over the world who would later do refined analyses. The group in Houston had little experience with optical emission spectroscopy compared with Ross's experience, so it seemed logical to try to subtly recruit him to stay on and do the analyses. It was easy because I think he had the same idea in mind, so we both felt very proud of our negotiating skills when agreement was reached. Ross and his team did superb analyses of the Apollo 11 and 12 rocks, and subsequent analyses by other investigators were in good agreement. He barely escaped lunar quarantine, which was a protocol for Apollos 11 to 14 if one were exposed to unsterilized lunar samples. Six of us were incarcerated, but he was so important to the preliminary examination that I told him to run for it before I hit the panic button that summoned the biological team, whose job it was to lock us up for 12 days. The press was later shocked to find that someone was walking the streets after having been exposed to the lunar samples.

The lunar experience was the most exciting scientific time in the lives of those of us who were heavily immersed in it. Ross was no exception. He went on to write numerous papers on the geochemistry of lunar samples and their origin and the origin and evolution of the Moon (including a widely used textbook that synthesizes our knowledge up to 1975, and a later one in 1982). He has since broadened his interests, and in a fairly recent, very well received textbook, he has objectively synthesized *Solar System Evolution.*

Taylor also did excellent work on meteorite impact glasses, the geochemistry of meteorites, the origin and evolution of the rock types of Earth's crust, and the composition and evolution of the terrestrial continents. His terrestrial work (and, after all, Earth is a planet) constitutes another entire career for which he is as well known as for his extraterrestrial work. His book with Scott McLellan, *The Continental Crust: Its Origin and Evolution,* is widely cited and used. He has written six books in all—on the Moon and planets and on spectrochemical analysis.

Taylor has received a number of important awards and honors, including the Bowen Award from the Volcanology, Geochemistry and Petrology Section of AGU and the Goldschmidt Medal from the Geochemical Society; he is a Fellow of the Australian Academy of Science, and last, but by no means least, he is a Foreign Associate of the U.S. National Academy of Sciences.

Ross Taylor is broader scientifically than most of his colleagues and has carved out a career that would be considered more than respectable if only one of his interests was under consideration. His outside interests and sense of humor are also broad; his humor is dry and catholic. He is encyclopedic, especially about military encounters, and he has visited many battlefields both military and scientific. He is respected and liked by virtually all who know him. His wife Noël is also a scientist (an Australian crystallographer by way of Oxford) and she has therefore accepted the rigors of the scientific life. Such nice people deserve one another, but this rarely happens; they are very fortunate.

I am most happy to present Ross Taylor for the Gilbert Award; he is a very distinguished awardee.

Response by STUART ROSS TAYLOR

I thank Robin for his kind words, which I always await with trepidation, to learn what kind of outrageous escapades I am alleged to have committed. Harold Urey was initially responsible for getting me interested in planetology by demonstrating, when he was on sabbatical in Oxford in 1956, that it was possible to study the surface of the Moon, using the excellent series of Lick Observatory photographs. He talked a lot about G. K. Gilbert and his recognition in 1893 of the Imbrium impact and also about Ralph Baldwin's book *The Face of the Moon.* He also talked about primitive solar system objects (which included the Moon in his cosmology), and the compositions of meteorites and tektites, about which he held forth during morning tea sessions. Tektites were something one could analyze, and as a first step, I started looking at their alkali element compositions, asserting in 1959 that, since their K/Rb ratio was terrestrial, they could not come from outside the solar system, as had been suggested, since K and Rb were formed in different nucleosynthetic processes in stars and would have a different ratio in extraterrestrial matter. I did not expect that 35 years later, in 1994, I would still be writing on tektites (with Chris Koeberl).

The lunar vs. terrestrial battles over the origin of tektites were conducted with great ferocity during the 1960s. The stakes were high, and I still retain many scars and even a residual division of the world between “them and us.” Working on tektites naturally led to speculation about the composition of the Moon. Even in the early 1960s it seemed unlikely that the lunar surface had a composition similar to terrestrial sediments. Siliceous ash flows were popular candidates for the lunar highlands, but, if so, they were distinct from their terrestrial analogues, if tektites were coming from the Moon. All this was a good grounding in comparative planetology, a discipline that had yet to be invented.

My interest in tektites led, by a curious path, to my involvement with lunar samples and so eventually to this event. It was all the fault of Robin Brett. When he learned, through an exchange of Christmas cards (a great way to communicate), that I would be at the Corning Glass Symposium on tektites in March 1969, he suggested that I come by Houston, where he was the newly appointed chief of the Geochemistry Branch at what was then the NASA Manned Spacecraft Center. I innocently accepted his invitation, little realizing his Machiavellian plans.

He showed me the Lunar Receiving Laboratory, where Elbert King, then curator of lunar samples, had installed an emission spectrograph to carry out the preliminary examination of the lunar samples expected in July. I had spent much of the previous 15 years involved in that technique. Brian Mason had supervised my Ph.D. thesis, which had involved a lot of emission spectrographic work, and I had learned many of the dark secrets and philosophy of the technique of rock analysis from Louis Ahrens. When I saw the lunar laboratory, it was clear that a lot had still to be done to get ready in the two or three months before the expected arrival of unknown samples from the Moon. It wasn't long before Robin had me hooked on that task, and it was six months before I escaped, having undergone in the meantime the most interesting and at times traumatic professional experience of my life, the initial analysis of the first lunar samples. Meanwhile I had left my wife in Canberra to cope with a half-built house, which she successfully saw to completion.

When I left Houston, Robin said, “What are you going to do for an encore?” I always take Robin's advice, so I kept working away on lunar geochemistry, encouraged by the directors of what was then the Lunar Science Institute, first Bill Rubey and then Joe Chamberlain, who invited me in 1973 to spend a year at Houston writing a review of lunar geochemistry. This turned into *Lunar Science: A Post-Apollo View.* While engaged on this task, I was greatly helped by Petr Jakes in constructing the Taylor-Jakes model for lunar evolution, a model that still seems reasonably robust. To the dismay of Harold Urey, the Moon turned out to be a thoroughly differentiated body. Jim Head succeeded Joe as director at the Lunar and Planetary Institute, and he, Bob Pepin, Tom McGetchin, Roger Phillips, Kevin Burke, and David Black always made me very welcome in Houston. Kevin says that I have spent more time at the institute than most of the directors. As a result, I have managed to write two more books at Houston. The last one was on the solar system, since Kevin Burke told me, “You're not allowed to write another book about the Moon.” So I had to broaden my horizons.

The past 25 years have been a remarkable time in planetary science. Suddenly a whole host of new worlds have been revealed to us in stunning detail, the most recent being the Magellan views of the surface of Venus, followed this year with the sobering reminder of the importance of impacts by the collision of the Shoemaker-Levy cometary fragments with Jupiter. Largely as a result of the Apollo missions, a new type of scientist has arisen, capable of dealing with all sorts of extraterrestrial materials and problems. The resulting planetary science community is one of the national treasures of the United States, and this award should really be shared among many of them. Larry Haskin and John Wood have both remarked to me how fortunate we were to have been born at the right time to see all these marvels.

In conclusion, I wish to thank the Division of Planetary Sciences of the Geological Society of America for the G. K. Gilbert Award and to add that I have always been made extremely welcome in this country. One of Harold Urey's favorite comments was, “I'm only a country boy from Indiana.” In the midst of all this wealth of expertise in planetary science, no one seems to mind the presence, to paraphrase Harold Urey's comment, of a country boy from New Zealand, nor a citation from a town boy from Australia.

SAGE REMARKS

Robert A. Matthews, University of California, Davis

Mentorship and Research-Oriented Minority Science Student Program

The Forum section in the September 1991 issue of *GSA Today* featured several perspectives on ethnic minorities in the geosciences. The six perspectives addressed the question of why so few ethnic minorities are employed in the geosciences.

Today, some three years later, the situation is not much improved, in spite of numerous programs and special activities designed to alleviate the problem. The situation in the physical and mathematical sciences is not much better. In 1993, only 6% of the underrepresented minority undergraduate students (African-American, Native American, and Chicano or Latino) attending the University of California, Davis, had declared a major in the physical and mathematical sciences. The percentage of underrepresented students in the geological sciences was even lower. With an interest in and intent of trying to address this situation in a state with a very large ethnic minority population, a small group of U.C. Davis faculty from the six disciplinary areas of the physical and mathematical sciences met to develop a program called Minority Undergraduate Research Participation in the Physical and Mathematical Sciences (MURPPS). MURPPS is a University of California, Davis, campus program, but operates in close coordination with a university-wide California Alliance for Minority Participation in Mathematics, Sciences, and Engineering. It is funded by the National Science Foundation and a smaller grant from the DuPont Corporation.

The primary goal of the MURPPS program is to institutionalize, in a major research institution, the premise that underrepresented undergraduate minority students are capable not only of surviving but excelling in the physical and mathematical sciences.

Three principal objectives of the MURPPS program include (1) increasing the persistence and matriculation rates of underrepresented minorities by including students in the university community as functioning members via faculty and student mentoring; (2) increasing the number of qualified, entering underrepresented students through outreach programs with community colleges, high schools, and the Mathematics Engineering and Science Achievement Program (MESA); and (3) increasing the number of underrepresented minority students who receive M.S. and Ph.D. degrees in the physical and mathematical sciences, and who enter into teaching and research careers in government, academia, and the private sector. The unique and most innovative aspects of this three-year program are the faculty mentorship and freshman research components.

The program works as follows. Incoming students, many of whom have not declared majors, are matched with a professor who agrees to serve as a mentor and advisor. The advisor assists the student in developing a research project in his/her research program. As a part of this project, students participate in an eight-week summer program, in which research is emphasized. The Summer Academy Program is designed to give research experience to both continuing MURPPS students and community college students. The summer program also serves as a pipeline for transfer students and helps them to select programs in the physical and mathematical sciences during the following school year. During the spring quarter of their second year, the students are required to give a presentation on the research project with which they have been involved for nearly two years.

Incoming students in MURPPS are also required to participate in the Freshman Seminar Series. In the fall quarter, the seminar introduces students to campus faculty in the physical and mathematical sciences, including those faculty that serve as mentors. In the winter quarter, the seminar speakers are professionals from outside the university and include mainly ethnic minority scientists from academia, government, and the private sector.

On the U.C. Davis campus, MURPPS has also developed a Saturday Outreach Program for high school students during the school year. The students, selected from 15 high schools in the area, spend a full day at the "Saturday Academy" with faculty representatives from each of the six disciplines along with master teachers from local high schools, graduate students, and MURPPS students (peer mentors). The high school students are exposed to laboratory and field-oriented programs in each of the six disciplines for two Saturdays per discipline. This outreach is intended to act as a pipeline to get minority students into the physical and mathematical sciences at the colleges and universities of their choice. MURPPS is cooperating with an existing high school outreach program called PIPELINE, which organizes the student groups, selects the master teachers, transports the students to campus, and works with U.C. Davis faculty in organizing classes for the six science areas.

Another key feature of the MURPPS program is the total funding of the students' costs, including university fees and room and board expenses (students are required to live in university dorms for their first year). The students receive a stipend of $500 per quarter and $2000 for the eight-week summer program, plus the costs for room and board. The rationale for funding the students is to relieve them from the necessity of working to support themselves during the program period. This allows them to concentrate fully on their studies and research.

Twenty-two students were chosen for the program in the fall of 1993 and were assigned or allowed to select a mentor. Of the 22 students, five chose geology mentors, though none had indicated interest in geology prior to the introductory programs. Seventeen students completed the first year, including four of the five students in the Department of Geology. The overall GPA of freshman students in the MURPPS program was slightly above the average for non-MURPPS freshman students in the physical and mathematical sciences.

Fifteen freshman students were selected for the second year, and we expect that they will prove equal to or better than the first-year students, because we required them to take part in the Special Transition Enrichment Program (STEP) run by the University Learning Skills Center. This special program is open to all entering freshman students. The program provides students with a comprehensive overview of university programs and services and serves to ease the transition from high school to university-level courses.

MURPPS is an innovative program designed to encourage and support underrepresented minority students in physical and mathematical sciences. Initial results indicate that this type of program is successful in achieving these objectives.

It is anticipated that at the end of the National Science Foundation funding period, the University and private-sector funding will be secured to continue the program. ■

The New PEP

As of January 1, 1995, the Partners for Excellence Program (PEP) has become the Partners for **Education** Program. The acronym remains the same, but we hope the name change will clarify our purpose to GSA members, and to teachers, students, and parents.

In conjunction with the name change, GSA is pleased to announce that Barbara L. Mieras has been appointed the full-time Partners for Education Program manager. This appointment was made possible by grants to GSA's Science Awareness through Geoscience Education (SAGE) program from the Exxon Education Foundation and other donors.

Mieras has been working with the SAGE program the past two years, and she brings a great deal of enthusiasm, energy, and expertise to the Partners for Education Program. She has a Ph.D. in geology and is an active Ph.D. candidate in the School of Education at the University of Colorado at Boulder. She has industry and consulting experience as a geologist as well as classroom experience teaching grades 7–12. She has taught geology and science methods courses at the University of Colorado; has worked on curriculum development for various groups, including the American Indian Science Engineering Society (AISES); and is a facilitator for Project WILD and Project Learning Tree. Mieras is also a member of the SEPM National Standing Committee for Education.

To become a member of the Partners for Education Program or for additional information on PEP, please contact Barb Mieras at GSA headquarters, (303) 447-2020, or fax 303-447-1133.

Donors *continued from p. 50*

David M. Miller
Gifford H. Miller
William G. Minarik
H. Kenneth Peterson
Phyllis M. Radack
Shirley A. Rawson
Michael P. Semet
Gary A. Smith
Daniel P. Spangler
Leeann Srogi
Rolfe S. Stanley
Desiree E. Stuart-Alexander
Page C. Twiss
Ben A. van der Pluijm
Louis P. Vlangas
Ralph H. Willoughby

SAGE
James O. Brown
Robert A. Christman
John R. Coash
Gerald I. Eidenberg
Ann I. Guhman
Pamela Hallock-Muller
Lincoln S. Hollister
Peter L. K. Knuepfer
Philip S. Koch
J. Richard Kyle
Stephen C. Lee
Steven E. Mains
Jody V. Maliga
Robert A. Matthews
Peter I. Nabelek
James V. O'Connor
J. Michael O'Neill
Douglas C. Pasley, Jr.*
Aurora Pun
Charles C. Rich
Lee R. Russell
Michael L. Sargent
Patricia O. Seaward
Gary B. Sidder
Nancy S. Stehle
Jack W. Travis
James W. Tucker

Second Century Fund
Clarence Allen*
Paul A. and Florence Bailly*
Boettcher Foundation*
William Bradley*
Campini Foundation*
Mark and Rhonda Cloos*
Fred A. Donath*
Robert H. Dott*
Gordon P. Eaton*
El Pomar Foundation*
Exxon Corporation*
Gates Foundation*
Robert D. Hatcher*
Frederick H. Leonhardt Foundation*
Howard and Jean Lipman Foundation*
Charles J. Mankin*
Maxxus Energy Corporation*
Haydn H. Murray*
Newmont Gold*
Elaine Padovani*
James L. and Donna L. Russell*
Ruth and Vernon Taylor Foundation*

Unrestricted—Foundation
Thomas F. Anderson
Thomas H. Anderson
Victor R. Baker*
William A. Bassett
James W. Baxter
James O. Brown
Severn P. Brown
George Frank Bryant*
Douglas Saxon Coombs
Edward J. Cording
Carolyn F. Corwin*
(in memory of Gilbert Corwin)
Henry W. Coulter*
Doak C. Cox
Richard Crook, Jr.
John C. Crowell*
Robert V. Cushman
Steven N. Daviess
Albert J. Depman
Robert S. Dietz
Joseph A. Dixon
Pamela P. Fisco
David P. Friedman
Virgil A. Frizzell, Jr.
Robert L. Fuchs*
John M. Garihan
Reinhard O. Greiling
Keith A. Howard
Arthur Mekeel Hussey
John B. Ivey
James A. Joy
William E. Kelly
A. David Kendrick
Carl H. Kiesewetter
John Edward Kilkenny
Charles W. Klassette
William F. Kohland
Konrad B. Krauskopf*
John T. Kuo
John A. Larson
S. Benedict Levin
Charles R. Lewis
Kathryn H. Lohmeyer
Neil Lundberg
Richard Lung
Robert J. Malcuit
Ennio Marsella
Stephen Marshak
Larry G. Mastin
John C. Maxwell*
James S. Mellett
Robert L. Melvin
James P. Minard
Jean Morrison
William R. Muehlberger
Scott L. Neville
Norman D. Newell
Martin R. Palmer
Douglas C. Pasley, Jr.*
Bernice Petersen
Donald W. Peterson
Thea Welsh Phinney
Forrest G. Poole
Anthony R. Porter
W. Robert Power
Richard H. Ragle
Douglas W. Rankin*
John A. Reinemund
J. Bruno Risatti
Peter Robinson
John W. Rold
Matthew E. Schramm
David H. Scofield
Eugene M. Shoemaker
Christopher A. Suczel
James B. Thompson*
David D. Tillson
Koike Toshio
R. Rexford Upp
George Viele*
Alexander A. Wanek*
Fred Webb, Jr.
Ronald Willden
Xerox Corporation*
Kenzo Yagi
Leland W. Younker

Unrestricted—GSA
John W. Anthony
James O. Brown
Richard L. Cooley
Cyrus W. Field
Julian R. Goldsmith
John P. Griess
Susan D. Halsey
Eric T. Hanssen
Richard C. Mielenz
Louis Moyd*
Scott L. Neville
Lincoln R. Page*
Douglas C. Pasley, Jr.*
W. Robert Power
Noel M. Ravneberg
Bernard B. Scheps
James B. Stevens
William A. Thomas*
Garrett E. Zabel

Women in Science
Robert L. Duba
Vicki L. Hansen*
Helen Lang
William G. Minarik
Daniel P. Spangler

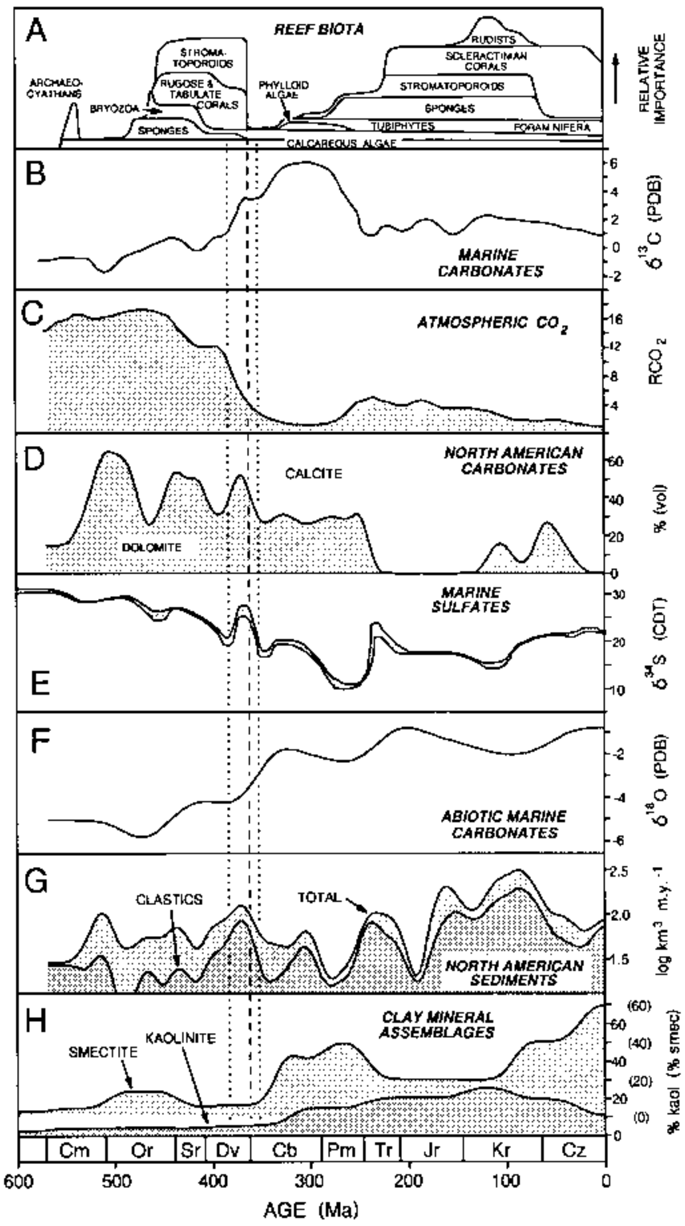


Figure 2. Phanerozoic records exhibiting Late Devonian anomalies: (A) dominant Phanerozoic reef-building groups (James, 1983); (B) marine carbonate $\delta^{13}C$ (Berner, 1989); (C) atmospheric CO_2 (RCO_2 is the ratio of CO_2 at a given time in the past to that at present; Berner, 1994); (D) North American dolomite abundance (as volume percent of total carbonate; this paper); (E) marine sulfate $\delta^{34}S$ (Holser et al., 1989); (F) abiotic marine carbonate $\delta^{18}O$ (Lohmann, 1988); (G) North American sediment survival rates (this paper); and (H) mineralogy of clay mineral assemblages (Weaver, 1967). PDB is Peedee belemnite

Plants *continued from p. 45*

VASCULAR LAND PLANT EVOLUTION

Although land plants appeared in the Late Ordovician or Early Silurian and vascular plants diversified in the Late Silurian and Early Devonian (Edwards and Berry, 1991), full colonization of land surfaces is likely to have been a protracted process that continued throughout the Devonian and later. Initially, the impact of land plants on their physical environment was negligible owing to small size, limited biomass, shallow rooting, and restriction to moist lowland habitats. As land plants increased in size and became more abundant and geographically widespread, they exerted a progressively stronger influence on their physical substrate. Two evolutionary innovations are of major significance in this regard: (1) arborescence, or tree-sized stature, and (2) the seed habit. With the advent of supporting tissues (2° xylem, 2° cortex) in the Middle Devonian (Fig. 3E), several groups of vascular plants (lycopods, cladoxylaleans, progymnosperms) exhibited increases in stature (Fig. 4; Chaloner and Sheerin, 1979; Mosbrugger, 1990). However, Middle Devonian trees mostly occupied riparian habitats, and flood-plain forests probably developed in the Frasnian with the appearance of the progymnosperm *Archaeopteris*. This genus, which grew ~30 m high, became the dominant element of terrestrial floras between the mid-Frasnian and mid-Famennian, but declined rapidly with the appearance of seed plants (Fig. 3E; Beck, 1981; Gensel and Andrews, 1984; Scheckler, 1986). Seed plants spread rapidly during the latest Famennian owing to the advantages conferred by seeds, including ability to adapt to diverse ecological conditions and to occupy drier upland habitats (Fig. 3E; Gillespie et al., 1981; Rothwell et al., 1989).

Close temporal relations exist between Late Devonian anoxic and extinction events and these paleobotanic developments. First, the onset of a protracted late Middle–Late Devonian interval of widespread oceanic anoxia (Fig. 3, B–D) followed closely the advent of secondary vascular supporting tissues (Fig. 3E) and coincided broadly with rapid increases in the maximum size of vascular land plants in the Middle Devonian (Fig. 4). Second, the F-F boundary Kellwasser event occurred within the mid-Frasnian to mid-Famennian interval of archaeopterid dominance and might represent the rapid spread of this genus (Fig. 3E). Third, the D-C boundary Hangenberg event is preceded by the appearance of the earliest known seeds by one conodont zone, or about 0.5 m.y. (Fig. 3E; Gillespie et al., 1981; Rothwell et al., 1989). In each case, an important paleobotanic development that probably led to a large increase in root biomass preceded major paleontologic, sedimentologic, and geochemical events by no more than a few million years. In this regard, first appearances are less

Plants *continued on p. 65*

Trends *continued from p. 47*

information about the key themes and key points presented at the forum.

In the 1970s and 1980s, the extractive-industries (petroleum and minerals)–oriented companies hired more graduating earth science students than any other category of employer, formerly providing employment to about two-thirds of all graduates. Employment and employment opportunities in these industries have declined sharply over the past decade. Domestic growth is expected to be flat. Contributing to the continuing low level of employment is the fact that extractive companies are increasingly moving their operations overseas, where they are hiring foreign nationals.

Employment opportunities in environmentally oriented companies are the brightest of those in any geoindustry. However, the evolution and maturation of the industry and its technologies has reduced employment opportunities when compared to the recent past. Competitive pressures have prompted personnel restructuring, including layoffs in some areas and the replacement of higher paid managers with lower paid, entry-level staff. Slow to moderate growth in employment is anticipated and should provide the greatest opportunities to students with B.S. and M.S. degrees. Continuation of the federal government's domination of environmental regulations will probably favor large, multidisciplinary firms.

Shrinking budgets have been and will continue to be responsible for decreasing employment of earth scientists by state and federal government agencies. The number of state-funded positions for professional staff in state geological surveys has declined about 8% in the past four years, while the number of contract employees has increased. Positions in the USGS have also declined over the past decade. These trends are likely to continue. Even larger reductions have occurred in the U.S. Bureau of Mines.

In academia, the number of faculty positions is expected to remain constant over the next 5–10 years. Faculty positions supported by external funds probably will decrease, because many of these positions do not provide revenue to the universities. Some universities are using postdoctoral fellows in place of teaching assistants. This creates more temporary slots for scientists seeking permanent positions.

Earth science job opportunities in the coming decade likely will be in positions that address important societal problems, such as natural hazards, health, infrastructure, energy and resource needs, and environmental protection and remediation. Employers will be seeking geoscientists who have knowledge of aqueous geochemistry, earth surface processes, and the youngest part of the geological time scale. Particularly attractive will be graduates with a solid foundation in fundamental science (biology, chemistry, engineering, geology, physics), mathematics, and computer science and with skills in foreign language and oral and written communication.

Forum participants expressed the sense that the generally prevailing college and university earth science curriculum, which has changed little over the past 50 years, must be redesigned to provide a multidisciplinary base that integrates scientific knowledge and basic scientific skills that would allow students to adapt to changing societal priorities. Although the forum did not provide a specific plan for revision, participants agreed that earth science societies and colleges and universities should encourage reform in several ways, including:

- Bringing together the academic community, professional societies, government, and industry to coordinate curricular reform.
- Developing benchmarks for the content of courses.
- Providing recognition and awards for innovative courses, curricula, and teaching excellence.

There was a consensus that earth science societies need to become more proactive in promoting the earth sciences to policy makers and the public at large in order to ensure the continued viability of the profession. The societies could promote earth sciences in several ways:

- Encouraging colleges and universities to provide integrative earth science courses and experiences for nonmajors, particularly for preservice and in-service K–12 teachers.
- Working with colleges and universities to inject earth science perspectives into allied professions, such as engineering, and to prepare earth science students for nontraditional careers in areas such as law, business, and politics.
- Working with academia and industry to provide access to lifelong, high-quality learning for practicing earth scientists.
- Encouraging and, where appropriate, coordinating the participation of earth scientists in local, state, and federal policy debates and decisions.

The key word at the forum was change. Employment opportunities for earth scientists have decreased significantly over the past decade, and this pace is likely to continue into the future. In the face of this rapid change, colleges and universities need to be constantly assessing their curricula. Geoscientists must work together to ensure a well-educated and skilled earth science workforce that will be able to meet the future needs of society, such as preserving the environment and providing an adequate supply of natural resources for a growing population. Perhaps the most important role for earth science societies in managing this change is the collection and dissemination of human resource data that can serve as the basis for wise decision making on employment and education issues. ■

Southeastern Section Meeting to Include Symposium on Energy and the Environment

A symposium, "Energy and the Environment in the Next Century," at the GSA Southeastern Section meeting in April will feature speakers from both the private and public sectors. The objective of the symposium, sponsored by GSA's Institute for Environmental Education, is to look at the many facets of the issue of energy use and its effects on the environment, according to organizer Otto Kopp (University of Tennessee).

Some of the subjects will be: acceptable levels of toxicity, fossil fuels and CO_2, the economics of nuclear power, and techniques for monitoring the environmental impact of energy production. The symposium will be open to all attendees at the GSA Southeastern Section meeting in Knoxville, Tennessee, April 6–7, 1995.

For further information, contact Otto C. Kopp, Dept. of Geological Sciences, University of Tennessee, Knoxville, TN 37996-1410, (615) 974-2366, fax 615-974-2368, E-mail: otto@yoda.gg.utk.edu.

Plants *continued from p. 64*

important than increases in abundance and biomass, which are harder to quantify but significantly more important in terms of geochemical consequences.

DEVELOPMENT OF THE RHIZOSPHERE AND SOILS

Soils are the geochemical interface between the lithosphere and the atmosphere-hydrosphere, and their importance in global geochemical cycles has been largely underappreciated. Although thick Precambrian soil profiles are known, generally high rates of physical weathering in the pre-Devonian probably yielded widespread barren rock surfaces and thin microbial protosoils similar to modern desert crusts (Campbell, 1979). Increases in the size and geographic distribution of large vascular plants and in root biomass probably resulted in substantial increases in the depth and volume of soils during the Late Devonian (Retallack, 1986).

Development of the rhizosphere had important short- and long-term effects on sedimentologic and geochemical processes associated with weathering (Fig. 5). In the short term, global weathering rates increased as relatively fresh substrates were physically and chemically attacked by rapidly spreading root systems. Enhanced physical weathering may have accompanied the transition from largely unvegetated to vegetated uplands, during which increases in root density would have accelerated mechanical breakup of rock but exerted only a weak stabilizing influence against erosion by episodic droughts, landslides, and wildfires (Stallard, 1985), yielding transient increases in regional or global particulate fluxes (Fig. 2G). Elevated chemical weathering rates resulted from "pumping" of atmospheric CO_2 into the soil during rhizosphere expansion. Rapid drawdown of atmospheric CO_2 led to a negative feedback on weathering rates, reestablishing a long-term balance in the rate of CO_2 utilization through weathering and the rate of CO_2 supply through volcanic outgassing (Berner, 1992, 1994). The transient increase in chemical weathering rates associated with rhizosphere expansion is likely to have caused a pulse in nutrient flux to the oceans, resulting in eutrophication of semirestricted epicontinental seas and stimulating marine algal blooms (Fig. 5). Such blooms may have been the source of high concentrations of marine algal matter in Upper Devonian black shales (Maynard, 1981) and of enigmatic fossils of wide geographic but restricted stratigraphic occurrence such as *Protosalvinia* (*Foerstia*; Schopf and Schwietering, 1970). Analogous relations have been documented from the modern Black and Baltic Seas, in which anthropogenic and natural increases in nutrient fluxes have caused eutrophication and transient expansion of oxygen-depleted bottom waters (Kuparinen and Heinänen, 1993; Lyons et al., 1993).

Long-term effects of rhizosphere development on weathering processes included increased landscape stabilization and a shift from weathering-limited to transport-limited weathering regimes (Fig. 5; Stallard, 1985; Johnsson, 1993). Weathering of rocks to a finer grained, compositionally more mature product was promoted by (1) production of organic and carbonic acids by roots, (2) trapping of moisture in soils, and (3) increased water-rock contact time as a result of soil stabilization and enhanced evapotranspirational recirculation (Berner, 1992). These developments are consistent with an Early Carboniferous shift from

Plants *continued on p. 66*

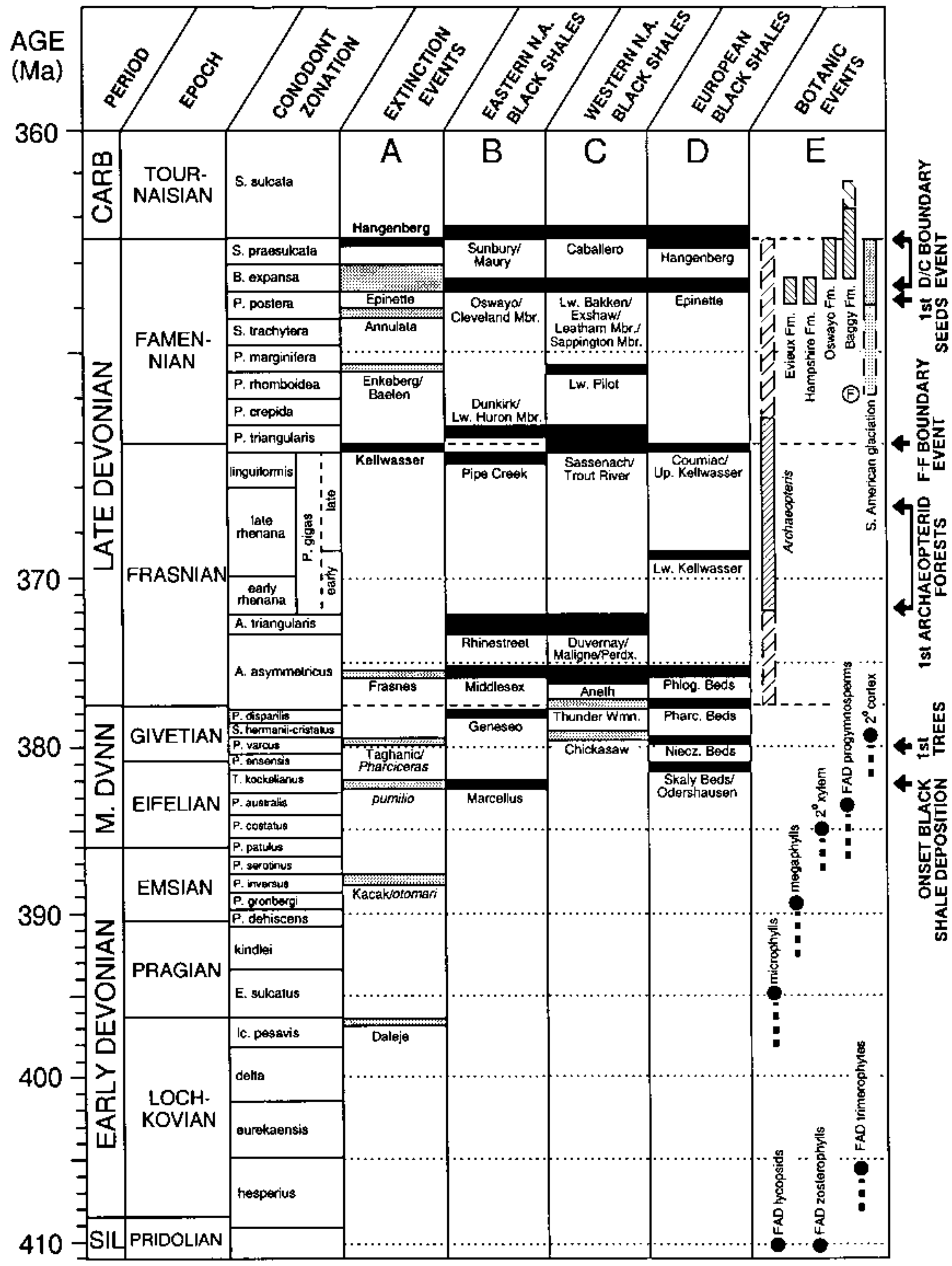


Figure 3. Correlation of Devonian events: (A) extinction events; black shales from (B) eastern North America, (C) central to western North America, and (D) Europe; and (E) paleobotanic events (data sources available upon request). For columns B–D, note that illustrated units represent anoxic maxima as determined by total organic carbon content; black shales were deposited through much of the late Middle and Late Devonian in some areas. In column E, FAD = first appearance datum; the range and peak abundance of *Archaeopteris* are shown by dashed and solid lines, respectively; and the age of South American glaciation is restricted by occurrence of *Foerstia* (F; dashed; Caputo, 1985) and miospores (solid; Streel, 1986). Conodont zonation from Ziegler and Sandberg (1990), and time scale from Harland et al. (1990).

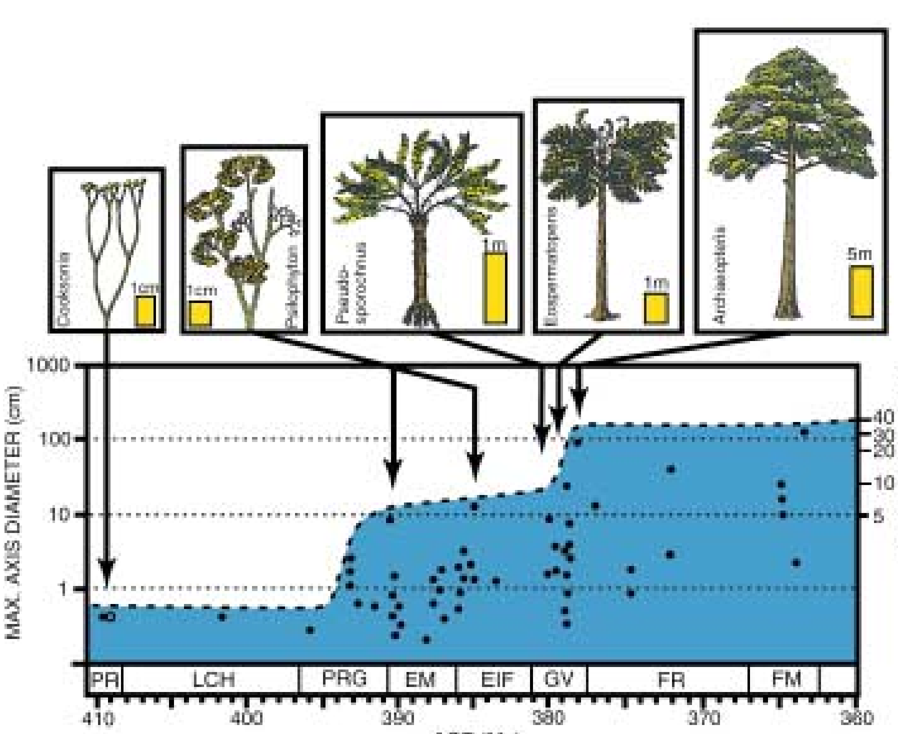


Figure 4. Maximum size of vascular land plants during the Devonian; note the rapid increase associated with appearance of trees in the Givetian. Maximum diameters of plant axes, estimated tree heights, and representative fossil genera from Chaloner and Sheerin (1979), Gensel and Andrews (1984), and Mosbrugger (1990).

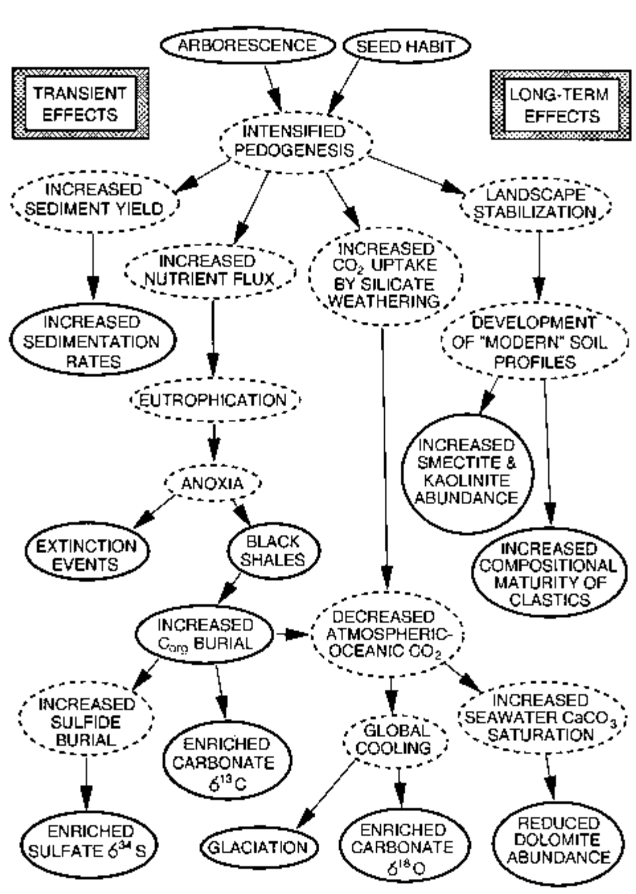


Figure 5. Model linking Late Devonian geochemical, sedimentologic, and climatic anomalies to the development of arborescence and the seed habit among vascular land plants. Features are arrayed by relative duration, transient effects on the left and long-term effects on the right. Solid outlines indicate documented geologic records; dashed outlines indicate processes linking records. See text for discussion.

Plants *continued from p. 65*

illite-chlorite– to smectite-kaolinite–dominated clay mineral assemblages (Fig. 2H; Weaver, 1967). At present, formation of smectite and kaolinite is closely associated with moderate to strong pedogenic weathering in temperate to semiarid and in humid tropical climate zones, respectively (Singer and Munns, 1991).

CONCLUSIONS

The influence of vascular land plants on weathering processes and global geochemical cycles is likely to have increased substantially during the Late Devonian owing to development of arborescence and the seed habit. These paleobotanic innovations led to rapid expansion of the global rhizosphere, resulting in a transient intensification of the rate of soil formation and in a permanent increase in the thickness and areal extent of deeply weathered soils. Intensified chemical weathering may have caused a transient increase in riverine nutrient fluxes, resulting in eutrophication of semirestricted epicontinental seaways and stimulating marine algal blooms and widespread deposition of black shales. Correlativity of black shale horizons with episodes of extinction of tropical marine benthos implicates oceanic anoxia rather than global cooling as the proximate cause of the Late Devonian biotic crisis. Drawdown of atmospheric CO_2 and global cooling were secondary effects of enhanced silicate weathering and rapid organic carbon burial. Thus, evolutionary developments among vascular land plants are likely to have been the ultimate cause of oceanic anoxic events, biotic crises, and global climate change during the Late Devonian.

ACKNOWLEDGMENTS

North American sediment massage distributions were compiled from Cook and Bally (1975) with assistance from Bradley Opdyke, Steven Boss, and Bruce Wilkinson. The manuscript benefited greatly from our discussions with Elso Barghoorn, John Hayes, Jacek Jaminski, Lisa Pratt, Greg Retallack, and Tom Robl, and from reviews by Patricia Gensel, Eldridge Moores, and an anonymous reviewer. Lisa Trump drafted Figure 1. Financial support was provided by the University of Cincinnati Research Council (Algeo); by National Science Foundation grant EAR-9117099 (Berner); and by the U.S. Department of Energy (Maynard). We are grateful to the many researchers whose contributions have been helpful in formulating the hypothesis of this paper.

REFERENCES CITED

Alvarez, L. W., Alvarez, W., Asaro, F., and Michel, H. V., 1980, Extraterrestrial cause for the Cretaceous-Tertiary extinction: Science, v. 208, p. 1095–1108.

Bambach, R. K., 1985, Phanerozoic marine communities, *in* Raup, D. M., and Jablonski, D., eds., Patterns and Processes in the history of life: Berlin, Springer, p. 407–428.

Beck, C. B., 1981, *Archaeopteris* and its role in vascular plant evolution, *in* Niklas, K. J., ed., Paleobotany, paleoecology, and evolution, Volume 1: New York, Praeger, p. 193–230.

Berner, R. A., 1989, Biogeochemical cycles of carbon and sulfur and their effect on atmospheric oxygen over Phanerozoic time: Palaeogeography Palaeoclimatology, Palaeoecology, v. 75, p. 97–122.

Berner, R. A., 1992, Weathering, plants and the long-term carbon cycle: Geochimica et Cosmochimica Acta, v. 56, p. 3225–3231.

Berner, R. A., 1994, Geocarb II: A revised model of atmospheric CO_2 over Phanerozoic time: American Journal of Science, v. 294, p. 56–91.

Campbell, S. E., 1979, Soil stabilization by a prokaryotic desert crust: Implications for Precambrian land biota: Origins of Life, v. 9, p. 335–348.

Caputo, M. V., 1985, Late Devonian glaciation in South America: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 51, p. 291–317.

Chaloner, W. G., and Sheerin, A., 1979, Devonian macrofloras, *in* House, M. R., et al., eds., The Devonian system: London, Palaeontological Association, Special Papers in Palaeontology 23, p. 145–161.

Claeys, P., Casier, J.-G., and Margolis, S. V., 1992, Microtektites and mass extinctions: Evidence for a Late Devonian asteroid impact: Science, v. 257, p. 1102–1104.

Cook, T. D., and Bally, A. W., editors, 1975, Stratigraphic atlas of North and Central America: Princeton, New Jersey, Princeton University Press, 272 p.

Copper, P., 1986, Frasnian/Famennian mass extinction and cold-water oceans: Geology, v. 14, p. 835–839.

Edwards, D., and Berry, C., 1991, Silurian and Devonian, *in* Cleal, C. J., ed., Plant fossils in geological investigation: New York, Ellis Horwood, p. 117–153.

Geldsetzer, H. H. J., Goodfellow, W. D., McLaren, D. J., and Orchard, M. J., 1987, Sulfur-isotope anomaly associated with the Frasnian-Famennian extinction, Medicine Lake, Alberta, Canada: Geology, v. 15, p. 393-396.

Gensel, P. G., and Andrews, H. N., 1984, Plant life in the Devonian: New York, Praeger, 380 p.

Gensel, P. G., and Andrews, H. N., 1987, The evolution of early land plants: American Scientist, v. 75, p. 478–489.

Gillespie, W. H., Rothwell, G. W., and Scheckler, S. E., 1981, The earliest seeds: Nature, v. 293, p. 462–464.

Harland, W. B., Armstrong, R. L., Cox, A. V., Craig, L. E., Smith, A. G., and Smith, D. G., 1990, A geologic time scale 1989: Cambridge, United Kingdom, Cambridge University Press, 263 p.

Holser, W. T., Maynard, J. B., and Cruikshank, K. M., 1989, Modelling the natural cycle of sulphur through Phanerozoic time, *in* Brimblecombe, P., and Lein, A. Y., eds., Evolution of the global biogeochemical sulphur cycle: Chichester, United Kingdom, Wiley, p. 21–56.

House, M. R., 1985, Correlation of mid-Palaeozoic ammonoid evolutionary events with global sedimentary perturbations: Nature, v. 313, p. 17–22.

James, N. P., 1983, Reefs, *in* Scholle, P. A., et al., eds., Carbonate depositional environments: American Association of Petroleum Geologists Memoir 33, p. 345–462.

Johnsson, M. J., 1993, The system controlling the composition of clastic sediments, *in* Johnsson, M. J., and Basu, A., eds., Processes controlling the composition of clastic sediments: Geological Society of America Special Paper 284, p. 1–19.

Kuparinen, J., and Heinänen, A., 1993, Inorganic nutrient and carbon controlled bacterioplankton growth in the Baltic Sea: Estuarine, Coastal and Shelf Science, v. 37, p. 271–285.

Lohmann, K. C, 1988, Geochemical patterns of meteoric diagenetic systems and their application to studies of paleokarst, *in* James, N. P., and Choquette, P. W., eds., Paleokarst: New York, Springer, p. 58–80.

Lyons, T. W., Berner, R. A., and Anderson, R. F., 1993, Evidence for large pre-industrial perturbations of the Black Sea chemocline: Nature, v. 365, p. 538–540.

Maynard, J. B., 1981, Carbon isotopes as indicators of dispersal patterns in Devonian-Mississippian shales of the Appalachian Basin: Geology, v. 9, p. 262–265.

McGhee, G. R., Jr., 1991, Extinction and diversification in the Devonian brachiopoda of New York State: No correlation with sea level?: Historical Biology, v. 5, p. 215–227.

Mora, C. I., Driese, S. G., and Seager, P. G., 1991, Carbon dioxide in the Paleozoic atmosphere: Evidence from carbon-isotope compositions of pedogenic carbonate: Geology, v. 19, p. 1017–1020.

Mosbrugger, V., 1990, The tree habit in land plants: Berlin, Springer, Lecture Notes in Earth Sciences 28, 161 p.

Playford, P. E., McLaren, D. J., Orth, C. J., Gilmore, J. S., and Goodfellow, W. T., 1984, Iridium anomaly in the Upper Devonian of the Canning Basin, Western Australia: Science, v. 226, p. 437–439.

Retallack, G. J., 1986, The fossil record of soils, *in* Wright, V. P., ed., Paleosols: Their recognition and interpretation: Princeton, New Jersey, Princeton University Press, p. 1–57.

Rothwell, G. W., Scheckler, S. E., and Gillespie, W. H., 1989, *Elkinsia* gen. nov., a Late Devonian gymnosperm with cupulate ovules: Botanical Gazette, v. 150, p. 170–189.

Scheckler, S. E., 1986, Geology, floristics and paleoecology of Late Devonian coal swamps from Appalachian Laurentia: Société Géologique de Belgique, Annales, v. 109, p. 209–222.

Schopf, J. M., and Schwietering, J. F., 1970, The *Foerstia* zone of the Ohio and Chattanooga Shales: U.S. Geological Survey Professional Paper 1294-H, 15 p.

Sepkoski, J. J., 1986, Phanerozoic overview of mass extinctions, *in* Raup, D. M., and Jablonski, D., eds., Patterns and processes in the history of life: Berlin, Springer, p. 277–295.

Singer, M. J., and Munns, D. N., 1991, Soils: An introduction (second edition): New York, Macmillan, 473 p.

Stallard, R. F., 1985, River chemistry, geology, geomorphology, and soils in the Amazon and Orinoco basins, *in* Drever, J. I., ed., The chemistry of weathering: Dordrecht, Netherlands, Reidel, p. 293–316.

Streel, M., 1986, Miospore contribution to the upper Famennian–Strunian event stratigraphy: Société Géologique de Belgique, Annales, v. 109, p. 75–92.

Talent, J. A., Mawson, R., Andrew, A. S., Hamilton, P. J., and Whitford, D. J., 1993, Middle Paleozoic extinction events: Faunal and isotopic data: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 104, p. 139–152.

Wang, K., 1992, Glassy microspherules (microtektites) from an Upper Devonian limestone: Science, v. 256, p. 1547–1550.

Wang, K., Attrep, M., Jr., and Orth, C. J., 1993, Global iridium anomaly, mass extinction, and redox changes at the Devonian-Carboniferous boundary: Geology, v. 21, p. 1071–1074.

Weaver, C. E., 1967, Potassium, illite and the ocean: Geochimica et Cosmochimica Acta, v. 31, p. 2181–2196.

Ziegler, W., and Sandberg, C. A., 1990, The Late Devonian standard conodont zonation: Courier Forschungsinstitut Senckenberg, v. 121, 115 p.

Manuscript received July 21, 1994; revision received September 6, 1994; accepted September 6, 1994 ■

GSA ANNUAL MEETINGS

■ 1995

New Orleans, Louisiana
November 6–9
Ernest N. Morial Convention Center,
Hyatt Regency New Orleans

NEW ORLEANS — BRIDGING THE GULF

General Chair: *William R. Craig, University of New Orleans*
Technical Program Chair: *Laura Serpa, University of New Orleans*
Field Trip Chair: *Whitney Autin, Louisiana State University*
See November 1994 *GSA Today* for a complete list of field trips.

CALL FOR PAPERS—APRIL *GSA TODAY*
Themes, Symposia, Field Trips, and Continuing Education Courses

■ 1996

Denver, Colorado • October 28–31
Colorado Convention Center, Marriott City Center

General Chairs: *Kenneth E. Kolm and Gregory S. Holden, Colorado School of Mines*
Technical Program Chair: *John D. Humphrey, Colorado School of Mines*
Call for Field Trip Proposals: *Please contact the Field Trip Chairs listed below.*
Charles L. Pillmore, Ren A. Thompson
U.S. Geological Survey, MS 913, P.O. Box 25046
Denver Federal Center, Denver, CO 80225
phones: Charles L. Pillmore, (303) 236-1240; Ren A. Thompson (303) 236-0929

For general information on any meeting call the GSA Meetings Department, 1-800-472-1988 or (303) 447-2020, ext. 141; E-mail: mball@geosociety.org

GSA SECTION MEETINGS

NORTHEASTERN SECTION

Radisson Hotel and Conference Center in Cromwell, Hartford, Connecticut, March 20–22, 1995. Information: Gregory McHone, Graduate Liberal Studies Program, Wesleyan University, 255 High St., Middletown, CT 06457, (203) 344-7930, fax 203-344-7957.

SOUTHEASTERN SECTION

Knoxville Hilton Hotel, Knoxville, Tennessee, April 6–7, 1995. Information: Robert D. Hatcher, Jr., Dept. of Geological Sciences, University of Tennessee, Knoxville, TN 37996-1410, (615) 974-2368, fax 615-974-2368, E-mail: bobmap@utkvx.utk.edu.

NORTH-CENTRAL and SOUTH-CENTRAL SECTIONS

University of Nebraska, Lincoln, Nebraska, April 27–28, 1995. Information: Robert F. Diffendal, Jr., 113 Nebraska Hall, University of Nebraska–Lincoln, Lincoln, NE 68588-0517, (402) 472-2410, fax 402-472-2410, E-mail: rfd@unlinfo.unl.edu.

ROCKY MOUNTAIN SECTION

Montana State University, Bozeman, Montana, May 18–19, 1995. Information: Stephan G. Custer, Department of Earth Sciences, Montana State University, Bozeman, MT 59717-0348, (406) 994-6906, fax 406-994-6923, E-mail: uessc@msu.oscs.montana.edu.

CORDILLERAN SECTION

University of Alaska, Fairbanks, Alaska, May 24–26, 1995. Information: David B. Stone, Geophysical Institute, University of Alaska, Fairbanks, AK 99775-0800, (907) 474-7622, fax 907-474-7290, E-mail: ffdbs@aurora.alaska.edu.

Student Travel Grants

The GSA Foundation will award matching grants up to a total of $3500 each to the six GSA Sections. The money, when combined with equal funds from the Sections, will be used to assist GSA Student Associates traveling to the 1995 GSA Annual Meeting in New Orleans in November and to the 1995 Section meetings. Contact your Section Secretary for application procedures.

Cordilleran	Bruce A. Blackerby	(209) 278-2955
Rocky Mountain	Kenneth E. Kolm	(303) 273-3932
North-Central	George R. Hallberg	(319) 335-4500
South-Central	Rena M. Bonem	(817) 755-2361
Northeastern	Kenneth N. Weaver	(410) 554-5532
Southeastern	Harold H. Stowell	(205) 348-5098

Each month, *GSA Today* features a short science article on fast-breaking items or current topics of general interest to the 17,000 members of GSA. What do you think of these articles? Do you have an idea for an article that you would like to see published in *GSA Today*? If so, please contact Eldridge Moores, Science Editor, *GSA Today*, (916) 752-0352, fax 916-752-0951.

CLASSIFIED ADVERTISING

Published on the 1st of the month of issue. Ads (or cancellations) must reach the GSA Advertising office one month prior. Contact Advertising Department (303) 447-2020, 1-800-472-1988, fax 303-447-1133, or E-mail:acrawfor@geosociety.org. Please include complete address, phone number, and E-mail address with all correspondence.

Classification	Per Line for 1st month	Per line for each addt'l month (same ad)
Situations Wanted	$1.75	$1.40
Positions Open	$6.50	$5.50
Consultants	$6.50	$5.50
Services & Supplies	$6.50	$5.50
Opportunities for Students		
first 25 lines	$0.00	$2.35
additional lines	$1.35	$2.35
Code number: $2.75 extra		

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

To answer coded ads, use this address: Code # ----, GSA Advertising Dept., P.O. Box 9140, Boulder, CO 80301-9140. All coded mail will be forwarded within 24 hours of arrival at *GSA Today* office.

Situations Wanted

AVAILABLE: Environmental Geologist, proficient in Japanese. Contact T. Massimino (810) 739-3083.

Positions Open

ENVIRONMENTAL GEOSCIENTIST/HYDROGEOLOGIST OREGON STATE UNIVERSITY

The Geosciences Department at Oregon State University seeks to fill a tenure-track position at the assistant professor level starting in September 1995, in groundwater geology, low-temperature aqueous geochemistry, geologic hazards, paleoclimatology, or engineering geology\. A Ph.D. is required. Successful applicants will be expected to develop a vigorous, externally funded research program, to supervise and teach undergraduate geoscience courses and graduate level courses in their specialization, and to direct the research of M.S. and Ph.D. candidates. The Geosciences Department has strengths in petrology, geologic structure, sedimentary geology, surficial processes, physical and resource geography, and spatial analysis. The department has 20 faculty, 90 graduate students, and 170 undergraduate majors. The candidate is expected to play a central role in developing an interdisciplinary program in earth and environmental geosciences. Collaborative research opportunities exist with other local programs in the Colleges of Forestry, Engineering, Agricultural Sciences, and Oceanic and Atmospheric Sciences, the Water Resources Research Institute, the Center for Analysis of Environmental Change, and the US EPA Environmental Research Laboratory-Corvallis. Oregon State University is a Land Grant, Sea Grant, Space Grant, and Carnegie Class I Research University.

Those interested in applying for the position should send a letter of interest, curriculum vitae, names of three references, and a statement of anticipated research and teaching interests, along with evidence of teaching effectiveness and scholarly activity to Alan Niem, Chair, Geosciences Search Committee, Department of Geosciences, Oregon State University, Wilkinson Hall 104, Corvallis, OR 97331-5506; Telephone (503) 737-1233; FAX 503 737-1200, E-mail: niema@bcc.orst.edu. Candidates will be notified before letters will be review began February 1, 1995, and will continue until the position is filled.

Oregon State University is an affirmative action/equal opportunity employer. OSU has a policy of being responsive to the needs of dual-career couples.

THE UNIVERSITY OF AKRON PALEONTOLOGIST / OPEN SPECIALIZATION

The Department of Geology seeks a tenure-track faculty member who is well-qualified to teach invertebrate paleontology/paleoecology. Candidates should possess a Ph.D. in geology and have interdisciplinary research interests in global climate change, environmental geology, and/or contemporary geological problems. Appointment will be at the assistant professor rank, starting August 1995, and is contingent on funding. Teaching responsibilities include courses in invertebrate paleontology, environmental geology for non-science majors, and an advanced course in their area of specilization. In addition to excellence in teaching, faculty are expected to develop strong research programs supported by external funding and to guide M.S. students.

The University of Akron has an enrollment of 28,000 students. The Department of Geology has nine faculty members and offers degrees in geology, geophysics, engfineering geology, environmental geology, and earth science to about 80 undergraduate majors and 30 graduate students. The department is well-equipped for both field and laboratory research and instruction.

Applicants should send a vita; a description of research interests; and names, addresses, and telephone numbers of three references to: Faculty Search Committee, Department of Geology, University of Akron, Akron, OH 44325-4101. Applications are currently being accepted and will be until the position is filled. The University of Akron is an affirmative action/equal opportunity employer.

EMPORIA STATE UNIVERSITY

The Earth Science Department invites applications for a nine-month, tenure-track, Assistant Professor position in earth-system science starting August 1995. The department offers baccalaureate and master's degrees, as well as teacher certification. The successful candidate will teach introductory earth science (geology, meteorology, astronomy), advanced courses in areas of expertise, supervise undergraduate and graduate student research, and be committed to interdisciplinary research in earth and/or atmospheric sciences with an emphasis on modern and/or ancient climates. Techniques of geographic information systems for teaching and research desirable. Excellence in teaching and research required along with an appropriate Ph.D.

The application should be sent to Prof. James Aber, Earth Science Search Chair, Campus Box 4030, Emporia State University, Emporia, KS 66801-5087 and should include a letter addressing teaching and research experiences, interests, and goals; transcripts; and a current resume with relevant supporting materials. The applicant should arrange for three letters of reference to be sent under separate cover. Screening will begin March 17, 1995, and continue until position is filled. Telephone (316) 341-5981, FAX 316-341-5997, E-mail: aberjame@esuvm1.emporia.edu.

ESU is an Affirmative Action/Equal Opportunity Employer and encourages applications from members of protected classes.

ARCHAEOLOGICAL GEOLOGIST

Desert Archaeology, Inc. seeks an archaeological geologist to conduct petrologic analysis of ceramic tempering materials. The position has the potential for considerable expansion and advancement. Minimum B.S. degree in Geosciences; experience in petrology; other geological experience and some background in archaeological studies desirable. Please send a curriculum vita, names of three references, and any supporting documents to Henry D. Wallace, Research Director, Desert Archaeology, Inc., 3975 N. Tucson Blvd., Tucson, AZ 85716. E-mail: hwallace@desert.com. Fax: 602-881-0325.

STAFF GEMOLOGIST

The GIA Gem Trade Laboratory has immediate openings in its east and west coast identification laboratories. Outstanding career opportunity for candidates with the right combination of academic background and gemological training. Excellent benefits and working conditions. BA or MA in Geology or Mineralogy and GG or FGA required. Send resume, earnings history and salary requirements to Personnel, P.O. Box 2110, Santa Monica, CA 90406.

Services & Supplies

CBLS*BOOKS*CBLS*BOOKS*CBLS*BOOKS*CBLS*
CBLS is a bookseller. You may order all your Geoscience books from us. * One Source * Prompt Service * Volume discounts. We also publish new books or reprint OOP books on demand. We have reprints of classical books as Azaroff "Elem. of X-Ray Crystallog." & "Electronic Processes in Mat'ls," Barker "Igneous Rocks," Bolt "Inside the Earth," Costa "Surficial Geol.," DeHoff "Quantita. Micros.," Edington "Pract. Elect. Micro. in Mat'ls Sci.," Grimshaw "Chem. & Phys. of Clays," Guy "Intro to Mat'ls," McKee "Cascadia," Megaw "Crys. Structures," Peters "Geol. in Coal Resource Utilization," Robinson "Basic Phys. Geol.," Sawkins "The Evolving Earth: A Text in Phys. Geol.," Stoddard "Field Tech. & Res. Meth. Geog.," Thomas "Transm. Elect. Mrcros.," etc. Call order at tel. 614-374-9458 or tel 703-758-1518 or fax at 703-352-8862; or write to CBLS, 119 Brentwood St., Marietta, OH 45750 USA.
CBLS*BOOKS*CBLS*BOOKS*CBLS*BOOKS*CBLS*

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

WANTED: Strain-free, D Plan or DAch, 100x, oil-immersion, objective or other accessory lens for Olympus BH-2. Reply to RFG, 4603 Hoskens Rd., North Vancouver, B.C., CANADA V7K 2R2.

Opportunities for Students

Research Assistantships in Geophysics: University of Texas El Paso. We anticipate up to 3 research Assistantships at the M.S. or Ph.D. levels will be available at the University of Texas at El Paso (UTEP) starting in summer of 1995. Areas of research include: 1) participation in a seismic refraction/ reflection study of the crustal structure of western Washington state slated for fall 1995; 2) development of a lithospheric model and geophysical database for northern Africa; and 3) participation in a seismic refraction/reflection study lithospheric structure in the Rocky Mountains in August 1995. For additional information, contact Dr. Diane I. Doser, Dept. of Geol. Sci., Univ. Texas-El Paso, El Paso, TX 79968-0555; (915) 747-5851; doser@geo.utep.edu. UTEP is an AA/EEO employer.

Graduate Fellowships in Geology at the University of Texas at El Paso. The Department of Geological Sciences at the University of Texas at El Paso anticipates funding for graduate fellowships at the doctoral level for women and minorities. The fellowship will pay up to $14,400 per year. Also included is the cost of tuition, books, fees, health insurance, and professional travel. Funding is assured for a five year period. The Department is fourteen faculty and fifty-five graduate students. We have strengths in environmental studies, geophysics, sedimentology, paleontology, igneous geology, and economic geology. El Paso is a vibrant border city in a superb geologic setting. Possible areas of research include Mexico and the southwestern and western United States. Information concerning the department is available with the command gopher geo.utep.edu. Interested individuals are encouraged to contact Dr. Elizabeth Anthony, Graduate Advisor, at the Department of Geological Sciences, University of Texas at El Paso, El Paso, TX 79968. The telephone number is 915-747-5483; e-mail, anthony@geo.utep.edu. Applicants must be U.S. citizens.

Traveling Fellowship: Interdisciplinary Research Training Group (RTG) in ecology, geology, archeology, geography, and soils. Graduate students are invited to Minnesota for up to 3 months to enhance training in "Paleorecords of Global Change." Stipend (provided for citizens, nationals or permanent residents of the U.S.), travel and living allowance, and tuition. Application deadline April 1 (for travel July 1 - December 31) and October 1 (for travel January 1 - June 30). For application contact RTG, University of Minnesota, Ecology, Evolution and Behavior, 1987 Upper Buford Circle, St. Paul, MN 55108. Phone (612) 624-4238; FAX 612/624-6777. An Equal Opportunity Educator and Employer.

California Institute of Technology. Postdoctoral Fellowships in Earth and Planetary Sciences. The California Institute of Technology announces two fellowships in Earth and Planetary Sciences: The O.K. Earl Postdoctoral Fellowship, and The Texaco Postdoctoral Fellowship.

These awards are from funds endowed by Orrin K. Earl, Jr., and by the Texaco Philanthropic Foundation. Each fellowship carries an annual stipend of $34,000 and offers a research expense fund of $1,000 per year and one-way travel to Pasadena. The duration of each appointment will normally be for two years, contingent upon good progress in the first year, and beginning with the 1995-96 academic year. Fellows are eligible to participate in Caltech's health and dental program.

These fellowships have been established to support the research of scientists, typically within two years after receipt of the Ph.D. The intent of the program is to identify and support innovative and creative work in the earth and planetary sciences, with particular emphasis on interdisciplinary work. Applicants with training in physics, chemistry, biology or computer sciences are urged to apply. The Caltech faculty is currently active in Geobiology, Geochemistry, Geology, Geophysics, Petrology, Seismology, and Atmospheric Sciences. It is expected that each fellowship holder will be hosted by a Division professor (designated by the Division Chairman) who will contribute to the fellowship support both financially and by providing intellectual guidance.

Application forms may be obtained by writing to Prof. E. M. Stolper, Chairman, Division of Geological and Planetary Sciences, Mail Code 170-25, California Institute of Technology, Pasadena, CA 91125 (e-mail: stover@arms.gps.caltech.edu).

Completed applications with references should arrive at Caltech by Friday, March 17, 1995.

Fellowship candidates will automatically be considered for other available postdoctoral positions at Caltech in their fields of interest.

Caltech is an Affirmative Action/Equal Opportunity Employer. Women, minorities, veterans and disabled persons are encouraged to apply.

Graduate Assistantships, Texas Christian University. The Geology Department and the Center for Remote Sensing and Energy Research has assistantships available for M.S. students. Areas of department expertise include hydrogeology, groundwater modeling and remediation, remote sensing, environmental geology and geochemistry, carbonate and clastic sedimentology, paleovolcanology, structure and tectonics, Precambrian geology, paleontology, and computer applications in geology. Field research is carried out in Scotland, the Sierra Nevada in California, and Africa, as well as in Texas and Oklahoma. Department facilities include analytical equipment for environmental analysis and a state-of-the-art remote-sensing lab with computer work stations and image processing/GIS software. Financial aid includes a yearly stipend of $7,000, full tuition waiver, and up to $1,500 for research expenses. Contact the Graduate Advisor, Department of Geology, Texas Christian University, Fort Worth, TX 76129 (817) 921-7270.

CALL FOR APPLICATIONS AND NOMINATIONS FOR

GEOLOGY CO-EDITOR

GSA solicits applications and nominations for the position of co-editor of *Geology*, to serve a three-year term, beginning in January 1996, as one of a two-editor team. Desirable characteristics for the successful candidate include:

1. Broad interest and experience in geology; international recognition
2. Iconoclastic; willing to take risks and try innovations
3. Familiar with many earth scientists and their work
4. Sense of perspective and humor
5. Organized and productive
6. Willing to work closely with GSA headquarters staff
7. Able to make decisions
8. Sense of fairness
9. Familiar with new trends in geoscience
10. Willing to consider nontraditional research in geosciences

This is not a salaried position, but GSA pays the expenses for secretarial assistance, mail, telephone, and travel to GSA headquarters.

If you wish to be considered, please submit a résumé and a brief letter describing why you should be chosen. If you wish to nominate another, submit a letter of nomination and the individual's written permission and résumé. Send nominations and applications to Donald M. Davidson, Jr., Executive Director, Geological Society of America, P.O. Box 9140, Boulder, CO 80301, by April 14, 1995.

THE GEOLOGICAL SOCIETY OF AMERICA

GSA OFFERS YOU MORE JOURNAL CHOICES IN '95

INCLUDING APPLIED SCIENCES

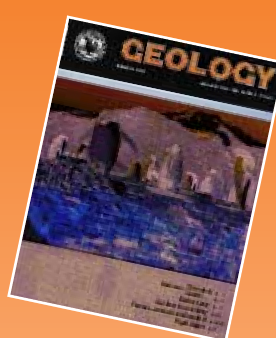
MONTHLY

RESEARCH

GSA Bulletin
Published continuously since 1890. An authoritative science journal of general geology, publishing 8 to 12 refereed, scholarly articles each month in the classical research-paper style. Covers a wide range of disciplines in terrestrial, extraterrestrial, and marine geology. The Discussion and Reply section lets authors interact and carry on a productive dialogue. About 1700 pages annually. Profusely illustrated, including some color and occasional large inserts.

MONTHLY

TOPICAL & CONCISE

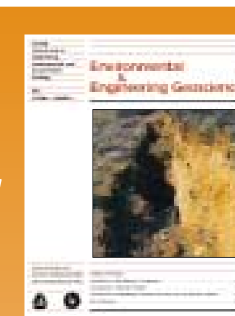


Geology
Undoubtedly the most popular and widely read general geological journal in print, each month bringing you 20 or more refereed articles that are concise (4-page maximum), current, and thought provoking, covering a wide range of geological subjects, including new investigations. The *Geology* Forum provides an arena for stimulating reader comments and responses on the articles. About 1150 pages annually. Profusely illustrated, includes color and occasional large inserts. The full-color covers are exceptional geological studies in themselves.

QUARTERLY

APPLIED SCIENCES

Hydrogeology Journal Formerly *Applied Hydrogeology.* Quarterly journal of the International Association of Hydrogeologists (IAH)*, available to GSA members at the IAH-member price. Features peer-reviewed papers in theoretical and applied hydrogeology. Published in English, with abstracts also in French and Spanish. Describes worldwide progress in the science and provides an affordable and widely accessible forum for scientists, researchers, engineers, and practitioners. Papers integrate subsurface hydrology and geology with supporting disciplines.



Environmental & Engineering Geoscience A joint, quarterly publication of the Association of Engineering Geologists (AEG)* and the Geological Society of America (GSA). Includes refereed articles on applied topics in the environmental and hydrological geosciences, and special features like the Geology of Cities series; technical notes on current topics; a comment and reply forum; memorials to geologists of note; book reviews; and biographies on well-known geologists in the applied fields. It will feature new theory, applications, and case histories illustrating the dynamics of the fast-growing, environmental and applied disciplines. Co-edited by AEG and GSA.

*MEMBERS OF IAH AND AEG RECEIVE THE RESPECTIVE JOURNALS AS PART OF THEIR DUES AND SHOULD NOT ORDER FROM GSA.

GSA Members: if you have not yet renewed your subscriptions for 1995 call Membership Services at 1-800-472-1988 or E-mail member@geosociety.org. Nonmembers contact our Subscriptions Department at the address and phone below or E-mail pubs@geosociety.org.

The Geological Society of America
3300 Penrose Place • P.O. Box 9140 • Boulder, Colorado 80301
800-472-1988 • 303-447-2020 • fax 303-447-1133

NEW ORLEANS
BRIDGING THE GULF

Call for Papers and First Announcement
for the

1995 GSA Annual Meeting

NOVEMBER 6–9

NEW ORLEANS, LOUISIANA

ERNEST N. MORIAL CENTER

See the April issue of *GSA Today*
for information from the Meetings Dept.:
(303) 447-2020 (ext. 141)
1-800-472-1988 (ext. 141)
fax 303-447-0648
E-mail: mball@geosociety.org

GSA JOURNALS ON COMPACT DISC

A CD-ROM publication of the Geological Society of America. Published since 1992, each annual disc contains an entire year of articles from *GSA Bulletin*, *Geology*, and *GSA Today*, plus the current year's *GSA Data Repository*, and a *Retrospective Electronic Index* to GSA's journal articles published since 1972.

Users can search the full ASCII text of all articles, or view, print, or export from them. Scanned, graphical page-images of all articles are also included, linked to the ASCII text; users can view or print these. High-resolution versions of all b&w and color photographs are provided, linked to the ASCII text, to overcome the low quality of these photos on the scanned pages. Starting in 1995, publication frequency changes to twice annually, and new technology greatly improves the photos on the scanned pages. The Data Repository, and any inserts, are available only as scanned images without ASCII text.

GSA Journals on CD is available for both DOS and Macintosh as follows:

- JCD001. 2-year, 2-CD introductory package (1992 & 1993), 6,000+ pgs. Available immediately. Net price: GSA Members $99, all others $125.
- JCD004. 1-year, 1-CD (1994), 3,000+ pgs. Available February, 1995. Net price: GSA Members $99, all others $125.
- JCD005. 1-year, 2-CDs (1995), 3,000+ pgs. First six-month-CD available July 1995; complete annual CD available February 1996. Net price: GSA Members $89, all others $125. This edition available in Windows version, also.

UNSURE? *A free demonstration diskette is available for DOS-based PCs showing in detail the operation of the CD — screens, menus, graphics, with many descriptive comments. Call or write for a copy.*

1-800-472-1988

303-447-2020; fax 303-447-1133

Indicate DOS or Macintosh platform when ordering.

JOIN THE DIGITAL REVOLUTION WITH GSA!

ISSN 1052-5173

The Geological Society of America
3300 Penrose Place
P.O. Box 9140
Boulder, CO 80301

SECOND CLASS
Postage Paid
at Boulder, Colorado
and at additional mailing offices