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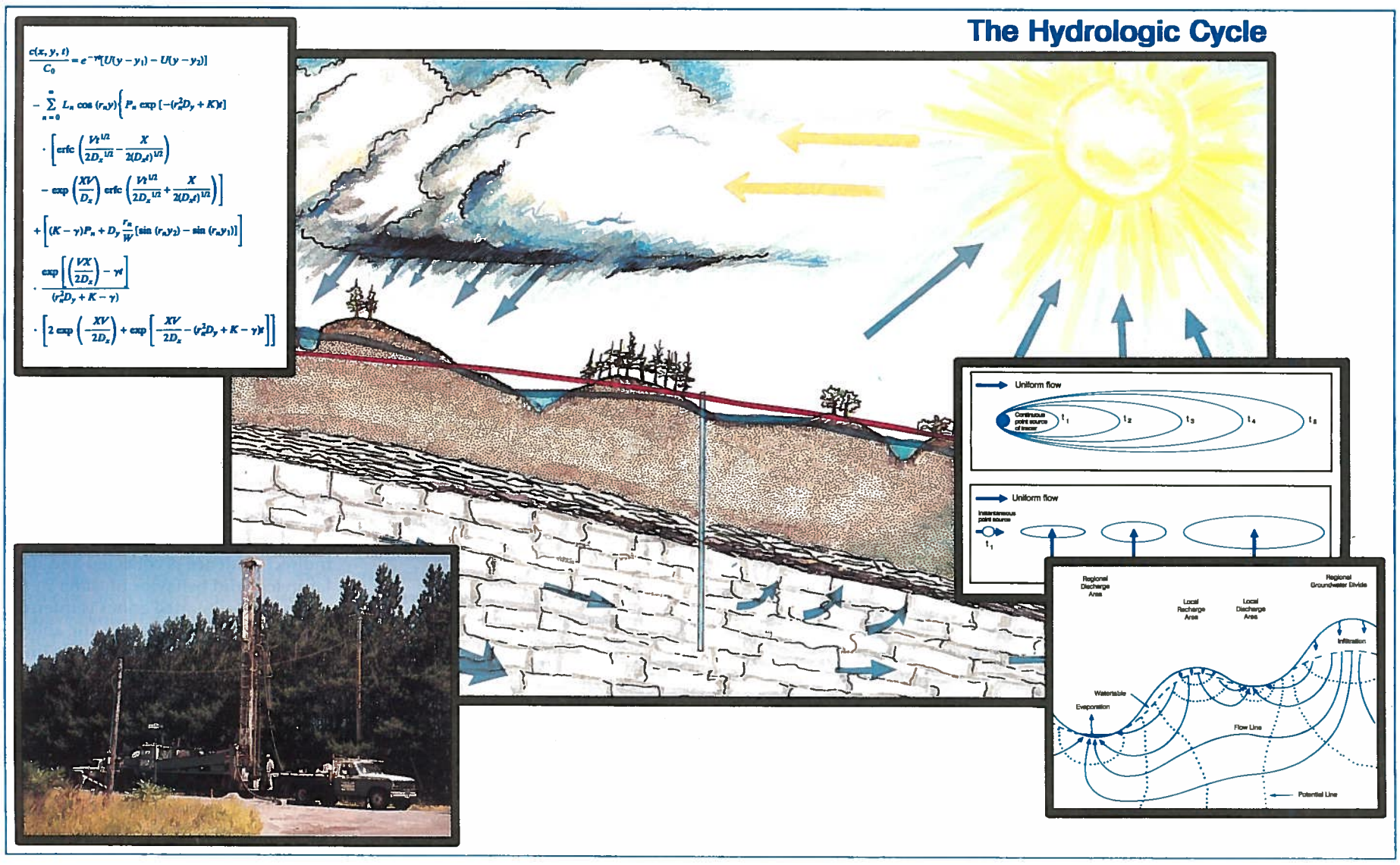
INSIDE



Hydrogeology: It Is

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ABSTRACT

The geoscience discipline of hydrogeology is experiencing vigorous growth and visibility, but also an unresolved tolerance within the geoscience community. The study of fluids within geologic materials and water as a geologic agent is as fundamental to geology as is study of mineralogy and petrology. Moreover, hydrogeology is also highly interdisciplinary, having interplay with other scientific, institutional, and engineering disciplines. Significant increased research is anticipated in both small-scale and regional-scale problem areas—all oriented to the behavior of fluids in geologic environments. Perhaps the single most pressing concern in hydrogeologic circles is the imbalance between supply and demand—the paucity of bona fide hydrogeology candidates for employment at virtually all levels. Those employers facing staff shortages are turning to persons who have little or no actual hydrogeological education or training.

INTRODUCTION

The discipline of hydrogeology has been declaimed, criticized, and sometimes dismissed within the geoscience community as too useful, too applied. Maybe this is so, in classical terms. But the fact remains: Hydrogeology is an interdisciplinary science within the geosciences. Concepts and terminology from nongeoscience disciplines incorporated into hydrogeology are perhaps more numerous than for the other geosciences. However, as Alvarez (1991) has noted, "There seems to be a close association between interdisciplinary science and revolutionary developments in geology...." The purpose of this article is to present the role of hydrogeology within the geosciences and to discuss the phenomenal growth in hydrogeology, current and future directions for the science, and several issues relating to supply and demand.

Hydrogeology is currently the fastest growing discipline within the geosciences. This growth is not a coincidence. It is a reflection of public, governmental, and industrial awareness of the value and fragility of water resources and the response of the geoscience community to that awareness. Few could quarrel with the highly visible employment of hydrogeologists in recent years. Claudy (1991a) has pointed out that the consulting industry will continue to be the fastest growing employment sector for geoscientists over the next several years; within that sector, hydrogeologists are in the greatest demand. Claudy (1991b) also noted that "related professional scientists" are increasingly in high demand.

In tandem with the market demand for hydrogeologists has been an ever-increasing impetus for research in hydrogeology. Over the past 10 years, research has been explosive because of the recognition of widespread groundwater contamination (see, for example, Moore and Rosenshein, 1990; Rosenshein et al., 1991). Thus, considerable research in the past decade has been concerned with processes that control groundwater flow and mass transport of chemicals in ground-water flow systems.

In spite of the employment demands for hydrogeologists and society's needs for hydrogeology, what is surprising is the volume of argument in geoscience circles as to the probable longevity of this discipline. In the past and to some extent continuing today, many in the academic community have argued about the appropriateness of hydrogeology being taught in a geoscience department (vs. an engineering department). Most geologists historically have been the interpreters of Earth history—a view that remains entrenched today. Geology periodically has seen a succession of applied areas, including ore deposits, petroleum geology, hydrogeology, and "global change." The experience for the traditional geologist includes envy (usually short term) to see so many dollars for research and possibilities for student employment pass them by, disappointment to see many opportunities for outstanding basic research lost in the stampede to solve industrial problems, and vast retrenchments in schools and programs once the bubble bursts (as

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it has in ore deposits and petroleum). Will it be any different with hydrogeology? If hydrogeology's fate is the same as that of ore deposits and petroleum, then the traditionalists' view of these applied fields will have been correct.

Time will tell. However, popularity and current trends aside, hydrogeology is a quantitative science with a significant and purposeful development from theory to practice. At the heart of hydrogeology is the need to understand the geologic framework through which fluids move as the critical control for interpreting water quality or quantity. Consider this statement about geologic aspects of water resource issues: "Few geologists find themselves able to pursue the subject of [ground water] into its practical details because of the multitude of more obtrusive issues pressed upon their attention." Modern-day statement? Not so. Those words were written by T. C. Chamberlin in 1884, just before he assumed the presidency of the Wisconsin Academy of Sciences, Arts, and Letters (Stephenson, 1978). One could argue that not much has changed in the past 100 years.

Hydrogeology Defined

There is considerable confusion about differences between such terms as "geohydrology" and "hydrogeology." Many recent authors support a concept that geohydrologists are more engineering oriented in that they deal with aquifer mechanics. Hydrogeologists deal with a broader array of topics, including, but not limited to, ground-water flow-system analysis. Domenico and Schwartz (1990) took an interesting approach to defining hydrogeology: they delayed a definition until they first developed an understanding of what hydrogeology is today and how it got that way, and who were some of the significant contributors to the field. Because we do not have the space to follow their lead to the fullest, we will skip ahead and offer a definition of hydrogeology: the interdisciplinary science of the study of water and its interrelation with rocks, soil, and humans, with an emphasis on ground water. We supplement this definition with discussions from several other sources:

Domenico and Schwartz, 1990: "... the study of the laws governing the movement of subterranean water, the mechanical, chemical, and thermal interaction of this water with the porous solid, and the transport of energy and chemical constituents by the flow."

Fetter, 1988: "... the interrelationship of geologic materials and processes with water."

Meyer et al., 1988: "... an interdisciplinary science that is dependent upon many branches of the physical, chemical, and biological sciences. It is an offspring of geology and hydrology...."

AGI *Glossary of Geology* (Bates and Jackson), 1987: "The science that deals with subsurface waters and with related geologic aspects of surface waters."

Narasimhan, 1982: "... the discipline concerned with those geologic processes that are influenced by water."

Two recent hydrogeological publications offer no succinct definition of hydrogeology but stress concepts of occurrence and movement of ground water as a resource: Freeze and Cherry (1979) and Back et al. (1988). These references are both substantial contributions directed toward hydrogeologists or those who aspire to become hydrogeologists.

The common thread in all the definitions above is that hydrogeology requires an understanding of geology.

HYDROGEOLOGY TODAY

Hydrogeologists work for federal and state research groups, agencies, or surveys, for hundreds of private environmental and engineering consulting companies, in environmental groups for major industries and special interest groups, and as teachers and researchers in colleges, universities, and national laboratories. The actual number of scientists working in the field of hydrogeology is difficult to ascertain for two reasons: (1) all hydrogeologists do not belong to a single professional organization and (2) because of the interdisciplinary nature of hydrogeology, it is difficult to separate the traditional geologically trained professionals from those associated with other related disciplines. We surveyed the membership of four professional organizations serving hydrogeologists and obtained employment statistics in an attempt to approximate the number of hydrogeologists (Table 1). The Association of Ground Water Scientists and Engineers (AGWSE), the largest organization that specifically seeks members who study ground water, states that between 15,000 and 20,000 professionals are currently working in hydrogeology or related fields.

TABLE 1. Membership in Organizations Specializing in Hydrology and Hydrogeology, 1989–1990

Organization	Membership
Association of Ground Water Scientists and Engineers	16,300
American Geophysical Union, Hydrology Division	4748
American Water Resources Association	2934
Geological Society of America, Hydrogeology Division	1871
U.S. Government Hydrologist Rating (1987 data)	2298
American Institute of Hydrology	1000

Of the more than 15,000 members of GSA, 1871 are in the Hydrogeology Division, which is the second largest of GSA's divisions (Table 2).

TABLE 2. Membership of the Largest Six Divisions of GSA, 1990

Division	Membership
Structural	2140
Hydrogeology	1871
Quaternary	1437
Engineering	1175
Sedimentary	1043
Geophysics	590

Note: Data from T. M. Moreland, GSA Membership Services (February 1991, personal commun.)

In the hydrogeological community two major kinds of hydrogeologists can be broadly identified: practicing and research-oriented. The research group includes those professionals who are exploring the role of ground water as a geologic agent. They are looking at such issues as single- and multi-component flow and the interrelated processes of mass and energy transport. There is exciting work to establish the relation between ground water and many of the classical problems of geology, including petroleum migration, ore genesis, and contaminant plume behavior in rocks or soils with low hydraulic conductivity and, frequently, secondary porosity. Many studies are concerned with a mathematical description of flow and transport phenomena.

The practitioners are applying a rapidly increasing technology and scientific understanding to contemporary problems. The dominant problems of the day concern water quality, closely followed by water supply. Current highly visible efforts are being made in: contaminant hydrogeology; conflicts and competition for supply between agriculture, municipalities, industry, and recreation; aquifer mechanics and ground-water–surface-water interaction; and consequences of mining ground water (e.g., land-surface subsidence and salt-water encroachment).

One recent activity bears mention. Hydrogeologists need either to be versed in geochemistry or to team with geochemists and other professionals to characterize the hydrogeologic system (including the mechanics and chemistry of the transport of solutes and contaminants in earth material) and to describe and quantify methods to represent saturated and unsaturated water flow (see, for example, Krabbenhoft et al., 1990a, 1990b). The focus in hydrogeology has shifted from ground-water flow analysis to chemical transport (Konikow and Papadopulos, 1988).

The Practice of Hydrogeology

Hydrogeologists attempt to characterize the occurrence, movement, quantity, and quality of water below the land surface. This task is mainly one of inference and interpretation: indirect evidence is collected and interpreted, and behavior of water in the vadose and saturated zones is inferred. Over the past several years, the ability to characterize these systems has improved dramatically, and the need to predict flow and contaminant migration has increased.

Today, hydrogeologists can describe and quantify regional groundwater systems. However, as we narrow our focus to parts or subsystems of larger systems, the geologic framework becomes more complex, demanding additional analysis. Because hydrogeologists do not always have the advantage of detailed three-dimensional views of these systems, they rely on geologic training and principals of physics, mathematics, and chemistry to diagnose the system and predict cause-and-effect relations. Hydrogeologic studies more frequently should include the team work of one or more specialists including mathematicians, statisticians, geochemists who work with inorganic and organic material, scientists who study soils and vadose-zone flow and transport, and microbiologists, in addition to the hydrogeologist.

An interesting aspect of hydrogeology is its close involvement with institutional issues. Representatives of both the practicing and research-oriented groups sit on advisory panels—at state, province, and national levels—to contribute to resolution of legal, economic, and institutional issues.

Today's practicing hydrogeologist is deeply involved with analysis, site characterization, and remediation of ground-water contamination resulting from spills of volatile organic chemical constituents and petroleum hydrocarbons. Contaminant-transport modeling has joined ground-water flow modeling as an essential tool in the kit required by hydrogeologists. Hydrogeologists are increasingly caught between major advances in the science and pressures from regulatory agencies to provide answers (Schwartz et al., 1990).

Research hydrogeologists are focusing on unraveling the behavior of fluids in porous media and are delving into such issues as the evaluation of mass-transport processes, modeling

techniques for complex flow and transport problems, and field studies related to contaminants. Current efforts are reflected in published research; Table 3 presents a summary of journal articles published in the past two years, categorized by subject matter.

TABLE 3. Ground-Water Articles Published in Six Leading Journals, 1988–1990

Ground-water subject	Number
Solute transport, geochemistry	191
Ground-water and soil-water flow	150
Field techniques	76
Parameter identification	47
Recharge and evapotranspiration	29
Management	28
Surface water–ground-water interaction	16
Coastal ground-water systems	13
Karst systems	7

Note: Journals include *Water Resources Research, Journal of Hydrology, Ground Water Monitoring Review, American Water Resources Bulletin,* and *Geological Society of America Bulletin.*

PERSPECTIVES ON THE PAST

Domenico and Schwartz (1990, p. 5) presented an interesting statistic: over 95% of all the hydrogeologists who ever lived are still alive and still working. The important message in this is that hydrogeology is a relatively new science within the broad realm of geoscience. Although the concepts and tools used by hydrogeologists have been generated over at least 6000 years of history, most of the concepts we utilize have evolved out of research conducted during the past 50 to 60 years.

There is a plethora of articles that summarize the historical elements of and recent advances in hydrogeology—for example: Bredehoeft (1976), Anderson (1979), Maxey (1979), Bredehoeft et al. (1982), Narasimhan (1982), Back and Freeze (1983), Freeze and Back (1983), Back et al. (1988), Fetter (1988), Domenico and Schwartz (1990).

The concept of the hydrologic cycle is central to any discourse on historical perspectives. Simply stated, the hydrologic cycle is a dynamic interaction between the sun's energy and Earth's gravity. Water is the medium of concern in this interaction between opposing forces. Although the hydrologic cycle is simple and the hydrologic character is reduced to three elements—climate, geology, and topography—centuries passed before the quantitative development of the science. Water-supply wells are known from at least 6000 years ago, but until the 1600s, scientific fact resolving hydrologic concerns was not forthcoming. There were many myths, some of which persist today. Back (1981) discussed water resources and water-related mythology and their role in water-resources management and even in success of civilizations.

In the 17th century, definition of the hydrologic cycle evolved. A series of 19th century investigators or events developed concepts and support for what is now within the realm of hydrogeology. These included Darcy's law, Dupuit's equilibrium equation, A. Thiem's use of tracers, and T. C. Chamberlin's work on artesian-water systems.

The 20th century has been characterized by quantification of ground-water flow and eventually chemical and heat transport. This century can be divided into three periods of differing activity.

1900–1935. Significant contributions were made by Slichter, G. Thiem, Terzaghi, and others. In 1923, O. E. Meinzer made a very important contribution with publication of two papers on the occurrence of ground water in the United States, and an outline of ground-water hydrology. These papers were among the first state-of-the-art contributions to the discipline of hydrogeology (see Meinzer, 1923a, 1923b).

1935–1960. A major contribution by C. V. Theis in 1935 was his development of the nonequilibrium flow equation. Using the Theis approach, the transient conditions of ground-water flow around pumping wells could be described. The transient flow of ground water and well hydraulics in general were the focus of attention by such researchers as Jacob and Hantush and their students. M. King Hubbert presented a monumental paper on ground-water motion (Hubbert, 1940). Hubbert's work was among the first to discuss natural flow of ground water in large basins. Thus, between 1935 and 1940, aquifer mechanics and ground-water flow-system analysis were introduced; they still govern hydrogeological research today.

Another notable contribution, much evident by the 1950s, was the evolution of chemical hydrogeology. Researchers of this era contributing to what is now called hydrogeochemistry included Stiff, Hem, Chebotarev, Back, and Garrels.

The 1930s dust-bowl days and World War II created situations where, for the first time in North America, considerable emphasis was placed on ground water as a major supply. This demand was partly due to the need for large supplies of constant-temperature water and partly due to development in well-drilling and well-construction techniques.

1960–1991. The changes in hydrogeology have been dramatic over the past 30 years. Both physical and chemical hydrogeology subdisciplines have received exponentially increasing research contributions. Ground-water flow-system analysis was related to topographic controls by Toth (1962, 1963) and subsequently to geologic controls by Freeze and Witherspoon (1966; Freeze, 1967). Subsequent researchers have added to basin-wide flow analysis, including deep-basin analysis.

This era is also characterized by dedicated efforts on the part of a handful of educators to begin training students who today are responsible for teaching or research in hydrogeology.

Hydrogeochemical analyses have been driven in part by significant institutional factors. The 1970s and 1980s were decades in which major federal environmental laws were enacted that led to creation of "contaminant hydrogeology." These laws included: the Clean Water Act; the Safe Drinking Water Act; the Surface Mining Act; the Resource Conservation and Recovery Act (RCRA); the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); and others more recently that add, or will add, leaking storage tanks, mining wastes, and radioactive wastes to the list of concerns.

FUTURE DIRECTIONS

Much of the recent growth in hydrogeology has been related to the regulatory drive for environmental protection and cleanup. The passage and implementation of the Resource Conservation and Recovery Act (RCRA) in 1976, with its requirement for ground-water monitoring, and the advent of the Superfund program to clean up

Hydrogeology *continued on p. 99*

Committee Service Provides Way to Affect GSA

The GSA Committee on Committees wants your help. As one of his duties, Vice-President E-an Zen has appointed a group to look for talent to serve GSA as members of our committees and as our representatives to other organizations.

The Committee on Committees will meet in late August or early September and will present at least two nominations for each open position to the Council at its October 23 meeting in San Diego, California. During the meeting, individual councilors may add other names to the lists for consideration. The entire Council will then select appointees for all positions, thus completing the process of bringing new expertise into Society affairs.

The Committee on Committees for 1991 consists of the following people: Chairman Robert D. Hatcher, Jr., Department of Geological Sciences, University of Tennessee, Knoxville, TN 37996-1410, (615) 974-6565; Richard L. Armstrong, Department of Geological Sciences, University of British Columbia, Vancouver, B.C. V6T 2B4, Canada, (604) 228-6208; Sharon Mosher, Department of Geological Sciences, University of Texas, Austin, TX 78713, (512) 471-4135; A.R. (Pete) Palmer, Geological Society of America, P.O. Box 9140, Boulder, CO 80301, (303) 447-2020; H. Catherine W. Skinner, P.O. Box 894, Woodbury, CT 06798, (203) 432-3787; David B. Stewart, U.S. Geological Survey, 959 National Center, Reston, VA 22092, (703) 648-6945.

This group is broadly based, both geographically and in disciplines, but its members cannot possibly know all the GSA members who are potential candidates for serving the Society. You can help them by volunteering yourself or by suggesting names of others you think should be considered for any of the openings and submitting your nomination on the form on page 98.

In making recommendations, please give serious consideration to the special qualifications of the individual for a particular committee. To assist you in nominating GSA members for these various positions, see the following brief summaries of what each committee does and what qualifications are desirable. *Please be sure that your candidates are Members or Fellows of the Society and that they meet fully the requested qualifications.*

All nominations received at headquarters on the official one-page form will be forwarded to the committee members. **DEADLINE: JULY 15, 1991**. Information requested on this form will assist the Committee on Committees with their recommendations for the 1992 committee vacancies. Council has determined that *"unless the nomination form is complete in every respect, the nomination will not be considered. Complete backup material must be supplied by the volunteer or the nominator."* Please use one form per candidate. (Additional forms may be copied or requested from GSA headquarters.)

Listed below are the committees and the number of vacancies that will occur. Appointments will be made by the GSA Council at its meeting in San Diego in October.

Committees and Qualifications

Day Medal (2 vacancies)
Selects candidates for the Arthur L. Day Medal.

Committee members should have knowledge of those who have made "distinct contributions to geologic knowledge through the application of physics and chemistry to the solution of geologic problems."

Education (1 vacancy)
Stimulates interest in the importance and acquisition of basic knowledge in the earth sciences at all levels of education.

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

Geology & Public Policy (3 vacancies)
Translates knowledge of the earth sciences into forms most useful for public discussion and decision making.

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

Honorary Fellows (2 vacancies)
Selects candidates for Honorary Fellows, usually non–North Americans.

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

Long-Range Planning (1 vacancy)
Assesses the purpose and objectives of the Society in each of its major program areas, and reviews proposals for new policies or program initiatives. Reviews annually the basic mission, the strategic objectives, and goals of the Society with respect to changes in the science of geology.

Committee *continued on p. 98*

Attention Journal Subscribers

The March and April issues of *GSA Bulletin* and *Geology* were mailed to U.S. and Canadian addresses without packaging in an attempt to reduce our use of poly. The experiment has failed. Damage claims were unexpectedly high, and many subscribers wrote or called to ask us to return to the protective packaging.

Our primary goal is to deliver your journals in first-class condition. It is now clear that packaging is required, and we believe that functional, recyclable poly packaging is better than any other packaging medium available to us—and we have tried them all.

With the May issues, we are returning to poly packaging. If you subscribe to both journals, your May issues may or may not be combined in one package, but your June issues will be. Our thanks to all who wrote or called to keep us informed and share your feelings. —*Jim Clark, Publications Production Manager*

GSA FORUM

Bruce F. Molnia

Forum is a monthly feature of *GSA Today* in which many sides of an issue or question of interest to the geological community are explored. Each Forum presentation consists of an informative, neutral introduction to the month's topic followed by two or more opposing views concerning the Forum topic. Selection of future Forum topics and participants is the responsibility of the Forum Editor. Suggestions for future Forum topics are welcome and should be sent to: Bruce F. Molnia, Forum Editor, U.S. Geological Survey, 917 National Center, Reston, VA 22092; (703) 648-4120; fax 703-648-4227.

ISSUE: Future Energy Needs and Utilization of Fossil Fuel—Implications for National Security, Environmental Controls, and Geoscience Employment

This Forum, which is a condensation of the Geology and Public Policy Forum presented at the 1990 Annual Meeting, is in two parts. Part 1, presented last month, addressed basic issues and summarized resources. Part 2, presented here, addresses Federal programs and human resources.

PERSPECTIVE 4: U.S. Department of Energy (DOE)—Fossil Energy Program Plan and Objectives

Michael R. McElwrath, DOE

If there is one lesson that will emerge from the recent problem in the Middle East, it is a recognition that energy is not an inalienable right, unique to this country. Energy is a commodity that the United States must work to acquire and that requires dedication of resources, application of creativity, and the ability to look beyond the present. That's the profound irony of today's energy situation. The United States is an energy-rich nation with tremendous energy resources. Yet, we agonize over when, or whether, the next tankerload of oil will arrive. The United States hasn't touched the surface of its true energy strength or potential. A large part of the reason for this is the U.S. energy system, a system assembled piecemeal, shaped by laws, regulatory decisions, and consumer behavior, which, more often than not, developed independently of each other.

Last July, President Bush ordered the development of a National Energy Strategy. Its purpose is to lay bare the real energy choices before the United States and the consequences of those choices. Long-term patterns of energy production and consumption must be clear if we are to convincingly argue about policy changes and the tradeoffs that will be needed in the future. The long-term patterns we will have to confront are as follows: (1) If current conditions persist, our dependence on imported oil will increase. Projections being developed in the National Energy Strategy show that, if we do nothing, imports could rise from 44% of U.S. oil consumption in 1989 to more than 80% by the year 2030. (2) We cannot avoid the linkage between oil imports and the Free World's dependence on the Middle East. Two-thirds of Earth's oil reserves are located in a region that shows no signs of stability or reliability. (3) U.S. oil production will continue to decline. Domestic crude oil and natural gas liquids production will drop by about 50% by the year 2030, from 9 to 4.2 million barrels/day. (4) Investments in energy efficiency are needed in every sector of the U.S. economy. Even the most optimistic projections of higher productivity indicate only slowed energy growth, not elimination of it. (5) There is no alternative but for coal use to increase. By the year 2030, according to our base case projections, the amount of coal consumed in this country will, at a minimum, double. If the "nuclear option" doesn't materialize or if the United States isn't as successful as it would like to be in energy conservation, then the use of coal could triple. (6) Natural gas consumption will increase, at least initially, although in DOE's projections, we see a gradual decline in consumption toward the end of our 40-year time frame as prices increase. The most rapid growth sector is the electric utility industry as combined cycle and high-efficiency turbines penetrate the marketplace.

So, these are the prospects that the United States faces, prospects that send the message that we can no longer afford a business-as-usual attitude. In these areas, DOE is not taking a business-as-usual approach.

Here are some of the key initiatives the DOE has underway.

Oil Resources Program. The United States faces an imminent danger due to its dependence on foreign imports. It is also in danger of losing access to as much as 70% of available onshore oil resources if the rate of oil-field abandonment can't be slowed. Higher oil prices will help, but, even with prices in the $30/barrel range, as much as 60% of the conterminous U.S. resource base may be abandoned by the year 2000.

The United States has an aging oil resource. It's a resource we cannot afford to give up, not when this country has 300 billion barrels (Bbl) of oil that is beyond the range of today's economics or technology. Getting to that oil, or at least some of it, will take a major R&D effort just to slow the abandonment rate.

Therefore, DOE has restructured its oil recovery research program on one very clear premise: The United States must create and then take advantage of a synergism between the petroleum geologist and the production engineer. DOE believes that synergism holds the greatest promise for the future, bringing together geologists who can define the anatomy of a reservoir, its internal architecture, geometry, composition, and fluid distribution, with reservoir engineers who can turn those definitions into quantitative barrels of oil. This interdisciplinary approach is at the heart of DOE's new five-year oil research program effort. The program is focused on preventing well abandonments and improving the economic producibility of remaining oil resources. It is a two-step effort. First, DOE is determining which potentially productive reservoirs are at greatest risk, grouping them by classes based on similar geologic histories and characteristics. The hypothesis is that similar geology implies similar production barriers. In this way, DOE can focus its efforts on broadly applicable problems related to major reservoir groups. Second, as data are collected, DOE will begin working with researchers and operators in specific reservoirs to try to select techniques that have proven successful in other reservoirs of the same class. DOE's approach will be similar to the work of the Bureau of Mines in the 1950s that familiarized operators with water-flooding techniques. DOE's plan is to rank the reservoir classes according to the magnitude of the oil production target, with both current and advanced technology, and the urgency in terms of abandonment risk. This ranking will determine the priority and schedule for specific field activities. These activities will address barriers to production and the recovery of more oil. DOE has estimated that a successful effort could result in the addition of as much as 75 Bbl of oil to our reserve base over the next 40 to 50 years. This still leaves a large target for longer range research.

Gas Resources Program. The major emphasis in the gas program is to make DOE's gas database comparable to that for oil, so that in the future, reservoir characterization data will be available. To date, attention has been focused on the geology and production history of the most important classes of gas reservoir in the United States. Running in concert is the Secondary Gas Recovery Program, to determine the validity of a DOE prediction that substantial reserve growth can come from existing fields. Additionally, DOE is continuing research into new production techniques for hard-to-produce gas. To guarantee a long-term supply of deliverable natural gas, DOE realizes that an aggressive R&D program must be coupled with appropriate tax incentives. If this plan is successful, there is little doubt that the United States can sustain gas production at the level of 17 to 20 trillion cubic feet for the next 30 to 50 years.

Coal Resources Program. The Clean Coal Technology Program is the single largest energy and environmental initiative underway in the Federal government, with an expected multiyear value totaling more than $6 billion. At its base is a $250 million/year coal research effort.

In contrast to its oil and gas program, DOE's coal program focuses heavily on end-use technology. DOE is just beginning to increase its emphasis on interdisciplinary activities to integrate coal geoscience with end-use technology. The main effort to this point has emphasized increases in environmental performance and efficiency of coal use. DOE's signature program is the Clean Coal Technology Demonstration Program. Thirty-eight projects are currently part of the program; 30 are underway. As DOE completes the program, 50 to 70 U.S. projects will be up and running. These projects are demonstrating a wide variety of pollution-control techniques that can help U.S. industry meet air-quality standards, including the more stringent standards in the amended Clean Air Act. In addition, several of the projects will be demonstrating new high-efficiency, super-clean power-generating options. These options will be necessary if new coal plants are to be built under the post-2000 emission cap set by the amendments.

PERSPECTIVE 5: Geoscience Enrollment and Employment Trends: Implications for the Oil and Gas Industry

Charles G. Groat, American Geological Institute

The fossil fuel industries have historically employed the greatest number of geoscientists. Major oil price fluctuations affect the vitality of the petroleum industry. Its hiring practices and, consequently, enrollments in university geology programs, have reflected these effects. Traditionally, high oil prices result in the employment of many geologists, and the prospects of good job opportunities at attractive salaries lure students into university geology programs. Significant price declines cause rapid decreases in hiring, leaving the universities brimming with geology majors suddenly facing a job market with few employment opportunities. When prices recover and the demand for geologists is restored, geology departments are empty because the lean years result in less interest in geology as a major. Enrollments decline drastically in the universities that traditionally supply the most geologists and geophysicists to the petroleum industry. This cyclical enrollment and hiring pattern, with supply out of phase with demand, is a dreaded hallmark of the geological profession.

Current Employment Trends. The present employment and enrollment situation is the result of several years of very low oil prices in the middle and late 1980s. Low prices and a supply glut produced a predictable decrease in hiring, persisting long enough to allow the resident supply of students to graduate into a depressed job market. Many have taken nongeological positions. Enrollments in the undergraduate geology-major population reached a record low point, as low as 10% of peak.

What happens when the glut of cheap oil disappears, prices increase, and demand for geologists and geophysicists to find and produce oil increases? How long will it take to fill the geologists pipeline? Will we ever again need great numbers of traditional exploration geologists and geophysicists? Citing changes in technology and decreased prospects of long-term success for independents and small firms, prognosticators suggest that the oil and gas industry of the future will need fewer geologists, with a skill mix different from the traditional geology curricula.

The invasion of Kuwait provided the dramatic increase in oil prices that historically has triggered the boom part of the geologist-demand cycle. Questions about how long the high-price incentive would last and about the impact of events on oil supply resulted in little immediate response in terms of hiring or enrollments. The stage for change was set and the issue of geologists and geophysicists supply has again been revived.

Geoscience Employment and Enrollment Surveys. The 1987 AGI employment survey indicated that there were 38,500 geologists and geophysicists employed in the oil and gas industry and 11,000 in the mining sector. Of those in oil and gas, 17,000 worked for integrated companies and 20,800 for independents. For integrated companies, 48% of the geoscientists were in exploration and 25% in field development and production. For the independents, the numbers were 80% and 7%, respectively. Thus, most

petroleum industry geoscientists are involved in exploration. Among the independents, the percentage is large, which correlates well with the fact that independents drill most of the exploratory wells in the United States.

A look at enrollment information and the number of geology and geophysics degrees awarded reveals some interesting trends. It is clear that enrollments respond to the price of oil. This is demonstrated by the increase following the embargo and Middle East wars of the early and mid-1970s and the decrease in enrollments during the supply glut and low prices of the mid- and late 1980s (Fig. 3). It is notable, however, that the total number of students enrolled in graduate programs has not varied as greatly as the number enrolled in undergraduate degree programs, nor has it fluctuated as dramatically. With approximately 2100 graduate (M.A. or M.S. and Ph.D.) degrees awarded in 1988 and projected new hires of 840, and with 87%, or 731, of those openings being for graduate degree holders, there was no supply problem in that year. Nor was there a supply problem in the post-embargo years when the number of graduate degrees was not significantly different from that in 1988 (Fig. 4).

Future Need for Geoscientists. It would appear that if the demand for geoscientists were to return to the most recent levels of increased demand, the supply would be more than adequate, given the relative stability of the availability of graduate-degree holders and the industry preference for them. Should demand return to the levels of the 1950s, it would be a different story. There have been no predictions that this is likely. Other factors suggest that demand won't outstrip supply. There has been a major move away from exploration in general and domestic exploration in particular by the major integrated oil companies. Domestic exploration, now left largely to the independents, is increasingly hindered by environmental and operating regulations that limit access to desirable targets and make the cost of doing business unacceptable. These factors are discouraging growth in the independent sector and may limit any major increases in domestic exploration that could result from increased demand and prices. With most of the exploration drilling left to the independents, these limitations on their activity could further diminish the demand for exploration geologists and geophysicists.

There is one factor that clouds the geologist and geophysicist supply situation. This is the composition of the comparatively stable populations of graduate student and graduate degree awardees. While the numbers haven't declined greatly, the number of U.S. citizens enrolled has—a steadily increasing proportion of geoscience graduate students are foreign nationals, some holding visas that restrict employment in the United States.

Figures on foreign-student enrollment in geology and geophysics graduate degree programs have not been available. However, estimates suggest that foreign students constitute 20%–30% of the population. The AGI enrollment survey for 1989–1990 requested this type of information for the first time. Preliminary analysis of the data supports this estimate and indicates that Asian students are most numerous, the greatest number of foreign students being enrolled in universities that have traditionally supplied geoscientists to the oil and gas industry. Even if the foreign geology and geophysics graduate-student population approaches 30% in these schools, the fact that some of the students can accept employment in the United States diminishes the impact on what may be an adequate supply even without counting on any of the foreign nationals to enter the domestic industry.

Another factor is the reserve supply of geologists, the large number of professionals forced out of the oil business by low prices and company layoffs. A boom may very well lure some of them back into the fold, supplementing the supply afforded by the nation's universities. Thus, we enter the 1990s without a clear indication that the traditional oil price vs. supply motivator for increased demand for geologists and geophysicists will persist, or that, if it does, the demand is in danger of outstripping the supply of choice candidates.

If numbers turn out not to be a problem, we shouldn't assume we are problem-free. The role that geoscientists will play in the oil and gas industry in the future is changing. There is increasing emphasis on improved recovery efficiency through infill drilling, more effective reservoir management, and enhanced recovery in a mature domestic setting that can likely supply more new oil from old reservoirs than it can from those not yet discovered. This will call for geologists with increased understanding of reservoir geometry, heterogeneity, and distribution in known fields than for those using regional approaches to geology aimed principally at drilling wildcats. The need for geophysical tools to better define reservoirs and measure their properties will also be paramount. We must be concerned not only about whether our graduate degree programs are producing an adequate supply of geoscientists, but also about whether they are educating students appropriately for the work they will be called upon to perform as professionals. ■

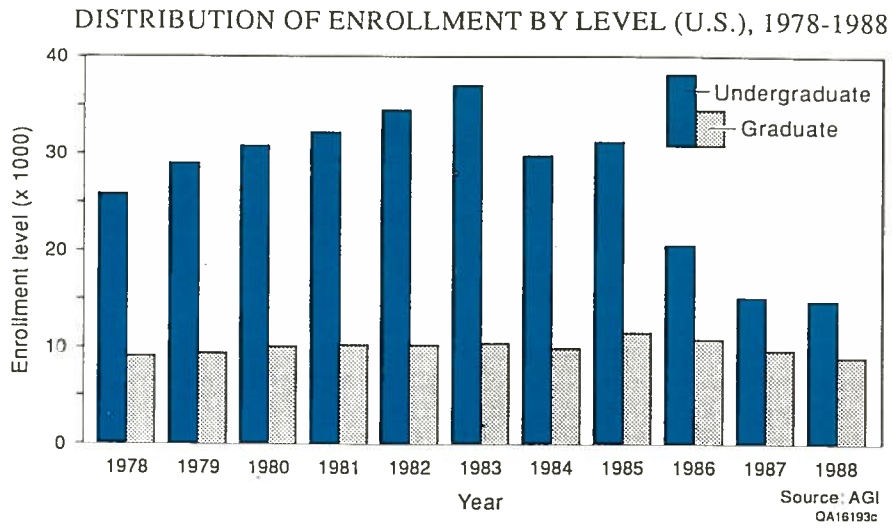

Figure 3. Enrollment in the geosciences reached an all-time high of more than 35,000 undergraduates in 1983 and drastically decreased in the late 1980s. Graduate school enrollment, on the other hand, during the same period increased slightly and overall has remained more steady.

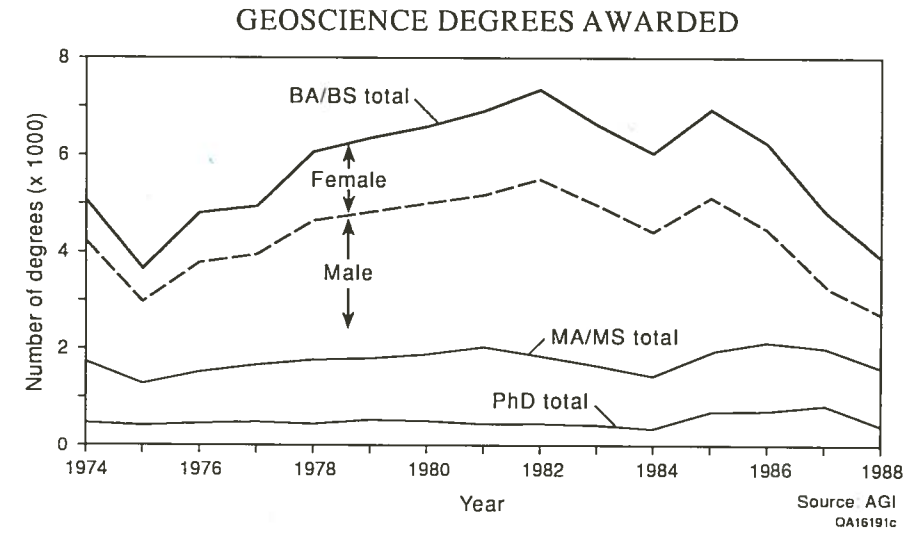

Figure 4. The number of geoscience degrees awarded tracks enrollment trends in the 1970s and 1980s. On the basis of the latest AGI geoscience enrollment and employment survey, the supply of new graduates coming out of school is meeting employment demands.

LETTER TO THE EDITOR

In the book *The Arctic Ocean Region*, Volume L of GSA's DNAG series, The Geology of North America, edited by Arthur Grantz, L. Johnson, and J. F. Sweeney, the cover description (p. ii) is as follows: "Passage through the ice—June 16, 1818. Drawn by Capt. Ross., R.N., Engraved by R. Havell and Son *in* Captain John Ross, 1919 [sic], A Voyage of Discovery in His Majesty's Ships Isabela [sic] and Alxender [sic] for the Purpose of Exploring Baffin's Bay and Inquiring into the Possibility [sic] of a North West Passage: London, John Murray, facing page 46."

Nearly everything in this description is wrong. Internal errors are the date of publication (recte 1819), the spelling of the ships (recte *Isabella* and *Alexander*) and the replacement of "Probability" by "Possibility." The most significant error is that the cover illustration is not taken from Ross's book. There is an illustration facing page 46 of that volume; the caption is "Passage through the ice . . .," but the illustration is of ten square-rigged whaling ships, not of a bark with auxiliary power, as on the cover of *The Arctic Ocean Region*.

Having confirmed that the cover illustration was not from Ross's book, I wondered, What is its source? My own Arctic library failed to provide the answer. To resolve the question, I placed it before Thomas Frisch, well known for his knowledge of both Arctic geology and literature. In short order he came up with the answer.

The illustration used on the cover of *The Arctic Ocean Region* is in *Arctic Expeditions from British and Foreign Shores from the Earliest Times to the Expedition of 1875–76* by D. Murray Smith, F.R.G.S., Edinburgh, Thomas C. Jack, Grange Publishing Works, 1877. The original illustration faces page 144 of Smith's book and measures 16 × 23.5 cm. The caption is simply "The Sun at Midnight." The name of the ship is not given. Dr. Frisch suggests that it is H.M.S. *Discovery*, which was a bark with the stack aft of the mainmast, like the ship on the cover. H.M.S. *Discovery* was used in the expedition of 1875–76 led by Captain Sir G. S. Nares to northern Ellesmere Island and Greenland.

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Committee *continued from p. 95*

Committee members should have a broad understanding of programs and research in the geosciences, and have actively participated in the affairs and programs of other earth science societies.

Membership (2 vacancies)
Screens Member and Fellow applications; evaluates membership benefits and makes recommendations to the Council about them.

Committee members must be GSA Fellows and must be able to attend one meeting a year. Previous experience in recruitment programs and in the evaluation of professional qualifications is desired.

Nominations (5 vacancies; one position for a member from Canada or Mexico)
Recommends to the Council nominees for the positions of GSA officers and councilors.

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

Penrose Conferences (2 vacancies)
Accepts or rejects Penrose Conference proposals; recommends and implements guidelines for the success of the conferences.

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

Penrose Medal (3 vacancies)
Selects candidates for the Penrose Medal.

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

Research Grants (2 vacancies)
Evaluates research grant applications and selects grant recipients.

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

Young Scientist Award (Donath Medal) (2 vacancies)
Selects candidates for the Donath Medal.

Committee to have members covering a broad range of disciplines, i.e., geophysics, economic geology, stratigraphy, etc.

Committee members should have knowledge of young scientists with "outstanding achievement(s) in contributing to geologic knowledge through original research which marks a major advance in the earth sciences."

GSA Representative to the North American Commission on Stratigraphic Nomenclature (1 vacancy)
Must be familiar with and have expertise in stratigraphic nomenclature. ■

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Brief summary of education:

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Hydrogeology *continued from p. 95*

hazardous-waste sites clearly provided a major growth opportunity for hydrogeology. Remediation and cleanup issues in North America, Europe, and elsewhere will be addressed for the next 50 or more years. As a result, a variety of research efforts will evolve, focusing on the behavior of fluids in all geologic environments and particularly relating to transport of chemicals (i.e., definition of contaminant plume in terms of position and movement). An issue confronting hydrogeological practioners and researchers alike is the ability to restore contaminated aquifer systems to required cleanup levels. Travis and Doty (1990) found that, on the basis of the past 10 years of rather unsuccessful remediation efforts, hydrogeologists may be required to concentrate on plume containment rather than on aquifer system restoration.

Although unit-specific studies will be demanding, interest in regional-scale issues will be renewed. Moreover, the interrelation among areas of classical concern—petroleum, ore deposits, diagenesis, tectonics, sedimentology, and hydrogeology—will expand. Toth (1988), for example, concluded that "factual knowledge concerning petroleum migration is woefully deficient." Toth's research is one example that will certainly lead to additional emphasis on hydrogeological approaches to petroleum exploration.

The use of computers and the application of computer models to ground-water systems has increased greatly during the past 10 years. Many of these models were restricted in their use because of the limitations in speed and memory of the available computers. This restriction will not be as severe in the future, and the linkage of flow, transport, and reaction models will become more common. Hydrogeologists dealing with modeling of ground-water systems have felt that the complexity of the models has progressed beyond the capacity of current field techniques to gather reliable data. Konikow and Papadopulos (1988) stated, "In these times of computer models and simulation, it should be reemphasized that the real world is complex, three dimensional, heterogeneous, and commonly anisotropic. This reality can only be described accurately through careful hydrogeologic research in the field." New field techniques must be developed that provide spatially distributed data rather than point data for hydrogeological analysis. Economically efficient remote-sensing techniques will be an area of great impact over the next 10 years.

Our efforts to predict the future of hydrogeology require extrapolating trends, taking educated guesses, and doing some pure speculation. A review of research trends over the past 30 years reveals two paths, one of basic research in flow and ground-water chemistry and a second of applied environmental research. These paths are not parallel; instead, they join, branch, and rejoin repeatedly. Applied research has grown out of the need to develop a better understanding of basic principles of flow and solute transport.

As we enter the 1990s, applied research will focus first on waste disposal, manufacturing, and mining. Future work in this decade will continue to focus not only on characterizing the behavior of hundreds of organic compounds in different flow regimes but also on the testing of methods to treat affected ground-water. Basic research will continue to improve our ability to describe mathematically the behavior of ground water and contaminants in both small- and large-scale problems. This research will require the development of methods to describe more accurately and precisely the spatial variation of aquifer properties. Our modeling capabilities currently outstrip our ability to describe the actual ground-water system; thus, many of the predictions of future impacts are suspect. Some of this ground-water characterization will be led by hydrochemists developing techniques to fingerprint ground water and to date water using scales of weeks instead of hundreds to thousands of years. Our efforts to predict the consequences of past, current, or probable future impacts to a ground-water system will become statistically based, and uncertainty in our work will be better quantified.

Our applied research will begin to expand from hazardous-waste sites to further examination of the consequences of cumulative impacts from dispersed or nonpoint sources (e.g., agricultural chemicals, multiple small-scale mining efforts, and waste disposal of domestic wastes by septic systems). As we attempt to come to grips with these large-scale effects, we will see the development of field and numerical techniques to evaluate these complex and areally extensive problems. Hydrogeochemical research will include the development of additional tools to examine the chemical interaction of more than one solute or fluid in the ground-water system and its transport. Our understanding of the mechanics of the movement of colloidal substances, viruses, and bacteria in soil and ground-water systems will be expanded by joint basic and applied research. Emphasis will also continue on the management of wastes for extreme time periods (i.e., radioactive wastes) and in identifying the pathways and mechanisms for the transport of such wastes. Research efforts will continue to focus on flow and solute transport in fractured systems.

Hydrogeologists are also involved in internationally emerging concerns about global climatic change. Paleohydrogeology and evaluations of potential impacts on hydrologic systems from climatic changes are being investigated.

EDUCATION REQUIREMENTS AND RELATED ISSUES

The average working degree for a hydrogeologist is normally considered to be the Master of Science. Students entering graduate studies should be well versed in geology, engineering geology, or geological engineering, emphasizing the processes that create the geologic framework through which fluid moves (e.g., depositional environments and structural character). Without such a basis, links between complex theory and application are poorly grounded. The hydrogeologist's education also includes a strong background in mathematics, physics, chemistry, and computer programming and application. In particular, knowledge of mathematics, computer science, and quantitative techniques are as necessary as a strong geological background. Without this background, graduates are at a decisive disadvantage.

A traditional geological curriculum is not sufficient today. Students should be required to complete courses in environmental aspects of the earth sciences and related areas, including institutionally oriented courses. Some schools (such as the University of Waterloo) are establishing hydrogeology–environmental science undergraduate majors, which provide the appropriate mixture of traditional geology, mathematics, and other sciences.

To produce qualified hydrogeologists, the curriculum should include courses that describe the geologic framework, such as stratigraphy, structural geology, sedimentation, Quaternary geology, and mineralogy-petrology. Additional desired courses are basic and advanced hydrogeology (which includes components of flow through porous media), surface-water hydrology, aqueous geochemistry or hydrogeochemistry, numerical methods, and field techniques. With this foundation and depending on their interest and degree level, students can then choose additional course work in ground-water modeling, characterization and modeling of vadose zones, ground-water resource analyses, and contaminant hydrogeology and/or contaminant transport modeling. Typically, solutions to hydrogeological problems require an interdisciplinary approach; thus, the student needs to acquire a working knowledge of related fields by taking courses outside the geology department. This course list is not intended to be complete, and rarely are all these courses offered in one department or school.

Although hydrogeology graduates are in demand, a relatively small number of students are graduating each year with M.S. or Ph.D. degrees with this described level of hydrogeological education. The result is a large imbalance between supply (low) and demand (high) for qualified hydrogeologists. Claudy (1991b) pointed out that nongeoscience persons are being hired into geoscience fields because of the decline in the geoscience employment pool. But that only characterizes part of the problem relative to a low supply of hydrogeologists.

The key issue is that productivity from hydrogeology centers of excellence (a critical mass of hydrogeologically oriented faculty on a single campus) does not meet employment demands. Quite the opposite: even allowing for decreasing enrollments, there have been inadequate increases in those geoscience programs predicted to be needed by society and industry for many years to come. The academic problems that affect hydrogeology are retention of students beyond the Bachelor or Master of Science level and underfunding of hydrogeology programs (in terms of equipment, teaching assistantships, and field studies) compared to that awarded to traditional areas of geology, which have fewer students. The interdisciplinary nature of the subject dictates a combination of courses, within and outside the geology department (Stephenson et al., 1981). It is the success of the hydrogeologist's education and subsequent training by the employer that has allowed the discipline to grow to its current level. Those in the discipline are concerned about the next generation.

A FINAL LOOK

The future of hydrogeology will be one of continuing change and development, but throughout it will be led by broadly based individuals with a thorough background in geology. The strength of the discipline is in this understanding of the connection between earth processes and fluid systems.

Hydrogeologists have not been highly successful in communicating about their work either to the public or to the geosciences community. This public-relations task deserves attention. We close with three thoughts:

- "[Ground water's] importance does not need argument though it may need emphasis" (Chamberlin, 1885).
- "Hydrogeology is a science that has great practical value ..." (Konikow and Papadopulos, 1988).
- "Why justify hydrogeologists at all? They are!" (J. Benoist, 1991, personal commun.)

ACKNOWLEDGMENTS

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WASHINGTON REPORT

Bruce F. Molnia

Washington Report provides GSA membership with a monthly 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.

The National Energy Stategy: Powerful Ideas for America?

On March 4, Secretary of Energy James D. Watkins announced that a comprehensive bill, the National Energy Strategy Act, was transmitted to Congress. Arrangements had been made for bipartisan sponsorship of the bill in both the House and Senate. The bill closely parallels the National Energy Strategy (NES) document (subtitled Powerful Ideas for America), released in February. Watkins described the legislative package as relying "on America's strengths: the ingenuity of our people: our leadership in science and technology; and our reliance on free markets and competition to stimulate economic growth and social progress." Watkins also stated, "The actions included in this bill, along with the many non-legislative NES actions, are part of a balanced and comprehensive strategy that could reduce domestic oil consumption by 3.4 million barrels per day (mbd) and increase projected domestic oil production by about 3.8 mbd by the year 2010. Together, the NES initiatives would vastly reduce our economic vulnerability to disruptions in the world oil market." Critics of the NES call it a "non-strategy" and a "non-policy," and focus on the absence of strong conservation and alternative energy measures and on the lack of mandated increases in automobile fuel efficiency, the Federal Corporate Average Fuel Economy rules.

Totaling more than 250 pages, the NES describes itself as laying "the foundation for a more efficient, less vulnerable, and environmentally sustainable energy future." Specific actions not included in the NES because they would result "in higher prices to American consumers, lost jobs, and less competitive U.S. industries" include: "oil import fees; large taxes on gasoline; subsidies for the production of liquid fuels from coal, shale, and natural gas; broadly mandated use of alternative transportation fuels; and sharply higher fuel-efficiency standards that would compel the use of smaller, possibly less safe cars." The NES is not a strong enforcement-oriented directive. The document states that "investment in R&D to increase technology performance and reduce costs is a more appropriate role for the Federal Government than is using taxes or regulations to subsidize or mandate the use of particular technologies."

The purpose of the NES is "achieving greater energy security." This is to be accomplished in four primary thrusts: increasing energy and economic efficiency, securing future energy supplies, enhancing environmental quality, and fortifying foundations. To achieve the first, the NES makes a commitment to "significantly expand its support for R&D on a wide range of more energy-efficient building technologies." To achieve the last thrust, the NES desires to "expand the role of energy science and technology in achieving energy, economic, and environmental objectives" and "promote excellence and productivity throughout the U.S. research establishment," while maintaining "U.S. preeminence in fundamental science and engineering research." This Washington Report focuses on the middle two thrusts.

Securing Future Energy Supplies

Oil. The NES states that "for the foreseeable future, oil will remain a critical fuel for the U.S. and all other industrialized nations." Consequently, the NES proposes initiatives to: reduce the economic consequences of disruptions in world oil markets, and increase domestic oil and petroleum product supplies. Among the measures identified to reduce the impact of oil market disruptions, the NES proposes removal of barriers to investment in petroleum development in countries outside the Persian Gulf and to expanding the Strategic Petroleum Reserve, stored in underground salt caverns at five sites in Texas and Louisiana, to 1 billion barrels. At the start of 1991, the reserve stood at 585.7 million barrels. To increase domestic production, the NES proposes to open access to currently unavailable resources on Federal lands. This includes "environmentally responsible development" in part of the coastal plain of the Arctic National Wildlife Refuge (ANWR) and removing a moratorium now prohibiting leasing of several Outer Continental Shelf (OCS) areas. In June 1990, President Bush deferred leasing of OCS areas including the coasts of Washington, Oregon, and north, central, and southern California, as well as the North Atlantic area, and part of the Gulf of Mexico. A congressional leasing moratorium denies access to all areas under presidential restriction and to other OCS areas in the north Aleutian Basin, the mid-Atlantic, and parts of the eastern Gulf of Mexico. The NES "recommends that the OCS areas currently under congressional moratoria, along with those now available for leasing, be considered . . . in formulating the new 5-Year OCS Program for 1992–1997." Additionally, the NES calls for the accelerated development of "five major discovered fields" on the North Slope of Alaska. The fields are West Sak, Point Thompson, Seal Island/North Star, Gwydyr Bay, and Sandpiper Island. None of these fields is undergoing development now. The NES will also deregulate oil pipelines, implement oil and gas tax incentives, increase the production and export of California heavy oil, and promote horizontal well drilling. Last, the NES recommends that the Administration request that Congress authorize leasing of the Elk Hills Naval Petroleum Reserve in California.

Natural Gas. The NES states that the natural gas industry "continues to be hampered by inefficient and outmoded regulation." Consequently, the NES will try to remedy this problem by: expediting gas pipeline construction, streamlining the National Environmental Policy Act process associated with natural gas pipeline construction, deregulating sales rates, reforming the design of natural gas pipeline pricing structure, improving access to natural gas pipeline transportation services, eliminating the Department of Energy's oversight of import and export transactions, and encouraging the use of natural gas as an alternative transportation fuel.

Coal. Coal is the most abundant fossil fuel in the United States. To take advantage of "our enormous, low-cost coal reserves," the NES defines two goals for coal's future: maintain coal's competitiveness while meeting environmental, health, and safety requirements; and creating a favorable export climate for U.S. coal and coal technology. To accomplish these goals, the NES identifies the need to develop and demonstrate new clean coal technologies, reduce uncertainty over environmental regulation, provide regulatory incentives in commercial deployment of new clean coal technology, and remove barriers to construction of coal slurry pipelines.

Nuclear Power. The NES states that if utility executives once again consider the "nuclear option" technically, politically, and economically feasible when new power capacity is needed, then power generation from nuclear plants could double by 2020. The NES will reform the nuclear power licensing process, provide a site and strategy for proper management and disposal of high-level nuclear wastes, and encourage the development of light-water reactors incorporating the concept of "passive safety." The NES goal is to have a demonstration plant for production of inertial or magnetic fusion energy operating by about 2025 and a commercial powerplant by 2040.

Enhancing Environmental Quality

Critics have attacked the NES for being especially weak in its concern about the environment. The NES, however, presents a different opinion. According to the NES document, the NES proposes action that will improve public health; enhance the quality of our air, water, and land; and protect the global environment. This will be accomplished by: use of market mechanisms; increased efficiency in every phase of energy production, transformation, and use; increased use of natural gas; development of cost-competitive renewable energy supplies; development and use of cleaner transportation fuels, including reformulated gasoline; development and use of clean coal technologies; improvements in the process used to site energy facilities, including refineries; and reduction in the production of energy-related and other industrial wastes. ■

Future Washington Reports will keep you posted on the progress of the National Energy Strategy Act through the Congress, and on the fate and implementation of the National Energy Strategy.

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Nominations Open for AAAS/ Westinghouse Award

The American Association for the Advancement of Science invites nominations for the 1990 AAAS/Westinghouse Award for Public Understanding of Science and Technology. This annual award recognizes scientists and engineers who make outstanding contributions to the popularization of science and are *not* members of the media. It will be presented at the AAAS Annual Meeting in Chicago, Illinois, February 6–11, 1992. The award carries a $2500 stipend.

Types of contributions to be considered include: publishing, broadcasting, lecturing, museum presentation and exhibit design, and other public outreach activities.

The deadline for nominations is August 1, 1991. For further information, contact Patricia S. Curlin, AAAS, 1333 H St., N.W., Washington, DC 20005; (202) 326-6602.

Contact Metamorphism

The Mineralogical Society of America Short Course
San Diego, California
October 17–20, 1991

This two and one-half day course will be held just prior to the annual GSA/MSA meeting. The short course, convened by Derrill M. Kerrick of the Pennsylvania State University, will utilize theoretical, experimental, and field information to elucidate the processes and controls of contact metamorphism. Speakers will review current knowlege and will explore avenues for future research. Particular emphasis is given to a multidisciplinary analysis of contact metamorphism (igneous & metamorphic petrology, geochemistry, thermal modeling, structural geology). Specific topics and speakers include: intrusives (George Bergantz & Mark Barton); contact metamorphism of pelites: phase equilibria, thermobarometry and fluids (David Pattison & Robert Tracy); contact metamorphism of calcareous rocks, metabasites and other non-pelitic rocks: phase equilibria, thermobarometry and fluids (Robert Tracy, Ronald Frost & David Pattison); physical and chemical properties of fluids and mass transport in contact metamorphic aureoles (Theodore Labotka); mineralogical and geochemical effects of fluid-rock interaction during contact metamorphism (John Ferry & Mark Barton); stable isotope monitors of contact metamorphism (Peter Nabelek); thermal modeling (Kevin Furlong, James Bowers & Brooks Hanson); kinetics of contact metamorphism (Ray Joesten, Tony Lasaga & Derrill Kerrick); aureole tectonics (Scott Paterson & Ron Vernon); aureole systematics (Mark Barton, Derrill Kerrick & Brooks Hanson).

Early registration is strongly advised. Registration forms can be obtained from the Mineralogical Society of America, 1130 17th Street, N.W., Suite 330, Washington, DC 20036, USA, telephone (202) 775-4344; fax 202-775-0018.

GSAF UPDATE

Robert L. Fuchs and Edward E. Geary

SAGE Sense—and Dollars

The SAGE (Science Awareness through Geoscience Education) program to enhance geoscience education and increase public awareness of geology will be a major focus of GSA for the foreseeable future. Certainly this is true in terms of people involved and members of the public directly affected. However, educational reforms will not just materialize because we need them, and an undertaking of this magnitude holds significant long-term financial ramifications for the Society.

GSA has been financially fortunate during the past 60 years. In 1931 R.A.F Penrose, Jr. gave the Society $3.9 million, and it is this endowment that has been the monetary base for most programs. Income from the Penrose Fund, and occasionally principal, finances the annual operating deficit, which is budgeted to be $548,000 in 1991. Thanks to the generosity of former GSA President Penrose, the Society is able to offer publications to members at prices that are consistently below the out-of-pocket preparation and printing costs. Membership and employment services are also subsidized by Penrose Fund money.

In addition to covering the operating shortfall on a regular basis, the Penrose Fund supports a number of activities under the budget category Council-Approved Expenditures, such as Research Grants and the Congressional Fellowship. This category is also the source of funds for new GSA programs—the Society's financial incubator, so to speak. DNAG and the Foundation saw the light of day in 1980 as a result of this venture funding.

In 1991, Council-Approved Expenditures include an amount of $140,000 to finance the birth of SAGE. This money will cover administration and some of the preliminary undertakings such as Teacher Awards for Excellence and Partners for Excellence. The SAGE long-range budget must include provision for rapid increases in expenditures to support the work that is scheduled. This seed contribution from the Penrose Fund will quickly be exceeded.

The forecast presented to GSA's Long-Range Planning Committee last year foresaw the following annual costs: 1992—$440,000; 1993—$608,000; 1994—$737,000.

The forecast also envisioned the elimination of Penrose Fund support after 1991. In other words, *SAGE must become financially self-sufficient starting next year.* How will this be possible given the current tiny asset base available to the program? The only endowment currently earmarked for SAGE is its Fund and the Donald L. Biggs Memorial Fund; together they total only $6000.

We have given the SAGE fund-raising effort top-priority status. Clearly, a major fund-raising effort is required, but we need your help if SAGE goals are to be realized. There are two aspects to raising this money. Program money is available in the form of grants from government, industry, and institutions. This will be the main source of SAGE money for the next three to five years. Longer term, there must be an endowment that SAGE can tap in order to carry on its important work.

The endowment is where you, our GSA members, can carry the flag. Large organizations are generally oriented to grants for specific, time-limited activities. On the other hand, GSA's commitment to education is long-term and continuing. Regular contributions from members such as those being made to the SAGE Fund and the Donald L. Biggs Fund are the most time-tested way to build the base of an endowment. The ultimate success of an endowment of the order contemplated for SAGE will depend heavily on special gifts such as bequests and large contributions.

Special designated opportunities for giving already exist for SAGE, and this list offers several examples that members might wish to endow:

Awards for Excellence, endow one award in perpetuity. $4000

GSA Annual Meeting minority programs, endow annual support $30,000

GSA film production and distribution, per film $50,000

SAGE Mentor, endow a geoscience professional working on educational outreach $75,000

There are additional opportunities for supporting specific parts of the program, for which the donor will receive appropriate recognition. Please call the Foundation office to discuss these, and the overall funding of SAGE. Use the accompanying coupon to make a contribution to SAGE today. ■

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Penrose Conference Report

New Methods for Dating Geomorphic Surfaces

Conveners

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The Penrose Conference on New Methods for Dating Geomorphic Surfaces followed an earlier AGU symposium organized by W. E. Dietrich and M. C. Monaghan (1987) to bring technique developers in contact with a representative group of geomorphological users. The Penrose conference emphasized the in situ build-up of cosmogenic isotopes (^{3}He, ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl, ^{41}Ca) in exposed rocks, rock varnish, and more conventional (soils, weathering rinds) approaches of estimating the age of surface exposure of landforms.

Most agreed that all dating techniques should be viewed as experimental, that as many different methods as possible should be used in conjunction, and that these techniques need to be tested in well-controlled circumstances. Oral and poster presentations were mixed with field trips to Bloody Canyon (Phillips et al., 1990) and collection sites in the Owens Valley (Dorn et al., 1990), as well as demonstrations of ^{36}Cl extraction and rock varnish radiocarbon dating. Discussions were most lively on ^{3}He, rock varnish dating, and the Lathrop Wells volcanic center. Sterling presentations by W. E. Dietrich and W. B. Bull focused attention on how surface-exposure dating can play a key role in the development of geomorphic theory.

D. Elmore emphasized the optimism in being able to make measurements of cosmogenic isotopes in the range of 10^{-15}, but he also sobered all by the reality that the funds for accelerator mass spectrometry are limited.

In developing a strategy for surface exposure dating to assess the history of a landform (not separating process from form), a three-level approach was discussed.

Level 1. Before Sampling Assessments. Before any sampling is conducted, a thorough understanding of morphostratigraphy is needed. All independent chronological information should be gathered. Reincarnations of Elliot Blackwelder's (1927) concerns over the role of fire in spalling boulders forced everyone to realize that a detailed knowledge of the processes of surface weathering and erosion at potential sampling sites is a critical issue that needs closer scrutiny.

Level 2. Iterative Sampling. The focus of the study must be defined: whether the interest is in the age of the landform or the nature of weathering. Most agreed that a procedure of iterative sampling is the best approach. Given the costs involved in accelerator analyses, many felt that the best preserved surfaces should be sampled first. A few argued for sampling the best and worst places first to determine the end members. Still others pointed out that using low-cost methods like varnish cation-ratio dating might be used to determine which samples would be best for the more expensive cosmogenic dating methods.

Level 3. Weighing Advantages and Disadvantages of Different Methods. Some argued that even bringing up this topic is premature, that the methods are not understood well enough to do a proper assessment. For example, a lot has been learned about the production rates of cosmogenic isotopes in rocks, but all agree that these rates must be constrained by multiple calibration techniques in many different circumstances. However, some key issues were brought up in the uses of different methods.

A. ^{10}Be and ^{26}Al extraction from quartz (Nishiizumi et al., 1989) requires a lot of time to prepare samples, but paired isotopes from the same material yield the most information on exposure histories of rocks. D. Lal and Jeff Klein pointed out that by using more isotopes (e.g., in situ ^{14}C [Jull et al., 1989] with ^{10}Be and ^{26}Al) with widely varying half-lives, the most information on rates of rock-surface erosion and landform history can be gained.

B. A single isotope such as ^{36}Cl that can be extracted from whole rocks (Phillips et al., 1990; M. Zreda et al., unpublished) is much easier to prepare than ^{10}Be and ^{26}Al and would be most appropriate where many measurements were needed, where a prior exposure history is unlikely, and where rock-surface erosion is minimal.

C. Stable isotopes such as ^{3}He (Kurz et al., 1990; Cerling, 1990) have the great advantage of not requiring accelerators for measurement. All agreed that olivine was retentive of ^{3}He, and evidence was presented for good retention in quartz, but there was considerable debate over this and over the best way to prepare quartz samples.

D. Rock varnish methods are inherently inferior to cosmogenic methods of dating landforms in areas outside of deserts because varnish dissolves in acidic environments, and in circumstances where the surface of rocks is not stable because varnish is lost if the rock surface is degraded by even 1 mm. Rock varnish methods are most appropriate in circumstances where a prior exposure history is likely for the rock under the varnish—for example, in dating the cessation of eolian abrasion on a boulder or in dating varnish formed on petroglyphs.

All varnish parties actually agreed on a few points: that the cation ratio of (K+Ca):Ti lowers over time, and that in situ analysis of varnish chemistry by the SEM method (Harrington and Whitney, 1987) is not comparable with bulk chemical analysis of varnish scrapings (Dorn et al., 1990). Both approaches measure varnish chemistry, but not necessarily on the same material; the SEM method measures the surface chemistry of the varnish, whereas bulk analysis is of the entire varnish. Some questioned the theory of cation leaching as the cause of these chemical changes over time, based on profiles of elemental composition through varnish layers; others supported this theory with Arrhenius temperature experiments on cation leaching of rock varnish and with electron microscope textures produced by leaching. Also stressed was the need to account for biogeochemical variables, other than time, that can influence varnish dating (e.g., Krinsley et al., 1990).

E. Soils (D. L. Elliott-Fisk) and weathering rinds (T. Chinn) were discussed but not intensively, because the focus of the conference was on new methods. However, strong similarities were noted between data trends for these conventional approaches and cosmogenic nuclides.

Several key phrases kept coming up in discussions. "Let the buyer beware" in reference to the fact that consumers of dating information need to pay close attention to inherent uncertainties in dating methods. All dating techniques, including radiocarbon, are experimental. All dating techniques go through cycles of high and low confidence, as new problems are encountered and addressed. Knowledge of the morphostratigraphy and field relations are absolutely critical before sampling can be conducted and results interpreted. The number of techniques that should be employed on a problem depends on the individuals' assessments of the exposure history and the money available.

In the final session, it was made clear that technique developers believe it is imperative that geomorphologists and archaeologists have access to these new surface-exposure dating methods. But this will require current and potential users to actively lobby the National Science Foundation to support national centers for accelerator mass spectrometry. In the future, the main roadblock to widespread application will be the total number of samples that can be analyzed.

In spite of possible problems with analytical availability and technology transfer to geomorphological and archaeological users, the conferees were largely enthusiastic about the future role of the new surface-exposure dating techniques. These methods constitute a major step forward in quantifying both the history of Quaternary landforms and the rates of geomorphic processes. We anticipate that these techniques will play an increasingly important role as concern grows about predicting the effects of global climatic change.

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Penrose Conference Participants

Andy Bach
John Bell
Paul Bierman
Weston Blake
Arthur Bloom
Ed Brook
Erik Brown
William Bull
George Burr
Marc Caffee
Thure Cerling
Duane Champion
T.J.H. Chinn
G. Michael Clark
Jonathan Davis
William Dietrich
Jack Donahue
Deborah Elliott-Fisk
Dave Elmore
Edward Evenson
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Steven Forman
Andrew Fox
J.D. Gibson
Robert Giggenbach
Robert Hall
Charles Harrington
Bryant Hudson
Nancy O. Jannik
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Jeffrey Klein
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Peter W. Kubik
Mark Kurz
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Tanzhuo Liu
Ivo Lucchitta
Paola Macchiorilla
Larry Mayer
Wilton Melhorn
Patricia McDowell
Leslie McFadden
Jim McKean
Roger McNeely
Marc Monaghan
Kuni Nishiizumi
Kenneth Osmond
Milan Pavich
Steven Reneau
Dale Ritter
Michele Seidl
Roy Shlemon
Jack Shroder, Jr.
Janet Slate
John Stone
Terry Swanson
Brent Turrin
C.R. Twidale
Paulo Vasconcelos
Kenneth Verosub
Alan Watchman
Stephen Wells
John Whitney
Marek Zreda

In Memoriam

William H. Matthews, III
Beaumont, Texas
February 14, 1991

Harriet W. Morrison
Golden, Colorado
February 6, 1991

Preston Cloud
Santa Barbara, California
January 16, 1991

William A. Waldschmidt
Midland, Texas
December 28, 1990

John H. Brineman
Hunt, Texas
December 6, 1990

Bruce T. Pearson
Midland, Texas
August 17, 1990

Morris F. Skinner
Ainsworth, Nebraska
December 15, 1989

George E. Heim
Sacramento, California
December, 1989

BOOK REVIEWS

Oil and Gas Forecasting: Reflections of a Petroleum Geologist. *Lawrence J. Drew. Oxford University Press, New York, 1990, 252 p., $45.*

This very readable and sometimes feisty memoir recounts Larry Drew's career in the geostatistics of energy and mineral deposits. An initial three-year stint in an oil-company research laboratory followed by service with the U.S. Geological Survey gave him a ringside seat on domestic petroleum exploration. We follow Drew's explication of discovery process modeling and its use in making predictions as to the amount of oil and gas remaining to be discovered and future rates of discovery. He first validates the 1958 Denver basin model developed by Arps and Roberts and then applies that model to the Powder River and Permian basins and the Gulf of Mexico region. A final chapter deals with quantitative assessments of undiscovered mineral resources on Federal wilderness lands.

Earth scientists who have been personally involved in the process of petroleum discovery will enjoy recognizing familiar creatures as Drew first encounters their statistical spoor and ultimately identifies them. These include newly found "fairways" (clusters or trends of related trap/reservoir combinations within a petroleum accumulation system) and their ensuing exploration plays, the results of a surge in promotional drilling, and the effects of oil prices and interest rates on the amount of undiscovered petroleum resources in a region. Indeed, some of those belated revelations lend an element of suspense to the narrative. For example, one waits until the next-to-last page for acknowledgment that platform cost is the main reason why economic truncation of the low end of the field-size distribution curve is more abrupt in offshore areas than onshore.

Drew documents the rejuvenation of the Pleistocene play in the Gulf of Mexico brought on by rising natural gas prices in the 1970s. His analysis makes clear that significantly higher oil and gas prices—if dependable over the long term—would add substantially to our petroleum resource base as the economic threshold drops to include smaller fields. In the Gulf of Mexico OCS, for example, recoverable resources could be increased by at least 20%.

Drew's scrutiny of oil and gas forecasting does not cover the whole range of methods and applications. His models are applicable only in regions where drilling is well advanced and where the discovery of new fairways is not anticipated. Only in passing does he mention volumetric yield methods applied to virgin or lightly drilled basins, and the combined geological and statistical methods that have largely replaced them. There is no discussion of the Monte Carlo method as applied to Outer Continental Shelf petroleum resource estimates. Controversies surrounding U.S. oil and gas estimates, the subject of Wildavsky and Tenenbaum's *The Politics of Mistrust* (1981), receive little attention, though Drew's antipathy toward uninformed critics of the oil industry is made clear. Other essays deal with economists and environmental issues.

This book deserves to be read by all those employed in the economic evaluation of exploratory drilling proposals. Other petroleum geologists will find easy going through the brief mathematical passages and may well be convinced by the statistical relationships as they are developed. In addition, Drew's insights on petroleum exploration should be useful to statisticians and others outside the energy industry.

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Computer-Assisted Microscopy: The Measurement and Analysis of Images. *John C. Russ. Plenum Press, New York, 1990, 543 p., $59.50.*

The acquisition and interpretation of images are fundamental tasks practiced by virtually every earth scientist. Nevertheless, image analysis is a field of endeavor that has only recently made its way into the curriculum of earth science programs. This book addresses the revolution in image analysis made possible by recent technological advances in microscopy (for acquiring images) and computer science (for processing them). Russ takes the reader through the procedures involved and follows a logical progression from image acquisition to processing to various types of measurements. Although this book is not written specifically for earth scientists, anyone who has a very basic understanding of microcomputers should find it "user friendly." The writing is lucid and the book is very well illustrated: Russ uses examples of images, taken from a wide variety of physical and natural sciences, which were obtained on Apple/Macintosh interfaced systems. He produced all the text, figures, and tables on a Macintosh, and the product is extremely readable. I would recommend this book to scientists who desire an approachable introduction to the field of image analysis.

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Analysis of Geological Structures. *N. J. Price and J. W. Cosgrove. Cambridge University Press, New York, 1990, 502 p., cloth: $125; paper: $49.50.*

Price and Cosgrove have produced a welcome and useful addition to the structural geology literature. Throughout *Analysis of Geological Structures*, the authors emphasize the application of mechanical principles to geologic problems, complementing the largely geometrical approach taken in the pair of advanced structural geology textbooks by Ramsay and Huber.

Following an almost obligatory first chapter on the fundamentals of theoretical and experimental rock mechanics, Price and Cosgrove systematically review mechanical analyses of the major types of structures, in 16 chapters. Some structures, such as concordant and discordant intrusions, merit only one chapter. Others, such as faults and folds, merit several specialized chapters each. For example, folding-related topics are covered in chapters titled Introduction to Folding, Surface and Single Layer Buckling, Multilayer Folds and Associated Structures, The Buckling of Anisotropic Rocks, Initiation of Large Buckle Folds and Fracture-Fold Relationships, The Life and Times of a Buckle Fold, and Boudinage and Pinch-and-Swell Structures. The final chapter is a short introduction to classical structural analysis and the geologic history of complexly deformed areas.

Analysis of Geological Structures does have some shortcomings. Although most of the classic geomechanical literature by Biot, Ramberg, Hafner, Sanford, and Hubbert and his colleagues is cited, references to some important recent work are missing. Checking the chapters on minor fractures, single-layer folding, and thrust faulting, I found no references more recent than 1982. For example, mention of the detailed mapping and mechanical analysis of interacting crack tips by Pollard, Segall, and Delaney is missing from the chapter on systematic jointing. Likewise, there is no mention of the Davis, Suppe, and Dahlen Coulomb wedge model of thrust sheet deformation embraced by many geologists. Specialists in other areas will no doubt find similar omissions. To their credit, Price and Cosgrove acknowledge this problem in their Preface.

Although *Analysis of Geological Structures* could form the basis for a graduate-level class in advanced structural geology, extensive reference to a more detailed mechanics text such as Johnson's *Physical Processes in Geology* would be necessary. One would almost certainly want to work through some important derivations for which Price and Cosgrove present only the final results. Examples might include the relation of deflection, bending moment, and fiber stress in a simple beam: the dominant wavelength of a buckled layer; or some simple solutions to the biharmonic equation. Other problems—for example viscosity and density instabilities in thick beams and multilayers—will be beyond the skills of all but the most advanced and dedicated students. In such cases, Price and Cosgrove wisely chose to discuss only the results and implications of various analyses.

All in all, *Analysis of Geological Structures* successfully illustrates how many problems in structural geology can be analyzed as problems in continuum mechanics. It should be an important addition to the libraries of most structural geologists. With additional effort on the part of instructors, it might also serve as a valuable graduate-level textbook.

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Cataclysms and Earth History: The Development of Diluvialism. *Richard Huggett. Oxford University Press, New York, 1989, 220 p. $53.*

In the current climate of renewed interest in catastrophes and especially in rapid changes of sea level, a volume with this title might be expected to be ever so timely. Unfortunately, this slim volume tries to cover too much ground and fails to live up to the promise of its title. Huggett, an English geomorphologist aimed "to bring to the notice of Earth scientists at large, rather than to historians of geology and geomorphology, the rich and colourful history of diluvial thought...." Had he kept to the traditional sense of diluvialism that refers to the Biblical Flood and its presumed sedimentary record, provided more from original sources rather than secondary ones, and added some analysis of the current emphasis on diluvialism by creationists, he might have had a more coherent book. Instead, he chose to broaden the inquiry to include all sorts of fluctuations in water levels: early interpretations of elevated shell beds, local floods (Spokane and Bonneville), transgressions and regressions, super-floods or tsunamis produced by bolide impacts, and even speculations about the effects on sea levels of polar wandering and Earth's encounter with Venus (Velikovsky). The book does provide references to the literature of diluvialism, especially works in English, and it could also offer the material for a lecture on the subject to undergraduates.

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Petrophysics. *V. N. Kobranova. Springer-Verlag, New York, 1989, 375 p., $59.50.*

The design of geophysical field studies and the interpretation of the results relies on one's knowledge of physical properties of rocks and minerals. Petrophysics, the study of the physical properties of reservoir rocks, is important in applied geophysics and geophysical investigations of the structure and composition of Earth's lithosphere. This book is a useful review of research in the USSR on various physical properties and their utilization in geophysical prospecting for oil and gas.

The volume is organized into thirteen chapters. The first five chapters focus on porosity and water content of rocks. Chapter 6 deals with the density of rocks and minerals. Useful figures summarize the range of densities for sedimentary, igneous, and metamorphic rocks and ores. In addition, several relationships between density and other petrophysical quantities are presented. Chapter 7 provides a summary of permeabilities of sedimentary rocks. This is followed by chapters on electrical, thermal, and magnetic properties of rocks. Each chapter provides a brief introduction which includes definitions and mathematical relationships, followed by figures and tables summarizing the properties for various rock types. Chapter 11 examines radioactivity of elements, minerals, and rocks. The neutron activity of minerals and rocks is examined in Chapter 12. The final chapter reviews elastic properties. The elasticity of anisotropic minerals is briefly discussed, as well as the attenuation of elastic waves. A summary of compressional and shear wave velocities, Young's moduli, shear moduli, and Poisson's ratios for a variety of rocks is presented in table form.

The main value of this book is in providing an overview of the state of research on rock properties in the USSR. A major shortcoming is the limited bibliography. Journal articles from which many of the more interesting figures originated are not referenced. The book should primarily be of value to the researcher with an interest in rock physical properties.

Nikolas I. Christensen
Purdue University
West Lafayette, IN 47907 ■

1991 Annual Meeting Theme Sessions and Symposia

Technical sessions consist of both invited and volunteered papers organized in one of three presentation formats: symposia, theme sessions, and discipline sessions. All abstracts are due for review by *July 3, 1991*. Abstracts must be submitted on the 1991 Abstract Form, available from the Abstracts Coordinator at GSA headquarters.

1991 Technical Program Chairmen

Richard W. Berry
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Volunteered Papers

This format includes all abstracts that are not specifically invited for a symposium. Two types of sessions are available:
1. **Discipline Sessions.** Papers are submitted to one scientific category (discipline). The Joint Technical Program Committee (JTPC) representatives select and schedule the papers in sessions focused on this one discipline, e.g., hydrogeology, geochemistry.
2. **Theme Sessions.** Papers are submitted to a specific pre-announced title AND to ONE scientific category. Theme sessions are interdisciplinary; each theme may have as many as three categories from which authors may choose. After each theme title below, the categories are identified by name and number as they appear on the 1991 Abstract Form. The full theme descriptions appear in the April 1991 issue of *GSA Today* and were distributed with the 1991 Abstract Forms in March. Schedules for theme sessions will be available immediately after the JTPC meeting in August and will appear in the September issue of *GSA Today*.

T1. **The Global Challenge: Predicting Our Future, How Good Are the Models?** Environmental Geology (6), Global Geoscience (13), Quaternary Geology (28).

T2. **Resources: The Costs and Consequences of Use.** Economic Geology (4), Global Geoscience (13), Petroleum Geology (21).

T3. **Global Climate Changes—I: The Geologic Record of Climate Dynamics.** Marine Geology (16), Paleoceanography/Paleoclimatology (19), Paleontology/Paleobotany (20).

T4. **Global Climate Changes—II: The Past, a Key to the Future.** Geochemistry (8), Global Geoscience (13), Paleoceanography/Paleoclimatology (19).

T5. **Global Warming and Geologic Evidence of Aridification During Late Quaternary Time.** Geomorphology (10), Hydrogeology (15), Quaternary Geology (28).

T6. **Fluvial Response to Base-level Changes: Eustatics vs. Tectonics—Part II.** Geomorphology (10), Sedimentology (30), Stratigraphy (31).

T7. **Processes Controlling the Composition of Siliciclastic Sediments.** Sedimentary Petrology (25), Sedimentology (30).

T8. **Global Sedimentary Geology of the Phanerozoic: A Theme Session in Honor of A. B. Ronov.** Geochemistry (8), Global Geoscience (13), Sedimentology (30).

T9. **Approaches to Sequence Stratigraphic Analysis—Examples from the Tertiary.** Global Geoscience (13), Sedimentology (30), Stratigraphy (31).

T10. **The K-T Boundary—I: Late Cretaceous Extinctions: Catastrophes or Not?** Paleontology/Paleobotany (20), Stratigraphy (31).

T11. **The K-T Boundary—II: Nonmarine Fossil Record at the Cretaceous-Tertiary Boundary.** Paleontology/Paleobotany (20), Stratigraphy (31).

T12. **Actinide-series Disequilibria in Igneous and Geothermal Processes.** Aqueous Geochemistry (7), Igneous Petrology (23), Volcanology (34).

T13. **Solution Mass Transfer and Volume Strain in Crustal Rocks.** Hydrogeology (15), Metamorphic Petrology (24), Structural Geology (32).

T14. **Site Characterization Studies Related to Ground-water and Surface-water Contamination at Sites Operated by the U.S. Department of Energy.** Engineering Geology (5), Environmental Geology (6), Hydrogeology (15).

T15. **Geology, Hydrogeology, and Tectonics of Southern Nevada in Relation to the Potential Storage of High-level Nuclear Waste.** Hydrogeology (15), Tectonics (33), Volcanology (34).

T16. **Characterization and Monitoring of Ground-water Contamination at Hazardous Waste Sites: Research and Case Histories.** Engineering Geology (5), Environmental Geology (6), Hydrogeology (15).

T17. **Urban Geologic Hazards.** Engineering Geology (5), Environmental Geology (6), Hydrogeology (15).

T18. **Soil and Ground-water Remediation Techniques.** Engineering Geology (5), Environmental Geology (6), Hydrogeology (15).

T19. **Contamination of Fractured Bedrock Aquifers: Investigation Techniques and Case Histories.** Aqueous Geochemistry (7), Hydrogeology (15), Structural Geology (32).

T20. **Geologic Controls on Multiphase Fluid Flow in Porous Media.** Environmental Geology (6), Hydrogeology (15), Petroleum Geology (21).

T21. **Geophysical Exploration for Ground-water in Arid and Semiarid Regions.** Engineering Geology (5), Geophysics (11), Hydrogeology (15).

T22. **Multivariate Statistical Methods in the Geosciences.** Computers (3), Global Geoscience (13), Hydrogeology (15).

T23. **Failure Mechanisms of Megaslides.** Engineering Geology (5), Quaternary Geology (28), Structural Geology (32).

T24. **Active Margin of Antarctica—Proterozoic to Holocene.** Igneous Petrology (23), Structural Geology (32), Tectonics (33).

T25. **Cenozoic Extension in the Cordillera: Geometry, Timing, Mechanisms, and Regional Controls.** Geophysics/Tectonogeophysics (11), Structural Geology (32), Tectonics (33).

T26. **Mesozoic Stratigraphic and Structural Evolution of Northwestern Mexico.** Stratigraphy (31), Structural Geology (32), Tectonics (33).

T27. **Jurassic Magmatism and Tectonics of the North American Cordillera.** Igneous Petrology (23), Stratigraphy (31), Tectonics (33).

T28. **Tectonics of Modern and Ancient Accretionary Prisms.** Marine Geology (16), Metamorphic Petrology (24), Tectonics (33).

T29. **Landscapes of Tectonically Active Strike-slip, Normal, and Reverse Faults.** Geomorphology (10), Quaternary Geology (28), Tectonics (33).

T30. **New Views of the Moon: The Lunar Frontier Revisited.** Geochemistry (8), Geophysics (11), Planetary Geology (26).

T31. **Southern California Areal Mapping Project—Accomplishments, Work-in-Progress, Goals** (Poster Session). Igneous Petrology (23), Stratigraphy (31), Tectonics (33).

T32. **Baja California: Geologic History of the Peninsula and Gulf of California.** Paleontology/Paleobotany (20), Stratigraphy (31), Structural Geology (32).

T33. **Geology of the Future—Now** (Poster Session). Environmental Geology (6), Stratigraphy (31), Other (35).

T34. **Earth Scientists and Science Educators: Common Ground.** Geology Education (9).

Invited Papers (Symposia)

This format includes only abstracts that have been invited by the convener of a symposium. Abstracts are sent directly to the convener by July 3.

S1. **Archaeological Geology of the Archaic Period (8–3 ka) in North America.** Archaeological Geology Division. E. Arthur Bettis III, Iowa Dept. of Natural Resources, Iowa City.

S2. **Coalbed Methane: Geology, Recovery Technology, and Resources.** Coal Geology Division. Walter B. Ayers, Jr., University of Texas, Austin.

S3. **Georisk Assessment.** Engineering Geology Division. Charles Welby, North Carolina State University; Rhea Lydia Graham, Science Applications International Corp., Albuquerque, New Mexico.

S4. **Depositional Environments and the Development of Aquifers.** Hydrogeology Division. Mark W. Evans, Emory University; Robert L. Laney, USGS, Reston, Virginia.

S5. **Geology of the Pacific Rim.** International Division. Tadashi Sato, Tsukuba University, Tsukuba, Japan; Bruce Hanshaw, Consulting Geologist, McLean, Virginia.

S6. **Geologic Evidence of Late Quaternary Aridification in Western North America: Great Plains, Desert Southwest, and Great Basin.** Quaternary Geology and Geomorphology Division. Richard F. Madole and Daniel R. Muhs, USGS, Denver, Colorado.

S7. **Fluvial Response to Base-level Changes: Eustatics vs. Tectonics—Part I.** Sedimentary Geology Division. Paul L. Heller, University of Wyoming.

S8. **Strike-slip Faulting: Geological and Geophysical Perspectives** (full day). Geophysics and Structural Geology and Tectonics Divisions. Art Sylvester, University of California, Santa Barbara; Kristian Meisling, ARCO Oil & Gas Co., Plano, Texas; Gene Humphries, University of Oregon; Matt Golombek, Jet Propulsion Laboratory, Pasadena, California.

S9. **The Global Climate Transition from the Late Paleocene to Early Eocene.** Cushman Foundation. Kenneth G. Miller, Rutgers University; Lowell Stott, University of Southern California.

S10. **Lithospheric Contrasts in Northwestern North America: Vestiges of Archean and Proterozoic Crustal Growth.** Geochemical Society. Paul A. Mueller, University of Florida; Joseph L. Wooden, USGS, Menlo Park, California.

S11. **International Initiatives in Geoscience Information—A Global Perspective.** Geoscience Information Society (GIS). Dena Fracolli, Information Consultant, Fort Worth, Texas.

S12. **Contact Metamorphism.** Mineralogical Society of America. Maria Luisa Crawford, Bryn Mawr College; Robert J. Tracy, Virginia Polytechnic Institute and State University.

S13. **New Approaches to Introductory Geology Courses.** National Association of Geology Teachers. Noel Potter, Jr., Dickinson College, Carlisle, Pennsylvania.

S14. **Biotic Turnover Examined in a Phylogenetic Context.** Paleontological Society and Society of Vertebrate Paleontologists. David Archibald, San Diego State University; Sandra J. Carlson, University of California, Davis.

S15. **Applications of Micro-analytical Techniques to Economic Geology.** Society of Economic Geologists. C. Stewart Eldridge, Australian National University, Canberra.

S16. **Crustal-scale Controls on Ore Deposits** (full day). Society of Economic Geologists. Robert J. Bodnar, Virginia Polytechnic Institute and State University.

S17. **Organic Matter Survivable at High Temperatures: Implications for Life.** Organic Geochemistry Division of the Geochemical Society.

Stephen A. Macko, University of Virginia; Everett L. Shock, Washington University; Michael H. Engel, University of Oklahoma.

S18. **Enhancing Geologic Education through the Arts—A Metageologic Approach.** CANCELLED Ray Pestrong, San Francisco State University; Garry McKenzie, Ohio State University.

S19. **Continental Drift, Plate Tectonics, and Biogeography: The History of a Synthesis of Two Cultures.** History of Geology Division. Alan E. Leviton, California Academy of Sciences, San Francisco.

S20. **Venus and Earth: Tectonic and Volcanic Evolution.** Planetary Geology Division. Baerbel K. Lucchitta, USGS, Flagstaff, Arizona.

S21. **Geophysics of the Southwestern Cordillera—U.S. and Mexico.** George R. Jiracek, San Diego State University; Mario Martinez, Centro de Investigación Científica y de Educación Superior de Ensenada, Baja California, Mexico.

S22. **Pangea: Ice-house Processes and Events on a Super Continent.** Sedimentary Geology Division and Global Sedimentary Geology Program. George DeV. Klein, University of Illinois, Urbana.

Professional Horizons—1991 Annual Meeting GSA Short Courses

All courses sponsored by GSA will be held immediately before or after the GSA Annual Meeting. Increase the benefits of attending the GSA meeting by participating in one of GSA's professional instruction programs. The courses are designed for several different professional levels. A *GSA Certificate of Completion* will be given to each registrant. We hope you will find one that meets your needs.

Enrollment. Course participation is open to GSA members and nonmembers. Registration for the 1991 Annual Meeting is not required. Registration forms for the short courses and the Annual Meeting will appear in the August issue of *GSA Today*. HOWEVER, IF YOU WOULD LIKE TO REGISTER NOW, CONTACT THE COURSE REGISTRAR AND RECEIVE A GSA SHORT COURSE BROCHURE AND REGISTRATION FORM. Save significantly by registering in advance. On-site registration will be $25 additional and based on availability. PREREGISTRATION DEADLINE IS SEPTEMBER 20, 1991.

Cancellation. Fees will be refunded if we are notified that you will not be attending by September 27. Registration substitutions may be made at any time. For more information, contact Edna Collis, Course Registrar, GSA headquarters, (303) 447-2020 or 1-800-472-1988.

Concepts, Strategy, and Software for Practical Three-dimensional Contaminant Transport Modeling. Friday, October 18, 8 a.m. to 5 p.m., Saturday, October 19, 8 a.m. to 5 p.m., Sunday, October 20, 8 a.m. to 12 noon. San Diego Convention Center. Cosponsor: *Hydrogeology Divison.*

ATTENTION STUDENTS: The Hydrogeology Division will SUBSIDIZE THE FIRST STUDENT WHO IS A VALID DIVISION MEMBER. The student MUST PAY THE FULL COURSE FEE when registering, but will be reimbursed $50 after the GSA meeting by the Hydrogeology Division.

This *advanced* course is designed for the hydrogeologist familiar with flow modeling, but who has had limited experience in transport modeling, and for the hydrogeologist with some experience in transport modeling, who is interested in alternative software tools and approaches. The objectives of this short course are:

- To familiarize participants with fundamental concepts and mathematical methods underlying contaminant transport simulation. Emphasis will be placed on the implications of these concepts and methods for solution of practical field problems.
- To develop the ability of participants to formulate effective modeling strategies, considering project goals, available data, and field conditions. Discussions will center on when and how one can benefit most from the use of transport simulation and what components of the transport process (advection, dispersion, and chemical reactions) should be included.
- To provide an introduction to software for particle tracking and contaminant transport simulation which is compatible with the U.S. Geological Survey modular flow model (MODFLOW) and can be applied to transient or steady-state situations in two or three dimensions. Participants will have the opportunity to work with the relevant software during the class.

Faculty: **Chunmiao Zheng**, Hydrogeologist, S.S. Papadopulos and Associates, Rockville, Maryland; Ph.D., University of Wisconsin. Zheng has extensive experience in ground-water flow and transport modeling. He has developed a general particle tracking code, PATH3D, and a modular solute transport code, MT3D, and has participated in numerous projects involving the simulation of large, complex field problems. Zheng is also currently teaching a groundwater modeling course at George Washington University. **Charles B. Andrews**, Vice President, S.S. Papadopulos and Associates, Rockville, Maryland; Ph.D., University of Wisconsin. Andrews is nationally known for his creative solutions to difficult ground-water problems. In addition to directing remedial investigations and feasibility studies at major Superfund sites throughout the United States, he has provided technical expertise in important water-right litigation. Andrews' extensive experience includes project formulation and management; field investigations; analytical and numerical modeling of groundwater flow, contaminant migration, and heat transport; and design of remedial plans for mitigating groundwater contamination. **Gordon D. Bennett**, Senior Associate, S.S. Papadopulos and Associates, Rockville, Maryland; M.S., Pennsylvania State University. Bennett is an internationally known hydrogeologist with over 34 years of experience in groundwater hydrology, including 30 years with the U.S. Geological Survey, where he served as Chief of the Ground Water Branch and Assistant Chief of the Water Resources Division. Recipient of the 1981 O.E. Meinzer Award, Bennett has numerous publications in the field of well hydraulics and simulation techniques.

Limit: 30. Fee: $295; includes course manual and lunch both days.

Description and Analysis of Fluid-Mineral Equilibria Using the SUPCRT91 Software Package. Friday, October 18, 8 a.m. to 5 p.m., Saturday, October 19, 8 a.m. to 5 p.m. San Diego Convention Center.

The SUPCRT91 software package, developed by the present faculty in collaboration with H.S. Helgeson, facilitates the practical use of recent theories, equations, and data that permit quantitative description of chemical equilibrium among minerals, gases, and aqueous species from 1 to 5000 bar and 0 to 1000° C. The objectives of this advanced course are to review these recent advances, provide hands-on instruction in the use of SUPCRT91, and emphasize its practical application to defined equilibrium constraints on geochemical processes in diverse geologic systems. Specific applications will be presented that demonstrate the effective use of SUPCRT91 in geochemical studies of the ground-water environment, diagenetic systems, hydrothermal ore deposits, and metamorphic terrains. Although a background in theoretical geochemistry and experience using interactive software is helpful, the course is recommended for any advanced graduate student or professional who wishes to apply thermodynamic calculations and computer technology to solve geochemical problems. Each participant will receive a notebook of course materials: a user's manual for the SUPCRT91 package, lecture notes, reprints of relevant publications, and diskettes containing the SUPCRT91 source codes and database. Topics covered include:

- equations used to present the thermodynamic and electrostatic properties of H_2O,
- the revised Helgeson-Kirkham-Flowers equation of state for aqueous species,
- correlation algorithms for estimating the thermodynamic properties of aqueous species,
- equations used to describe the thermodynamic properties of minerals and gases,
- hands-on use of SUPCRT91: class and self-paced tutorials on the Mac II,
- geochemical information that can be obtained from SUPCRT91 calculations,
- practical application of SUPCRT91 to diverse geologic systems.

Faculty: **James W. Johnson**, Earth Sciences Department, Lawrence Livermore National Laboratory; Ph.D., University of Arizona. A research scientist at Lawrence Livermore National Laboratory since 1987, Johnson's research focuses on numerical modeling of transport and chemical processes in geologic systems. His areas of expertise include solvent and solute equations of state, fluid-mineral equilibria, critical phenomena in hydrothermal systems, thermodynamic databases, and software engineering. **Eric H. Oelkers**, Department of Geology and Geophysics, University of California; Ph.D., University of California. A post-doctoral fellow since 1988, Oelkers' research focuses on chemical transport and fluid/rock interaction in geochemical processes. His areas of expertise include prediction of the thermodynamic and transport properties of aqueous species and the calculation of chemical mass transport as functions of time and distance. **Everett L. Shock**, Department of Geology and Geophysics, Washington University; Ph.D., University of California. An Assistant Professor at Washington University since 1987, Shock's research involves fluid/rock interactions throughout crustal conditions. His areas of expertise include evaluation of diverse experimental data within a theoretical framework, estimation of the thermodynamic properties of aqueous species including organics and metal-ligand complexes, transport of metals at magmatic-hydrothermal conditions, and application of metastable equilibrium constraints to the study of hydrothermal alteration of organic matter.

Limit: 60. Fee: $295; includes course manual, computer diskettes, and lunch both days.

Deformation and Kinematics of High Strain Zones. Saturday, October 19, 8 a.m. to 5 p.m., Sunday, October 20, 8 a.m. to 5 p.m. San Diego

Short Courses *continued on p. 106*

Short Courses *continued from p. 105*

State University. Cosponsor: *Structural Geology and Tectonics Division.*

Designed for professionals and graduate students, participants in this course will be introduced to the techniques used in the determination of finite strain state and kinematic history of ductilely sheared rocks. The course will provide hands-on exercises in the analysis of rock deformation and preserved microstructures using petrographic microscopes and Macintosh computers. Only limited computer experience is required and no previous knowledge of microstructural analysis is necessary. Throughout the course, emphasis will be placed on the recognition of diagnostic criteria for general shear and its partitioning into pure shear and simple shear components. Topics covered:

- basic theory of purely simple shear and simply pure shear strain,
- deformation mechanism theory and kinematic analysis and their application to preserved microstructures,
- homogeneous and heterogeneous strain analysis using simple graphical methods,
- using Macintosh computer programs to teach the concepts of strain and kinematic theory,
- theoretical and kinematic basis for the analysis of general shear zones, i.e., those in which both pure shear and simple shear operate.

Faculty: **Carol Simpson**, Dept. of Earth and Planetary Sciences, Johns Hopkins University; Ph.D., ETH Zurich. Simpson is also a Visiting Scientist at the National Science Foundation in the position of Program Director for Tectonics. Her research interests are in the processes and kinematics of deformation in middle to lower crustal rocks. **Declan De Paor**, Dept. of Earth and Planetary Sciences, Johns Hopkins University; Ph.D., National University, Ireland. De Paor's research interests are in the mathematical basis of rock deformation, computer applications in structural geology, and field studies of displacement, deformation, and sedimentation in orogenic belts. He has developed software for a wide range of structural geology applications.

Limit: 50. Fee: $175; includes course manual, computer disks, ground transportation to and from San Diego State University both days, and lunch both days.

Fractals and Their Use in Earth Sciences. Saturday, October 19, 8 a.m. to 5 p.m., Sunday, October 20, 8 a.m. to 5 p.m. San Diego Convention Center.

Fractal geometry provides a means of mathematically describing and modeling some of the complex patterns that earth scientists map, measure, and describe in ever-increasing detail. Fractal geometry is a branch of mathematics for quantifying how the geometry of patterns changes from one scale to another. It provides a powerful tool for analyzing the roughness, size distribution, density or frequency of objects over a range of scales in time or space. Appropriate for government, academic, and industry earth scientists, including graduate students, this course is an introduction to the concepts of fractal geometry, and will include:

- the concepts of self-similarity and self-affinity,
- stochastic fractals,
- generation of synthetic fractals,
- methods for measuring the fractal dimension of earth science data sets,
- fractals and probability.

The purpose of the course is to enable participants to comprehend the fractal literature and to measure the fractal properties of their own data sets.

Faculty: **Christopher C. Barton**, Research Geologist, U.S. Geological Survey, Denver; Ph.D., Yale University. Barton has spent the past year as a U.S. Geological Survey G.K. Gilbert fellow pursuing fractal applications in the geosciences with Benoit B. Mandelbrot (the "father of fractals") at Columbia and Yale Universities. He and Paul LaPointe organized the symposium "Fractals in Geology" for the 1988 GSA Annual Meeting. He is the senior editor of two forthcoming books on fractals, *Fractal Geometry and Its Uses in the Earth Sciences* (GSA), and *Fractal Geometry and Its Uses in the Petroleum Industry* (AAPG). Barton has published several papers using fractal geometry to characterize the scaling law for fracture patterns in rocks for fluid-flow modeling of fractured rock. **Paul R. LaPointe**, Technical Coordinator for Mathematical Geology and Reservoir Assessment, ARCO Oil and Gas Co., Plano, Texas; Ph.D., University of Wisconsin. With over 15 years of experience in the application of mathematics and statistics to problems in geotechnical engineering and petroleum geology, LaPointe has published more than a dozen papers and monographs on quantitative spatial geological analysis. His research has focused on the geostatistical and fractal description of rocks and rock masses with an emphasis on natural rock fracture patterns and resource assessment. He is presently a Principal Research Geologist in the Research and Technical Services Division of ARCO Oil and Gas Company. **Alberto Malinverno**, Post-Doctoral Research Scientist, Lamont-Doherty Geological Observatory of Columbia University; Ph.D., Columbia University. Malinverno's research interest in fractals concerns mainly the quantification and analysis of submarine topography, especially abyssal hills (volcanic and tectonic features generated at the axis of mid-ocean ridges). Malinverno has taught a seminar on fractal geometry and its applications to the earth sciences for graduate and undergraduate students of Columbia University.

Limit: 60. Fee: $255; includes course manual, *Fractals* by Jens Feder, and lunch both days.

Quantitative Sedimentary Basin Modeling. Saturday, October 19, 8 a.m. to 5 p.m., Sunday, October 20, 8 a.m. to 5 p.m. San Diego Convention Center. Cosponsor: *Sedimentary Geology Division.*

ATTENTION STUDENTS: The Sedimentary Geology Division will SUBSIDIZE ALL STUDENTS WHO ARE VALID DIVISION MEMBERS. The student MUST PAY THE FULL COURSE FEE when registering, but will be reimbursed $50 after the GSA meeting by the Sedimentary Geology Division. To be reimbursed, students must apply in writing to: Dr. Mary J. Kraus, Department of Geology, University of Colorado, Boulder, CO 80309.

This course is aimed at those with a background in sedimentary geology, but with little experience in modeling. A basic undergraduate level background in mathematics is assumed. Divided into two parts, this course will first introduce researchers to the concepts and methods of constructing and modeling basin subsidence histories in various tectonic settings, and secondly, deal with how basin subsidence interacts with other primary factors, such as sediment supply and sea level, in the development of basin-filling stratigraphy. Both parts of the course show the essential math involved in basin modeling and provide an overview of much of the recent literature on quantitative basin analysis. Covered in the course will be:

- why basins form and subside—an overview,
- how to analyze basin subsidence histories, including: geohistory analysis, compaction corrections, and backstripping,
- thermal mechanisms affecting basin subsidence, including: thermal isostasy, uniform and nonuniform stretching models,
- lithospheric loading and basin flexure, including: thrust belts and foreland basins, and intraplate stress,
- summary of basin subsidence mechanisms in various tectonic settings,
- modeling the development of basin filling sequences generated by the interaction of subsidence, sediment supply, and sea level changes.

Faculty: **Charles L. Angevine**, Dept. of Geology and Geophysics, University of Wyoming; Ph.D., Cornell University. Angevine specializes in quantitative modeling of geologic processes; his current research interests include the thermal and flexural evolution of sedimentary basins and the stratigraphic sequence development of passive margins and foreland basins. **Paul L. Heller**, Dept. of Geology and Geophysics, University of Wyoming; Ph.D., University of Arizona. Heller's research interests include sedimentation, tectonics, and basin analysis. He is currently studying the influence of sedimentation, subsidence, and sea-level changes on basinal stratigraphy. **Chris Paola**, Dept. of Geology and Geophysics, University of Minnesota; Sc.D., Massachusetts Institute of Technology and Woods Hole Oceanographic Institution. Paola's specialty is sediment transport in modern and ancient systems with an emphasis on interaction between subsidence patterns and basin filling.

Limit: 100. Fee: $165; includes course manual and lunch both days.

Thermochronology: Applications to Tectonics, Petrology, and Stratigraphy. Saturday, October 19, 8 a.m. to 5 p.m., Sunday, October 20, 8 a.m. to 5 p.m. San Diego Convention Center.

Aimed at the *non*-isotope geologist, the objective of this course is to use actual case studies to illustrate how mineral geochronologic data can be applied to problems in tectonics, petrology, and stratigraphy. Participants will first be brought to a similar level of understanding of the isotope systematics for the U-Pb, Rb-Sr, $^{40}Ar/^{39}Ar$, and fission track dating techniques that are the common systems used in thermochronologic studies. The remainder of the course will be spent presenting and discussing how these techniques have been applied to solving the following problems:

- chronology of faulting and sequence of tectonic development,
- timing of peak metamorphisms and chronology of prograde and retrograde metamorphic processes,
- development of regional chronostratigraphic relationships,
- definition of denudation, uplift, and burial histories,
- chronology and rate of the mineralization process.

The various isotopic systems and minerals to be discussed will include:

- U-Pb; zircon, monazite, titanite (sphene), apatite, baddeleyite,
- Rb-Sr; hornblende, muscovite, biotite,
- $^{40}Ar/^{39}Ar$; hornblende, muscovite, biotite, K-feldspar, plagioclase,
- fission track; apatite, zircon, sphene.

Faculty: **John F. Sutter**, U.S. Geological Survey, Reston; Ph.D., Rice University. With strong expertise in $^{40}Ar/^{39}Ar$ geochronology and regional tectonics, Sutter has taught thermochronology courses for universities, petroleum companies, the GSA Northeastern Section, and the Soviet Union. The recipient of the Distinguished Teaching Award from Ohio State University, and the Carey Croneis Distinguished Alumni Lecturer Award from Rice University, Sutter has also received a Best Paper Award from the U.S. Geological Survey. **Peter K. Zeitler**, Dept. of Geological Sciences, Lehigh University; Ph.D., Dartmouth College. Zeitler's expertise is in the uplift, denudation, and burial histories of orogenic belts and their foreland basins using U-Pb (ion microprobe), $^{40}Ar/^{39}Ar$, fission track, and thermal modeling techniques. Zeitler's active research projects include the Himalayas, Andes, Appalachians, and Australia. **Robert D. Tucker**, Geochronology Laboratory, Royal Ontario Museum, Toronto; Ph.D., Yale University. Tucker's expertise is in field-oriented structural geology, petrology, and tectonics. He is the author of numerous papers on the application of U-Pb mineral isotopic systems to a wide variety of problems in the Scandinavian Caledonides, northern Appalachians, and the Canadian Grenville Province.

Limit: 40. Fee: $215; includes course manual and lunch both days.

Assessing the Mobility of Chemicals in the Vadose Zone. Sunday, October 20, 8 a.m. to 5 p.m. San Diego Convention Center. Cosponsor: *Engineering Geology Division.*

ATTENTION STUDENTS: The Engineering Geology Division will SUBSIDIZE THE FIRST FIVE STUDENTS WHO ARE VALID DIVISION MEMBERS. The student MUST PAY THE FULL COURSE FEE when registering, but will be reimbursed $50 after the GSA meeting by the Engineering Geology Division.

This course is targeted at practicing geologists with a limited background in environmental chemistry. The objective of the course is to provide some of the basic techniques necessary to evaluate the mobility of chemicals in both the vapor and aqueous phases of the soil. This type of evaluation is critical in selecting appropriate treatment alternatives and in assessing the hazards involved with leaving contamination in place. Topics covered:

- establishing site-specific concentration limits for soil contamination,
- identification of soil parameters which are critical in evaluating chemical mobility (e.g., moisture content, organic carbon content, porosity),
- identification of physical properties which are critical in evaluating chemical mobility (e.g., solubility, vapor pressure, partitioning coefficients),
- design of subsurface investigations to produce the type of data required to evaluate the mobility of chemicals,
- review of assumptions which are routinely employed to assess the mobility and persistence of vadose zone contaminants,
- equilibrium and kinetic factors involved in phase partitioning,

- vapor phase migration by diffusion and advection,
- aqueous phase migration via infiltrating water,
- review of available models to predict contaminant mobility,
- justification and verification of mobility predictions.

Faculty: **Donn L. Marrin**, Chief Executive Officer, InterPhase, San Diego; Ph.D., University of Arizona. An adjunct professor at San Diego State University, Marrin is the author of numerous journal articles and book chapters focused on the fate and transport of subsurface chemicals. His current research projects cover the biological degradation of organic chemicals to produce greenhouse gases.

Limit: 50. Fee: $105; includes course manual and lunch.

Computered-aided Illustration in Geology. Sunday, October 20, 8 a.m. to 5 p.m. San Diego Convention Center. Cosponsor: *National Association of Geology Teachers.*

This course provides an introduction to computer-aided illustrating in the geological sciences. The course focuses on hands-on training to construct geological illustrations such as index and geologic maps, stratigraphic columns, graphs, and other diagrams on a Macintosh computer using a graphic illustrator's program, Adobe *Illustrator 88* version 3.0. (*Illustrator* is available in DOS, Mac, and NeXT versions.) Of interest to any geologist who needs to make attractive and accurate illustrations for publication or teaching purposes; graduate students will find this course particularly useful for preparing thesis illustrations. *Each registrant will be provided with a computer.* Some prior computing experience is necessary, especially basic keyboarding skills, familiarity with mouse techniques, and a working knowledge of a graphical user interface such as Windows 3, the Macintosh GUI, or NeXTstep. Numerous simple techniques and topics will be presented, including:

- drawing straight lines, curves, ovals, and polygons,
- using auto-tracing,
- applying transformations such as scaling, shearing, rotating, and reflecting,
- handling text (fonts and object wrapping);
- using geologic symbol and pattern libraries,
- designing patterns,
- using fill and stroke for text and lines,
- using masks,
- blending objects for shading,
- scanner and laser printer tips and tricks.

Faculty: **Gary A. Novak**, Chairman, Department of Geological Sciences, California State University, Los Angeles; Ph.D., Virginia Polytechnic Institute and State University. Trained as a mineralogist, Novak has for several years concentrated on personal computer applications for geologists. He has led workshops in computer-aided teaching for science and humanities faculty and is president of the California State University at Los Angeles NeXT Users Group. Novak teaches graduate and undergraduate courses in computer graphics, spreadsheet applications, and desktop publishing.

Limit: 20. Fee: $295; includes course manual, disks containing course-related files, and lunch.

Earthquakes and Earthquake Preparedness. Sunday, October 20, 8 a.m. to 5 p.m. San Diego Convention Center. Cosponsors: *Geophysics Division* and *National Association of Geology Teachers.*

The October 1989 Loma Prieta earthquake and the recent prediction of a large earthquake in Missouri have significantly raised public awareness about the need for earthquake preparedness, both in California and in other states. This new awareness provides an excellent opportunity for geology departments to broaden their course offerings and increase their enrollments by offering a course on Earthquakes and Earthquake Preparedness. This outstanding course is designed for faculty from universities, four-year colleges, and junior colleges who would like to teach a lower division course in earthquakes but either lack the background they feel they need or lack the confidence to organize what they do know into a coherent course. Special attention will be given to the mechanics of organizing and teaching an introductory level course on earthquakes and earthquake preparedness. Other non-specialists interested in the topic are also welcome to attend. Topics covered include:

- once around the world—important recent and not-so-recent earthquakes,
- suddenly last summer—perceived effects of earthquakes,
- rock around the clock—basic principles of seismology,
- a crack in the earth—the revolution in plate tectonics,
- dancing in the dark—the art of lecturing with slides,
- it wasn't my fault—faults and fault hazards in the United States,
- shake, rattle, and roll—seismic hazards off the fault,
- don't build your house of bricks—earthquake engineering made simple,
- an ounce of prevention—earthquake preparedness for you and your home,
- my cat warned me—fact and fiction about forecasting and prediction,
- one step ahead—coping with large classes.

(Note: Due to the popularity of this topic, preregistration is strongly recommended.)

Faculty: **Kenneth L. Verosub**, Department of Geology, University of California, Davis; Ph.D., Stanford University. Verosub has been involved with earthquake education and earthquake preparedness since he arrived at the University of California in 1975. The lower division undergraduate course on earthquakes and other geologic hazards that he has taught for the past 16 years typically enrolls 250 to 300 students. Recipient of a Distinguished Teaching Award from the Academic Senate of the University of California at Davis and a member of the Earthquake Engineering Research Institute, Verosub has delivered many public lectures on earthquakes and earthquake preparedness to government, professional and civic groups, and to high school and elementary school classes. As the spokesperson on earthquakes at the University of California at Davis, Verosub has been interviewed many times by the press and the local television and radio stations. Verosub's primary research interest is sedimentary paleomagnetism and its application to geophysical and geological problems, and the majority of his 79 published papers and 128 published abstracts deal with this topic.

Limit: 100. Fee: $105; includes course manual, set of thirty 35-mm color slides, and lunch.

Hydrogeologic and Environmental Applications of Stable Isotopic Systems. Sunday, October 20, 8 a.m. to 5 p.m. San Diego Convention Center.

This course is designed to address the theory and applications of stable isotopes to hydrogeology and environmental geology. Background information will be provided for each isotopic system discussed so that the course will be appropriate for upper division undergraduates, graduate students, faculty members, and geoscientists in the commercial sector. Each application or case study will focus on a specific isotopic system, its utility, and potential limitations. For example, topics which will be used to introduce Sr, Pb, and light stable isotopic systems will include:

- fate and transport of fossil fuel waste (hydrocarbons, coal),
- source apportionment of heavy metals at Superfund sites,
- tracking of organics by stable and Pb isotopic systems.

Integrated isotopic studies will be presented in order to evaluate which isotopic systems are most appropriately used in a given situation.

Faculty: **Richard W. Hurst**, Department of Geology, California State University, Los Angeles; Ph.D., University of California, Los Angeles. Hurst began his career in 1968 as an AEC undergraduate fellow studying rare gases in lunar soils. He joined the faculty at California State University, Los Angeles in 1978 where he began the development of isotopic techniques to fingerprint biogeochemical processes. He has published one volume on environmental isotopes and 14 articles on the subject, and he develops short courses in forensic geochemistry. Recent honors include his nomination for the Outstanding Professor Award from California State University at Los Angeles, invited semminars on forensic geochemistry (DOE/EPA Hazmat meetings), and serving as an associate editor for the Society of Environmental Geochemistry and Health.

Limit: 50. Fee: $120; includes course manual and lunch.

Applications of Radar Remote Sensing: Terrestrial and Planetary. Friday, October 25, 8 a.m. to 5 p.m. Downtown hotel to be named. Cosponsor: *Planetary Geology Division.*

ATTENTION STUDENTS: The Planetary Geology Division will SUBSIDIZE THE FIRST TWO STUDENTS WHO ARE VALID DIVISION MEMBERS. The student MUST PAY THE FULL COURSE FEE when registering, but will be reimbursed $100 after the GSA meeting by the Planetary Geology Division.

In August 1990, NASA's Magellan spacecraft began systematic mapping of Venus using side-looking synthetic aperture radar (SAR) to penetrate the dense clouds surrounding the volcanically and tectonically complex planet. The quality of the radar image data being returned from Magellan has been outstanding. The use of SAR in geologic investigations is not limited to Venus, however, but is becoming one of the new breed of remote sensing tools for studying Earth. This sophisticated technology has been applied to Earth from aircraft, the Space Shuttle, and unmanned spacecraft to detect geologic features, structural relations, and other surface (and subsurface) phenomena not visible or so well enhanced by conventional sensors. This course is designed for students and educators in the geosciences who desire to learn about or be brought up to date on the latest applications of radar imaging in remote sensing exploration of Earth and other planetary bodies. Topics covered:

- basics of radar frequency sensors, including how images are obtained and processed and how they differ from conventional visible wavelength images,
- surface properties (terrestrial and extraterrestrial) that can be determined using radar systems of different wavelength and polarization options,
- an overview of the use of SAR for geologic applications,
- case studies, including the use of SAR data from the Shuttle Imaging Radar Experiments, the NASA aircraft (AIRSAR) program, as well as from the current Magellan radar mapping mission to Venus.

Faculty: **Gerald G. Schaber**, Astrogeologist, U.S. Geological Survey, Flagstaff; Ph.D., University of Cincinnati. Well known in the field of radar-remote sensing, Schaber has worked for the U.S. Geological Survey since 1965. An active participant in radar geologic research soon after its inception, he was a Team Member of the Apollo 17 Lunar Sounder Experiment in 1973. As a Co-Investigator on the first Shuttle Imaging Radar Experiment (SIR-A) in late 1981, Schaber was a member of the U.S. Geological Survey team that discovered and investigated the existence of now-relict ancient river channels buried by sand in the presently hyperarid Sahara Desert in southern Egypt and northwest Sudan, and portrayed on SIR-A images. For this discovery, Schaber and his colleagues were awarded the Autometric Award of the American Society of Photogrammetry. He is presently a Team Member of an arid lands experiment on the European Space Agency's ERS-1 SAR mission, and a Co-Investigator on the SIR-C Radar Experiment, the Earth Observing System SAR (EOS SAR), and the Magellan radar mapping mission to Venus. He received NASA's Outstanding Achievement Award in 1982 for participation in the Shuttle Imaging Radar (SIR-A) Development Team, and the U.S. Geological Survey's Meritorious Service Award in 1988. **Tom G. Farr**, Supervisor, Radar Science Group, Jet Propulsion Laboratory, Pasadena; Ph.D., University of Washington. Since joining JPL in 1975, Farr has participated in the Arctic Ice Dynamics Joint Experiment, the Seasat radar project, the Shuttle Imaging Radar-A (SIR-A), and the Geological Remote Sensing Field Experiment. Involved with Shuttle Imaging Radar C, a study of the geomorphology of northern China, Farr's interests include geological remote sensing of both Earth and other planets and the study of terrestrial volcanic surfaces for their planetary applications. His current research includes the use of remote sensing for correlation and mapping of desert surfaces produced and modified by past climate changes and the development of new, quantitative techniques for geologic interpretation of radar images.

Limit: 50. Fee: $135; includes course manual, precourse reception on Thursday evening, and lunch on Friday.

Contaminant Hydrogeology: Practical Monitoring, Protection, and Cleanup. Friday, October 25, 8 a.m. to 5 p.m., Saturday, October 26, 8 a.m. to 5 p.m. Downtown hotel to be named. Cosponsor: *Hydrogeology Division.*

ATTENTION STUDENTS: The Hydrogeology Division will SUBSIDIZE

Short Courses *continued on p. 108*

Short Courses *continued from p. 107*

THE FIRST STUDENT WHO IS A VALID DIVISION MEMBER. The student MUST PAY THE FULL COURSE FEE when registering, but will be reimbursed $50 after the GSA meeting by the Hydrogeology Division.

For newcomers and entry-level professionals who are interested in practical contaminant hydrogeology as it is applied daily to soil and ground-water contamination problems. This course emphasizes the consultant working approach to solving hydrogeologic problems of data collection, interpretation, and remediation as required by government regulation. This course will *not* include rigorous mathematical ground-water contamination modeling. Topics covered:

- theoretical and practical elements of geologic and hydrogeologic investigations,
- subsurface drilling procedures and sampling,
- monitoring well construction,
- water sampling techniques,
- contaminant transport and fate—general concepts,
- data interpretation,
- aquifer analysis—general concepts,
- criteria for selecting monitoring and remediation procedures,
- site cleanup,
- regulations,
- client and budgetary considerations.

Case histories explore the application of investigation techniques for UST, CERCLA, and RCRA projects, hazardous waste landfill siting, leaking underground tanks, and contaminated properties in several states.

Faculty: **Christopher M. Palmer**, Senior Geologist, Exceltech, Inc., Fremont, California; M.A., California State University. A registered geologist in California, Arkansas, and Florida, Palmer has 13 years of engineering geology and hydrogeology consulting experience for soil and ground-water quality, UST, RCRA, and landfill siting studies, and teaches contaminant hydrogeology at the University of California—Extension, Santa Cruz. Palmer is also a California Registered Environmental Assessor. **Jeffrey L. Peterson**, Senior Hydrogeologist, GeoStrategies, Inc., Hayward, CA; M.S., California State University. A registered geologist and a California Registered Environmental Assessor, Peterson has 12 years of consulting experience in geology, soil and ground-water quality, and contaminant hydrogeology dealing with UST, RCRA, and CERCLA investigations. He has performed RI/FS investigations for the U.S. Department of Defense sites. Peterson has conducted hazardous-waste investigation methods seminars, and workshops at California State University campuses, in addition to teaching introductory ground-water hydraulics at the University of California—Extension, Santa Cruz.

Limit: 40. Fee: $195; includes course manual and lunch both days.

Sedimentary Basin Systems. Friday, October 25, 8 a.m. to 5 p.m., Saturday, October 26, 8 a.m. to 5 p.m. Downtown hotel to be named. Co-sponsor: *Sedimentary Geology Division.*

ATTENTION STUDENTS: The Sedimentary Geology Division will SUBSIDIZE ALL STUDENTS WHO ARE VALID DIVISION MEMBERS. The student MUST PAY THE FULL COURSE FEE when registering, but will be reimbursed $50 after the GSA meeting by the Sedimentary Geology Division. To be reimbursed, students must apply in writing to: Dr. Mary J. Kraus, Department of Geology, University of Colorado, Boulder, CO 80309.

This course is designed for faculty in four-year colleges and M.S. degree programs; M.S. and Ph.D. graduate students; practitioners in oil and mining companies; hydrologists and engineering geologists; managers in oil, mining, or engineering firms; and professional earth scientists in state and federal agencies. Devoted to providing a systematic overview of basin analysis and sedimentary geology, the goal of this course is to stress the interdisciplinary aspects of basin analysis, focusing on how geodynamic processes of basin formation influence both the nature of sediment fills and the maturation of the sediment through diagenesis, fluid circulation, and thermal history. Additional topics covered:

- basin classification,
- paleogeography,
- sedimentary facies,
- black shales,
- cratonic sequences,
- sea level history—sequence and seismic stratigraphy,
- pelagic cycles,
- clastic diagenesis,
- fluid migration through sedimentary basins.

These topics will be used to illustrate the role of interpreting sediments as a barometer of basin tectonic processes, and extrinsic basinal processes during basin evolution. Basin analyses from the Arkoma and Illinois basins, the North Sea, and the Pacific Ocean back-arc basins, illustrating the interdisciplinary approaches, will be discussed. This course is a revised version of a comparable one-day course presented at the 1987 GSA Annual Meeting in Phoenix and a comparable two-day course presented at the 1989 GSA Annual Meeting in St. Louis.

Faculty: **George DeV. Klein**, Department of Geology, University of Illinois at Urbana-Champaign; Ph.D., Yale University. Klein has more than 25 years of experience and is the author of more than 100 publications.

Limit: 100. Fee: $145; includes course manual and lunch both days.

Arrive by Van or Pogo Stick; Camp or Stay in Style—There's Something for Everyone in San Diego!

TRAVEL

Getting To San Diego

By Air. San Diego International Airport—Lindbergh Field is one of the few airports to be only 15 convenient minutes from the Convention Center. Most hotels have free shuttle pick-up. Consider staying over Saturday night in San Diego for significant airfare savings.

By Car. San Diego is about a 2 1/2-hour drive from downtown Los Angeles via freeway route Interstate 5, which stretches from Canada to the Mexican border. Interstate 8 serves drivers from Yuma, Arizona, and beyond from the East Coast. Interstate 15 provides access from Nevada, Utah, Idaho, and Montana.

By Train and Bus. Amtrak passenger trains provide service to and from Los Angeles. Greyhound and Trailways provide bus service. Call the offices in your area to get the best rates.

Getting Around In San Diego

An excellent freeway system makes travel by car or bus easy throughout the county. San Diego Transit Corporation buses serve the metro area. Taxi service, inexpensive rental cars, and tour buses are readily available. In San Diego, call The Transit Store, 233-3004, for schedule information.

San Diego Trolley. The modern San Diego Trolley provides an excellent, inexpensive service in the downtown area; between downtown and the Mexican border; and to San Diego's East County.

GSA Shuttle. The shuttle will supplement trolley access to the San Diego Convention Center and to the Marriott Hotel and Marina, which will be home to all the meeting events. The shuttle will provide a convenient, daytime, free shuttle serving the GSA-selected downtown hotels and the Convention Center. The shuttle will also operate on Sunday, Monday, and Tuesday evenings.

LODGING

Tight budget? We're on your side. We've gotten the best possible rates for October including discounts of 30% or more. We've booked 12 properties that include a good cross section of lodging in the downtown area that should appeal to almost everyone's budget and taste.

We have reserved 300 rooms in various small Travelodge properties either downtown or within three miles of the downtown area and negotiated a special flat rate of $45 for one to four people. You may need to provide your own transportation.

Over and above the 1000 rooms at the headquarters hotel, there are 700 single rooms priced between $70 and $85, and 425 single rooms between $50 and $69. There is an excellent set of options within this group, including four-star properties and basic motels. All meet GSA's standards for rate reliability, cleanliness, service, and location.

The most outstanding property in the luxury class is GSA's headquarters, the Marriott Hotel and Marina, which is truly an impressive property. Immediately adjacent to the Convention Center and Seaport Village, it offers first-class services, dining, and a resort atmosphere right on San Diego Bay. Rates at $125 single and $149 double are the best group rates available in October and worth the cost by California standards.

Be sure to register in August to get the hotel you want. Hotel information and reservation forms will be available in the August issue of *GSA Today*. All housing, except suites, will be processed by the San Diego Housing Bureau. Please call the GSA Housing Coordinator for suite information.

ALTERNATIVE HOUSING

Beating the high cost of housing is a high priority of GSA staff and the 1991 Local Committee. Here are some alternatives:

- Call 1-800-555-1212 or check the Yellow Pages to learn the 800 number for your favorite hotel chains, such as Motel 8 or Comfort Inns, which have properties outside the downtown area.
- Check your library copy of the Hotel and Motel Redbook, which lists metro properties. Because of the hundreds of properties in the area (some good, some bad), GSA does not provide a general list.
- Consider camping or taking the trolley to/from El Cajon. The San Diego Local Committee has researched low-cost alternatives, including camping or other motels south of San Diego. Tent and RV campgrounds are available near the San Diego County foothills or on Mission Bay. Advanced reservations are required, and nightly fees range from $16 to $30. For additional information, contact Vanessa George, GSA Housing Coordinator.

CHILD CARE

Families should consider bringing their children to San Diego because of the variety and quality of family activities within the metropolitan area.

Due to prohibitive insurance costs and the legal issues that surround child care, daycare service will not be provided by GSA. We want to make it as convenient as possible, however, for families to make arrangements. Among the options provided are:

- GSA coordinates a family cooperative service in which parents can share responsibilities for caring for their children. After August 1, the GSA Meetings Coordinator will accept names, addresses, and phone numbers of interested parents. You may also include information on your children, and where you will be staying. In early October, the information will be mailed to everyone who has responded. Participants are responsible for contacting one another and making arrangements.
- San Diego has several excellent private child-care agencies. Although GSA cannot endorse any of these agencies, we are happy to give the names and phone numbers to you. Call the GSA Meetings Coordinator. You may also call the San Diego Marriott concierge, (619) 234-1500, for local child-care services.
- GSA will be providing a room for children and parents to relax together at the Convention Center. It will be a clean, quiet room with basic furnishings (no cribs or playpens). ■

ATTENTION STUDENTS: Some of the divisions that offered to subsidize division-affiliated students who registered for a 1990 Short Course never got the opportunity to make good. Why? Because too few division-affiliated students registered! Think about it.

RISING AIRFARES?
BEAT THEM WITH DISCOUNTS!

Call CAIN TRAVEL GROUP Today

(official travel agency for the San Diego meeting)

Cain offers up to 45% off coach*, and guarantees to meet or beat any airfare quote.

You can't lose. Book today. If airfares drop, Cain will automatically reissue your ticket at the lower rate!

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SHOP AROUND, BUT BE SURE TO CALL CAIN.

---

* Restrictions and penalties may apply. As with all airline reservations, please use caution regarding change and cancellation penalties that accompany low-fare tickets. This applies especially to field trip participants, whose trips may be canceled after the September 20 preregistration deadline.

Special Discount Fares. Cain can handle your Special Discount reservations too with no additional charge.

- There are several coupon offerings that are available as we go to print. Look for these and other specials in your area:
  - — American Express has been offering $129 roundtrip discount coupons to students who apply for the credit card. (You'll have to pay the annual dues of $55 upfront.) Check your campus bookstore.
  - —Gold "C" Coupon Book has a coupon with $100-off Continental fares.
- Over 55? Over 60? Several airlines offer 10% discounts.
- A few airlines still offer family discounts.
- Some airlines are dropping fares and offering no-penalty terms. Secure these special rates with a credit card reservation.

Call for Nominations 1991 John C. Frye Environmental Geology Award

In cooperation with the American Association of State Geologists, GSA makes an annual award for the best paper on environmental geology published each year, either by GSA or by one of the state geological surveys. The award is a $500 cash prize from the endowment income of the Foundation's John C. Frye Memorial Fund. Recipients of the first award, presented in 1990, were Linda Lawrance Noson, Anthony I. Qamar, and Gerald W. Thorsen for their paper "Washington State Earthquake Hazards" (Washington Division of Geology and Earth Resources Information Circular 85).

Nominations can be made by anyone, based on the following criteria: (1) paper must be selected from Geological Society of America or State Geological Survey publications, (2) paper must be selected from those published during the preceding three calendar years, (3) nominations should be sent to the Executive Director of the Geological Society of America, with a paragraph stating the pertinence of the paper, (4) deadline for receipt of nominations is *June 30, 1991*.

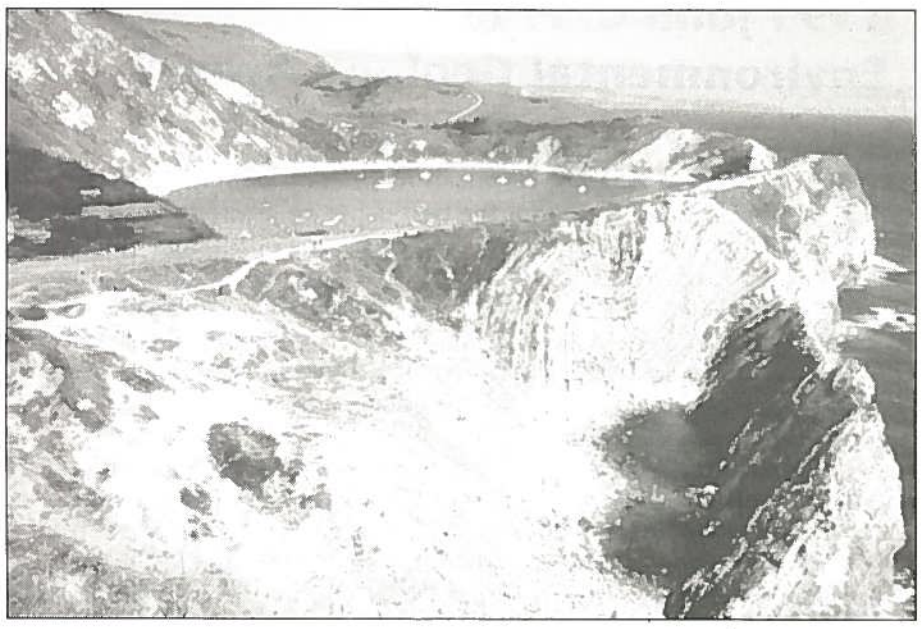
In addition, nominated papers must:

- 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 addresses the environmental need or resolves the problem. It is highly desirable that the paper be directly applicable by informed laypersons (e.g., planners, engineers).

Basis for selection:

- Must meet the criteria for nomination.
- Must be judged as best of those nominated based on uniqueness or significance as a model of its type of work and report and its overall worthiness for the award.

The Selection Committee (Earl H. Bennett, John P. Kempton, and Frank E. Kottlowski) will make the selection in time for the award to be presented at the AASG meeting during the Annual Meeting of the Geological Society in the fall of the year.



Great Britain GeoTrip: Lulworth Cove in the Hampshire Basin of south-central England. *Photo by Dottie Stout*

GSA GeoHostels

Planning to visit the West this year?
Join us in June for GSA's FIRST GeoHostel

GeoHostel is a learning experience for geologists. It is site-specific with a combination of classroom and field experiences which start from the same location each day. A GeoHostel is held for five to seven days at a destination that is rich in geological interest as well as plentiful in opportunities for side excursions.

GeoHostels offer:

- an enjoyable experience with an educational focus on topics appealing to a wide range of geologists and their guests
- ample free time to enjoy the special environmental and cultural aspects of the location
- leadership by enthusiastic, well-organized geologists who can speak well and who can cover the topics at a level appropriate for the professional non-expert.

Colorado GeoHostel Program

Colorado School of Mines, Golden, Colorado
Five Days: Sunday, June 23–Thursday, June 27

Scientific Leaders:
Kenneth E. Kolm and Gregory S. Holden
Colorado School of Mines

Colorado School of Mines is set in the foothills of the Colorado Rockies and is conveniently located between Denver and Boulder. June will be a wonderful time to visit Colorado and the spectacular high country of the Rockies.

GH91A **Evolution of Geologic Landscapes in the Colorado Rockies,** 8:00–9:30 a.m.

GH91B **Environmental and Engineering Issues in Colorado,** 9:30–11:00 a.m.

These two geology classes will be offered each morning and include local field trips. They are meant for professional geologists who are not experts in this area, but anyone may attend. A person may take one or both classes.

GH2B **Old Mining Towns of the Rockies,** 9:30–11:00 a.m.

Also offered, primarily for the nongeologist, is a fascinating class on Colorado's mining towns. This class will include at least one full-day trip to visit several mining towns. Persons registering in this class will not be able to take either of the geology classes.

Registration
Minimum age: 21 years. No other limits.

Program
Saturday, June 22: Welcoming Get-together
Sunday, June 23 through Wednesday, June 26: Morning Classes
Thursday, June 27: Full Day Field Excursion and Farewell Party

Fees and Deposit
GeoHostel cost: $350 (nonmembers and guests)
Special discount rate for GSA members: $325
Fee includes classroom programs and materials, field excursions, lodging (double occupancy), breakfast, welcoming and farewell events.
Not included are transportation to and from Colorado, transportation during non-class hours, meals or other expenses not specifically included.

Call today. The full amount is due with your reservation, and is payable by credit card or check. The amount is 50% refundable through May 15, but non-refundable thereafter.

GSA GeoTrips

GT912

Great Britain's Classic Geologic Sites

2 SPACES STILL OPEN AS WE GO TO PRINT. CALL ASAP.

Co-sponsored by NAGT
21 days: Saturday, June 15–Saturday, July 6

Scientific Leaders:
Donald McIntyre, Pomona College
Ron Roberts, Geological Museum of London
D. H. Tarling, Plymouth Polytechnic Southwest

This special educational adventure is being coordinated by NAGT President Dorothy (Dottie) Stout, Cypress College, California, who has had abundant experience with geologic trips to our sites in Great Britain, Wales, and Scotland. The itinerary includes visits to the following geologically and historically colorful places: London, Chalk Cliffs, Lyme Regis, Sidmouth, Cornwall, Stonehenge, Bath, Isle of Arran, Parallel Roads of Glenroy, Hadrian's Wall, Great Glen Fault, Torridonians, Moine Thrust, Siccar Point, Edinburgh, and Newcastle-upon-Tyne. Full details available from GSA GeoVentures Coordinator.

Registration
Value fee includes double-occupancy lodging, ground transportation, leaders, materials, all breakfasts plus 15 dinners and a farewell fête, entry fees, and theater tickets. *Airfare not included, but excellent rates are available.*

Open to all geologists and their friends.
GSA and NAGT members will enjoy a $100 special discount.
Minimum age: 21 years. Trip limit: 30 persons.

Fees and Deposit
(*Late registration period began March 1*)

Cost: $3190 (based on 25-person minimum)
Special for GSA and NAGT Members: $3090

Our ground suppliers in Great Britain have generously agreed to a lenient cancellation policy. As a result, fees are 50% refundable up to 35 days prior to departure: May 10. (60 days is the usual cut-off time.)

Airlines are also more lenient about cancellation penalties, so please check with our official travel agent for this trip. She will have information about the airlines as well as details about the itinerary.

Jodi Page, CAN-AM TOURS
1560 Superior Ave., Suite A2
Costa Mesa, CA 92627-3653

1-800-367-9917 • (714) 645-7171 • fax 714-645-7464
8:30 a.m. to 5:30 p.m., Monday–Friday, PDT

GT913

Grand Canyon Adventure

FILLED.

An educational adventure: rafting, hiking, and camping
Sunday, July 14–Monday, July 22

Scientific Leaders:
George H. Billingsley, USGS, Flagstaff
William K. (Ken) Hamblin, Brigham Young University

GEOVENTURES REGISTRATION

REGISTER TODAY! CALL GSA GEOVENTURES

(Please have your credit card ready)

1-800-472-1988 or (303) 447-2020

Questions welcomed anytime

Non–U.S.-based registrants are encouraged to use
GSA's fax number: 303-447-1133
Give name(s), address, phone, GeoVenture title, and credit card number

DNAG NEWS

Allison R. (Pete) Palmer

More Kudos

Two more books were completed and in our hands in January and early February. The second Canadian volume to be completed, *Geology of the Continental Margin of Eastern Canada*, is now printed and available. This 855-page volume with 17 accompanying plates represents the work of 64 contributors who are listed in this column. Those individuals, and libraries who bought full DNAG sets at the prepublication price, when we expected volumes comprising 400–500 book pages and 10 plates, are beginning to realize what a great bargain they now have.

All chapter galleys for the volume *Economic Geology of the U.S.* have been reviewed by the editors, and production of the final camera-ready pages is under way. Most of the 58 authors whose contributions arrived as early as 1986 can finally see the results of their labors. Senior authors of those early chapters were solicited for "Notes Added in Proof" and a number of chapter texts received some valuable additions.

Many thanks to all of the contributors listed here for their contributions to their volumes and to the DNAG Project. They bring the total number of authors and co-authors in completed components of this monster project to 1691.

One of the two remaining chapters for *The Precambrian: Conterminous U.S.* has been received for review. Only 14 chapters, including three introductions, are needed to complete the last five volumes of *The Geology of North America*, and only three of these are still pending review. When Van Schmus (Precambrian), Nehring (Gulf of Mexico Basin), and Jones (Alaska) complete their responsibilities, all substantive chapters will have reached the review stage and the end is really in sight.

Finally, the last two chapters of *Quaternary Non-Glacial Geology; Conterminous U.S.* have been received. The book is now complete and final production is underway. Only six more books to go! (Kudos to the Quaternary authors next month.) ■

Geology of the Continental Margin of Eastern Canada

J. Adams
A. E. Aksu
C. L. Amos
P. Ascoli
H. R. Balkwill
J. V. Barrie
M. S. Barss
C. Beamont
J. S. Bell
S. M. Blasco
G. Bonham Carter
J. D. Brown
D. E. Buckley
J. P. Bujak
G. R. Campbell
B. D'Anglejan
R. W. Dalrymple
R. Davidson-Arnott
E. H. Davies
G. B. J. Fader
R. A. Fensome
R. Gillie
F. M. Gradstein
A. C. Grant
P. B. Hale
I. A. Hardy
J. R. Harper
R. T. Haworth
P. R. Hill
D. A. Hodgson
R. D. Howie
D. A. Huntley
L. F. Jansa
I. G. Jones
H. W. Josenhans
A. S. Judge
C. E. Keen
M. J. Keen
R. Klassen
C. F. M. Lewis
B. D. Loncarevic
K. D. McAlpine
N. J. McMillan
K. Moran
P. J. Mudie
R. A. Myers
V. H. Noguera
G. Pe-Piper
B. R. Pelletier
D. J. W. Piper
D. Praeg
I. Reid
S. P. Srivastava
B. Stam
J. P. M. Syvitski
R. B. Taylor
G. Vilks
J-S Vincent
J. A. Wade
G. L. Williams
H. Williams
M. A. Williamson
J. Woodside
C.M.T. Woodworth-Lynas

Economic Geology: U.S.

W. R. Almon
R. P. Ashley
E. A. Beaumont
K. J. Bird
M. W. Bodine, Jr.
J. A. Breyer
B. W. Bromley
D. A. Brobst
G. C. Calhoun
D. C. Callaway
J. B. Cathcart
W. L. Chenoweth
B. Claxton
J. Clendening
A. T. Cross
D. M. Curtis
G. R. Curtis
H. H. Damberger
H. G. Davis
W. De Witt, Jr.
A. C. Donaldson
J. R. Donnell
J. B. Dunham
C. F. Eble
J. E. Fassett
R. M. Flores
M. P. Foose
N. H. Foster
J. E. Fox
C. M. Garrett, Jr.
E. H. Glasson
H. J. Gluskoter
B. M. Hanson
R. L. Horak
S. J. Mazzullo
P. J. McCabe
D. E. McGookey
F. F. Meissner
R. C. Milici
J. T. Nash
R. A. Northcutt
E. L. Ohle
T. L. Phillips
B. K. Powers
O. B. Raup
A. M. Reid
E. W. Rennie, Jr.
C. R. Reszca, Jr.
D. D. Rice
V. J. Rosato
D. R. Shawe
G. B. Sidder
G. D. Stricker
R. B. Taylor
E. W. Tooker
R. R. Vincelette
M. A. Warner
R. G. Worl

1992–1993 Competition Opens for Fulbright Scholar Awards for U.S. Faculty and Professionals

The Fulbright Scholar Program for 1992–1993 includes some 1000 grants for research, combined research and lecturing, or university lecturing. Opportunities range from two months to a full academic year; many assignments are flexible to the needs of the grantee. Nearly one-third of Fulbright grants are targeted for research, and many lecturing awards offer research opportunities. There are openings in more than 100 countries; in many regions, multicountry research is possible. Virtually all disciplines and subfields participate. Many offerings throughout the program allow scholars to propose their own lecturing or research projects. Scholars in all academic ranks are eligible to apply, from junior faculty to professor emeriti. Applications are also encouraged from professionals outside academe and from independent scholars. Fulbright seeks good teachers as well as active researchers.

The basic eligibility requirements for a Fulbright award are U.S. citizenship and Ph.D. or comparable professional qualifications. For lecturing awards, university or college teaching experience is expected. Language skills are needed for some countries, but most lecturing assignments are in English. There is no limit on the number of Fulbright grants a scholar can hold, and former grantees may reapply.

Deadlines are **June 15, 1991**, for Australasia, South Asia, most of Latin America, and the U.S.S.R., and **August 1, 1991**, for Africa, Asia, Europe, the Middle East, and Canada and for lecturing awards in the Caribbean, Mexico, and Venezuela. Other deadlines are in place for special programs.

Application materials are now available. For further information and applications, call or write the Council for International Exchange of Scholars, 3007 Tilden Street, N.W., Suite 5M, Box NEWS, Washington, DC 20008-3009, telephone (202) 686-7877.

Paleontological Society Announces New Awards

The Paleontological Society has instituted the Golden Trilobite Awards to recognize excellence in paleontological publishing, including writing, editing, and book design. The three categories of awards are popular or general public book, juvenile or young persons' book, and systematic paleontologic monograph.

The first award in the popular category goes to Stephen J. Gould for *Wonderful Life: The Burgess Shale and the Nature of History*, published by W. W. Norton and Co. The award for excellence in a systematic monograph goes to Lars E. Holmer for "Middle Ordovician phosphatic inarticulate brachiopods from Västergötland and Dalarna, Sweden," released as *Fossils and Strata* No. 26 and published by Universitetsforlaget (Norwegian University Press), Oslo; the editor is Stefan Bengtson. The winner in the juvenile category is *Maia, a Dinosaur Grows Up* by J. R. Horner and J. Gorman, published by the Running Press, Philadelphia.

The Paleontological Society plans to make these awards annually, and invites nominations from any interested person. Please send information about your candidates in any of the categories, published during the past year or so, to: J. T. Dutro, Jr., Room E-308, Museum of Natural History, Washington, D.C. 20560.

MEETINGS

■ Indicates new or changed information

1991

May

Caltech Mantle Plume and Hotspot Symposium, May 2–4, 1991, California Institute of Technology. Information: Don L. Anderson or Dee Page, Seismological Laboratory, California Institute of Technology, Pasadena, CA 91125; (818) 356-6901 or (818) 356-6903; fax 818-564-0715.

African Colloquium of Micropaleontology, May 6–8, 1991, Libreville, Gabon. Information: Comité d'Organization de Colloques, D.G.H.B.P. 2199, Libreville, Gabon; tel 241-76-39-23; fax 241-76-39-17.

Society for the Preservation of Natural History Collections, 6th Annual Meeting, May 6–11, 1991, Ottawa, Ontario. Information: G. R. Fitzgerald, Canadian Museum of Nature, Earth Sciences (Paleobiology), P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4, Canada.

14th Annual Spring Systematics Symposium: Origin of Anatomically Modern Humans, May 11, 1991, Chicago, Illinois. Information: Sophia L. Brown, Symposium Coordinator, Department of Geology, Field Museum of Natural History, Roosevelt Road and Lake Shore Drive, Chicago, IL 60605-2496; (312) 922-9410, x298.

Third International Seminar on Coastal Parks and Protected Areas, May 11–June 5, 1991, Florida and Costa Rica. Information: John R. Clark, University of Miami-RSMAS, 4600 Rickenbacker Causeway, Miami, FL 33149-1098; (305) 361-4620; telex 317454; fax 305-361-9306; Easylink mailbox 62845425.

International Symposium on Land Subsidence, May 12–18, 1991, Houston, Texas. Information: Ivan Johnson, A. Ivan Johnson, Inc., 7474 Upham Ct., Arvada, CO 80003; (303) 425-5610.

Fifth National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring, and Geophysical Methods, May 13–16, 1991, Las Vegas, Nevada. Information: Fifth National Outdoor Action Conf., National Water Well Association, P.O. Box 182039, Dept. #017, Columbus, OH 43218; (614) 761-1711.

Brazil Gold '91, May 13–17, 1991, Belo Horizonte, Brazil. Information: Organizing Committee, Av. Afonso Pena, 3880-3/5 andares, 30130 Belo Horizonte MG, Brazil; or Charles Thorman, U.S. Geological Survey, Box 25046, MS 905, Denver Federal Center, Denver, CO 80225; (303) 236-5601; fax 303-236-5603.

54th Annual Meeting of Northeast Friends of the Pleistocene, May 17–19, 1991, Herkimer, New York. Information: Jack Ridge, Dept. of Geology, Tufts University, Medford, MA 02155; (617) 381-3494.

14th International Radiocarbon Conference, May 20–24, 1991, Tucson, Arizona. Information: Austin Long, Dept. of Geosciences, University of Arizona, Tucson, AZ 85721; (602) 621-8888; fax 602-621-2672; telex 650-3839821.

XVII Pacific Science Congress—Towards the Pacific Century: The Challenge of Change, May 27–June 2, 1991, Honolulu, Hawaii. Information: Congress Secretariat, Nancy Lewis, Secretary General, 2424 Maile Way, Honolulu, HI 96822; (808) 956-7526, fax 808-956-3512.

■ **American Geophysical Union–Mineralogical Society of America Spring Meeting**, May 28–June 1, 1991, Baltimore, Maryland. Information: Spring Meeting, AGU, 2000 Florida Ave., N.W., Washington, DC 20009; fax 202-328-0566.

Geological Association of Canada–Mineralogical Association of Canada Annual Meeting held jointly with the Society of Economic Geologists, May 27–29, 1991, Toronto, Ontario. Information: J. J. Fawcett, Dept. of Geology, Earth Sciences Center, University of Toronto, 22 Russell St., Toronto, Ontario M5S 3B1, Canada; (416) 978-3027; fax 416-978-3938.

June

Gordon Conference on Estuarine Processes, June 24–28, 1991, New Hampton, New Hampshire. Information: A. M. Cruickshank, Gordon Research Center, University of Rhode Island, Kingston, RI 02881, (401) 783-4011.

July

Second International Conference on Industrial and Applied Mathematics (ICIAM 91), July 8–12, 1991, Washington, D.C. Information: SIAM Conference Coordinator, Dept. CC0990, 3600 University City Science Center, Philadelphia, PA 19104-2688; (215) 382-9800; fax 215-386-7999; E-mail siamconfs@wharton.upenn.edu.

11th International Symposium on Ostracoda, July 8–13, 1991, Warrnambool, Victoria, Australia. Information: Peter J. Jones, Bureau of Mineral Resources, P.O. Box 378, Canberra A.C.T. 2601, Australia; phone (06) 249 9737; fax 06-257-6465.

Former ENSO Phenomena in Western South America: Records of El Niño Events, July 10–13, 1991, Lima, Peru. Information: ENSO 1991 International Symposium, ORSTOM, Apartado 18-1209, Lima 18, Peru; fax 51-14-40-87-73.

Sixth International Symposium on the Ordovician System, July 15–19, 1991, Sydney, Australia. Information: Earth Resources Foundation, Edgeworth David Building, University of Sydney, Sydney, N.S.W., Australia, 2006; phone (02) 692 2038 (Int. 61+2); fax 02-692 0184 (Int. 61+2).

August

150th Anniversary Conference on the Permian System, August 5–10, 1991, Perm, USSR. Information: A.E.M. Nairn, Perm Conference, Earth Sciences & Resources Institute, University of South Carolina, Columbia, SC 29208; (803) 777-6484; fax 803-777-6437; telex 9102501347 USC ESRI UQ.

Sedimentary and Paleolimnological Records of Saline Lakes, August 13–16, 1991, Saskatoon, Saskatchewan. Information: Robin W. Renaut, Dept. of Geological Sciences, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0, Canada; fax 306-966-8593; W. M. Last, Dept. of Geological Sciences, University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada; fax 204-261-7581.

SEPM Midyear Meeting—Continental Margins, Tectonics, Eustacy and Climate Change, August 15–18, 1991, Portland, Oregon. Information: Sam Boggs, Jr., Dept. of Geology, University of Oregon, Eugene, OR 97403; (503) 686-4573.

4th International Symposium on Borehole Geophysics, August 18–22, 1991, Toronto, Canada. Information: P. G. Killeen, 4th Symposium on Borehole Geophysics, c/o Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8, Canada; (613) 996-2312; fax 613-996-9295; telex 053-3117 EMAR OTT.

Third U.S. Conference on Lifeline Earthquake Engineering, August 22–23, 1991, Los Angeles, California. Information: American Society of Civil Engineers, Specialty Conference Dept., 345 E. 47th St., New York, NY 10017; (212) 705-7139.

1st International Meeting of Young Geologists, August 22–28, 1991, Budapest, Hungary. Information: Anna Balog, Dept. of Geology, Technical University of Budapest, H-1521 Budapest, Hungary; phone (36-1) 16-67-370; fax 36-1-16-66-808; telex 225931.

International Symposium on Origin, Sedimentation and Tectonics of Late Mesozoic to Early Cenozoic Sedimentary Basins at the Eastern Margin of the Asian Continent and Workshop of IGCP 245: Nonmarine Cretaceous Correlations, August 25–30, 1991, Fukuoka, Japan. Information: Hakuyu Okada, Dept. of Earth and Planetary Sciences, Kyushu University, Fukuoka, 812 Japan; 92-614-1101; fax 92-632-2736.

Fourth International Conference on Seismic Zonation, August 26–29, 1991, Stanford, California. Information: 4th International Conference on Seismic Zonation, John A. Blume Earthquake Engineering Center, Department of Civil Engineering, Stanford University, Stanford, CA 94305-4020.

Antarctica in Global Change: Ocean Drilling Perspective, August 28–31, 1991, Santa Barbara, California. Information: James Kennett, Marine Science Institute, University of California, Santa Barbara, CA 93106; (805) 893-3764; fax 805-893-8062.

September

International Symposium on Computer Applications in Geoscience, September 2–6, 1991, Beijing, China. Information: Zhang Bojun, 31 Xue Yuan Rd., Beijing 100083, China; phone 2012233, ext. 312; fax 2024674; telex 222484 GBCC CN.

Geometry of Naturally Deformed Rocks (John Ramsay Meeting), September 9–11, 1991, Zürich, Switzerland. Information: E. Pour, Geologisches Institut, ETH-Zentrum, CH-8092, Zürich, Switzerland; phone 256 36 80; fax 252-70-08. (*Abstracts deadline: June 1, 1991.*)

International Symposium on Fossil Cnidaria Including Archaeocyatha and Porifera, September 9–14, 1991, Münster, Germany. Information: Fossil VI. Cnidaria, Pferdegasse 3, D-4400 Münster, Germany.

Gold and Platinum in Central Africa, September 11–13, 1991, Bujumbura, Burundi. Information: W. Pohl, Institute of Geosciences, Technical University, P.O. Box 3329, D–33 Braunschweig, Germany.

Wyoming Geological Association 42nd Annual Fall Field Conference: Mineral Resources of Wyoming, September 14–18, 1991, Laramie, Wyoming. Information: Gary A. Winter, General Chairman, P.O. Box 2957, Casper, WY 82602; (307) 261-5463, fax 307-261-5136.

Integrating Geographic Information Systems and Environmental Modeling International Conference, September 15–18, 1991, Boulder, Colorado. Information: GIS/Modeling Conference Secretariat, NCGIA, University of California, Santa Barbara, CA 93106; (805) 893-8224; fax 805-893-8617; E-mail ncgia @ncgia.ucsb.edu or ncgia@voodoo.bitnet.

Second International Conference on the Abatement of Acidic Drainage, September 16–18, 1991, Montreal, Québec. Information: Pamela Friedrich, Centre des Recherches Minérales, 1665, boulevard Hamel, Édifice 2, 1er étage, Québec, Québec G1N 3Y7, Canada.

2nd International Symposium on Environmental Geochemistry, September 16–19, 1991, Uppsala, Sweden. Information: Mats Olsson, Dept. of Forest Soils, Swedish University of Agricultural Sciences, Box 7001, S-750 07 Uppsala, Sweden; phone 46-18-672212; fax 46-18-300831.

■ **Geotechnica: International Trade Fair and Congress for Geo-sciences and Technology**, September 18–21, 1991, Cologne, Germany. Information: Alfred-Wegener-Stiftung zur Förderung der Geowissen-Schaften, Postfach 20 14 48, D-5300 Bonn 2, Germany; phone (0228) 302-260 261; (0228) 302-270.

22nd Annual Geomorphology Symposium: Periglacial Geomorphology, September 21–22, 1991, Buffalo, New York. Information: John C. Dixon, Department of Geography, University of Arkansas, Fayetteville, AR 72701; (501) 575-5808.

■ **Denver GeoTech/Geochautauqua '91, A Geocomputing Conference**, September 21–24, 1991, Denver, Colorado. Information: Mark Cramer, GeoTech, 11100 E. Dartmouth Avenue, #190, Aurora, CO 80014; (303) 752-4951; fax 303-752-4979.

Second Hutton Symposium on Granites and Related Rocks, September 23–28, 1991, Canberra, Australia. Information: ACTS, GPO Box 2200, Canberra City, ACT 2601, Australia.

15th International Cartographic Conference–9th General Assembly of the International Cartographic Association, September 23–October 1, 1991, Bournemouth, England. Information: James R. Carter, Academic Computing, Illinois State University, Normal, IL 61761; (309) 438-3758; fax 309-438-5319.

International Mine Water Association Fourth Congress, September 25– 30, 1991, Ljubljana, Yugoslavia. Information: Miron Veselic, S.P. Geoloski Zavod Ljubljana, Dimiceva 14, 61000 Ljubljana, Yugoslavia; fax 38 61 371 557.

New England Intercollegiate Geological Field Conference, September

28–30, 1991, Princeton, Maine. Information: Allan Ludman, Department of Geology, Queens College, 65-30 Kissena Blvd., Flushing, NY 11367-0904.

1991 American Association of Petroleum Geologists International Conference and Exhibition, September 29–October 2, 1991, London, England. Information: 1991 AAPG International Conference, P.O. Box 979, Tulsa, OK 74101-0979.

■ **Underwater Mining Institute**, September 29–October 2, 1991, Honolulu, Hawaii. Information: Allen H. Miller, UMI Coordinator, Underwater Mining Institute, 1800 University Ave., Madison, WI 53705; (608) 262-0645; fax 608-263-2063.

Society of Organic Petrology 8th Annual Meeting, September 30–October 1, 1991, Lexington, Kentucky. Information: Jim Hower, Center for Applied Energy Research, 3572 Iron Works Pike, Lexington, KY 40511; (606) 257-0261; fax 606-257-0220.

October

■ **Association of Engineering Geologists**, October 1–4, 1991, Chicago, Illinois. Information: Theodore R. Maynard, Bureau of Engineering, Department of Public Works, 320 North Clark Street, Room 700, Chicago, IL 60610; (312) 744-3530.

■ **Clay Minerals Society 28th Annual Meeting**, October 5–10, 1991, Houston, Texas. Information: Dave Pevear, Program Services/CM, 91, Lunar and Planetary Institute, 3303 NASA Rd. 1, Houston, TX 77058-4399; (713) 965-4452; fax 713-966-6115.

Fifth International Congress on Pacific Neogene Stratigraphy and IGCP 246, October 6–10, 1991, Shizuoka, Japan. Information: V-CPNS-IGCP246 Organizing Committee, Geoscience Institute, Faculty of Science, Shizuoka University, Shizuoka 422, Japan; fax 81-542-37-9895.

Federation of Analytical Chemistry and Spectroscopy Societies and Pacific Conference on Chemistry and Spectroscopy, October 6–11, 1991, Anaheim, California. Information: FACSS, P.O. Box 278, Manhattan, KS 66502; (301) 846-4797.

Rocky Mountain Friends of the Pleistocene Annual Field Trip, October 11–13, 1991, Lake Bonneville, Utah. Information: Richard Van Horn, U.S. Geological Survey, Box 25046, MS 966, Denver, CO 80225.

■ **Tri-State (Illinois, Wisconsin, Iowa) Geological Field Conference**, October 11–13, 1991, Charleston, Illinois. Information: Kaylin Johns, School of Adult and Continuing Education, Eastern Illinois University, Charleston, IL 61920.

International Symposium on Debris Flow and Flood Disaster Protection, October 14–20, 1991, Emeishan City, Sichuan Province, China. Information: Tong Yuling, International Research and Training Centre on Erosion and Sedimentation (IRTCES), P.O. Box 366, Beijing, China 100044; phone 8413372; telex 22786 ITCES CN; fax 8412539.

American Institute of Professional Geologists Annual Meeting, October 16–19, 1991, Gatlinburg, Tennessee. Information: Lawrence I. Benson, ERC/EDGE, P.O. Box 22879, Knoxville, TN 37933-0879; (615) 966-9761; fax 615-966-4155.

New York State Geological Association 63rd Annual Field Conference, October 18–20, 1991, Oneonta, New York. Information: James R. Ebert, Department of Earth Sciences, State University of New York, Oneonta, NY 13820-4015; (607) 431-3065; fax 607-431-2107.

International Symposium on Geological Hazards and Prevention, October 20–25, 1991, Beijing, People's Republic of China. Information: Chu Zhanchang, Secretariat, Organizing Committee, International Symposium on Geological Hazards and Prevention, 64, Funei St., Beijing, People's Republic of China; phone 658561-410.

Geological Society of America Annual Meeting, October 21–24, 1991, San Diego, California. Information: GSA, Meetings Dept., P.O. Box 9140, Boulder, CO 80301; (303) 447-2020; fax 303-447-1133.

Brazilian Geophysical Society Second International Congress, October 28–November 1, 1991, Salvador City, Bahia, Brazil. Information: Brazilian Geophysical Society—SBGf, Alberto Brum Novaes, Universidade Federal da Bahia/UFBa-PPPG, Rua Caetano Moura 123, Federacão 40.210, Salvador BA, Brasil; phone 55-071-2370408. (*Abstracts deadline: May 31, 1991.*)

■ **Arbuckle Group Core Workshop and Field Trip**, October 29–31, 1991, Norman, Oklahoma. Information: Kenneth S. Johnson, Oklahoma Geological Survey, University of Oklahoma, 100 East Boyd, Rm. N-131, Norman, OK 73019; (405) 325-3031.

November

Hydrology and Hydrogeology in the '90s: Issues, Strategies and Technologies, November 3–7, 1991, Orlando, Florida. Information: AIH, 3416 University Ave. S.E., Minneapolis, MN 55414; (612) 379-1030.

■ **Carolina Geological Society 1991 Field Conference**, November 8–10, 1991, Murphy, North Carolina. Information: Stephen A. Kish, Dept. of Geology B-160, Florida State University, Tallahassee, FL 32306; (904) 644-2065.

5th International Circum-Pacific Terrane Conference, November 11–28, 1991, Santiago, Chile. Information: D. G. Howell, U.S. Geological Survey, MS 902, 345 Middlefield Rd., Menlo Park, CA 94025; (415) 329-5430.

■ **Circum-Pacific Council for Energy and Mineral Resources Symposium**, Sustainable Development: Energy and Mineral Resources and the Environmental Impact of Their Utilization in the Circum-Pacific Region, November 11–14, 1991, Bangkok, Thailand. Information: Mary Stewart, Circum-Pacific Council, 5100 Westheimer, Suite 500, Houston, TX 77056; fax 713-622-5360.

Clean Seas 91, International Conference on Marine Pollution, November 19–22, 1991, Valletta, Malta. Information: Lesley Ann Sandbach, Project Manager, Clean Seas 91, The Spearhead Group, Rowe House, 55-59 Fife Road, Kingston upon Thames, Surrey KT1 1TA, UK; phone 081 549 5831 (intl: + 44-81-549-5831); telex 928042 SPEARS G; fax 081-541-5657 (intl: + 44-81-541-5657).

■ **Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection and Restoration**, November 20–22, 1991, Houston, Texas. Information: Petroleum Hydrocarbons Conference/National Water Well Association, P.O. Box 182039, Dept. #017, Columbus, OH 43218, (614) 761-1711.

December

■ **IGCP 264 Remote Sensing Spectral Properties (5th Meeting)—Geological Applications of Remote Sensing with Emphasis on Spectral Properties**, December 2–12, 1991, Pune, India. Information: Dr. Melvin Podwysocki, Co-Chairman IGCP264, U.S.G.S., National Center, MS 913, Reston, VA 22092; fax 1-703-648-6057.

Mining Indonesia '91, December 4–7, 1991, Jakarta, Indonesia. Information: Eileen M. Lavine, Information Services, Inc., 4733 Bethesda Ave., #735, Bethesda, MD 20814; (301) 656-2942; fax 301-656-3179.

1991 Penrose Conference

October

Development and Evolution of Foreland Basins, October 6–11, 1991, Oliana, Spain. Information: James H. Meyers, Dept. of Geology, Winona State University, Winona, MN 55987; (507) 457-5266 (dir.), (507) 457-5000 (dept.), fax 507-457-5586; Douglas W. Burbank, Dept. of Geological Sciences, University of Southern California, Los Angeles, CA 90089-0740; Lee J. Suttner, Dept. of Geology, Indiana University, Bloomington, IN 47405; Cai Puigdefabregas, Dept. de Politica Territorial, Servei Geologica de Catalunya, Diputacio, 92, 5e, 08015 Barcelona, Spain.

1992

February

First South Asia Geological Congress—GEOSAS-I, February 23–27, 1992, Islamabad, Pakistan. Information: Hilal A. Raza, GEOSAS-I Secretary General, Hydrocarbon Development Institute of Pakistan, P.O. Box 1308, Islamabad, Pakistan; phone 9251-823690 or 821417; telex 5516 HDIP PK; fax 9251-828773.

■ **Society for Mining, Metallurgy, and Exploration Annual Meeting**, February 24–27, 1992, Phoenix, Arizona. Information: Meetings Department, SME, P.O. Box 625002, Littleton, CO 80162; (303) 973-9550, fax 303-979-3461.

March

Second Conference on Earthquake Hazards in the Eastern San Francisco Bay Area, March 25–28, 1992, Hayward, California. Information: Sue Ellen Hirschfeld, Dept. of Geological Sciences, California State University, Hayward, CA 94542; (415) 881-3486.

April

XVII General Assembly of the European Geophysical Society, April 6–10, 1992, Edinburgh, Scotland. Information: EGS Office, Postfach 49, 3411 Katleburg-Lindau, Germany; phone (49) 5556-1440; fax 49-5556-4709; telex 965564 zil d; SPAN: LINMPI::EGS; EARN: U0085@DGOGWDG5.

■ **American Association of Petroleum Geologists Southwest Section**, April 12–14, 1992, Midland, Texas. Information: West Texas Geological Society, P.O. Box 1595, Midland, TX 79702; (915) 683-1573. *(Abstracts deadline: December 1, 1991.)*

May

■ **Pan-American Current Research on Fluid Inclusions** (PACROFI IV), May 22–24, 1992, Lake Arrowhead, California. Information: Michael A. McKibben, Department of Earth Sciences, University of California, Riverside, CA 92521-0423; (714) 787-3444, fax 714-787-4324. (*Abstracts deadline: March 1, 1992.*)

June

American Association of Petroleum Geologists Annual Meeting, June 21–24, 1992, Calgary, Alberta, Canada. Information: George Eynon, General Chairman, Bow Valley Industries, Ltd., P.O. Box 6610, Postal Station D, Calgary, Alberta, T2P 3R7, Canada; (403) 261-6100; or AAPG Convention Department, P.O. Box 979, Tulsa, OK 74101; (918) 584-2555.

Interpraevent 1992—Protection of Habitat against Floods, Debris Flows and Avalanches, June 29–July 3, 1992, Berne, Switzerland. Information: Interpraevent 1992, c/o Bundesamt für Wasserwirtschaft, Federal Office for Water Management, Postfach 2743, CH-3001 Berne, Switzerland.

July

7th International Symposium on Water-Rock Interaction, July 13–22, 1992, Park City, Utah. Information: Yousif Kharaka, Secretary-General, U.S. Geological Survey, MS 427, 345 Middlefield Road, Menlo Park, CA 94025; (415) 329-4535; fax 415-329-5110.

August

29th International Geological Congress, August 24–September 3, 1992, Kyoto, Japan. Information: Secretary General, IGC-92 Office, P.O. Box 65, Tsukuba, Ibaraki 305, Japan; phone 81-298-54-3627; fax 81-298-54-3629; telex 3652511 GSJ J.

September

■ **The Transition From Basalt to Metabasalt: Environments, Processes, and Petrogenesis**, September 9–15, 1992, Davis, California. Information: Peter Schiffman, Dept. of Geology, University of California, Davis, CA 95616; (916) 752-3669; E-mail PSchiffman@UCDavis.edu.

4th International Conference on Paleoceanography, September 21–25, 1992, Kiel, Federal Republic of Germany. Information: ICP IV Organizing Committee c/o GEOMAR, Wischhofstrasse 1-3/Bldg. 4, D-2300 Kiel 14, Germany.

American Institute of Professional Geologists Annual Meeting, September 27–October 1, 1992, Lake Tahoe, Nevada. Information: Jon Price, AIPG, P.O. Box 665, Carson City, NV 89702; (702) 784-6691.

October

Geological Society of America Annual Meeting, October 26–29, 1992, Cincinnati, Ohio. Information: GSA, Meetings Dept., P.O. Box 9140, Boulder, CO 80301; (303) 447-2020; fax 303-447-1133.

Send notices of meetings of general interest, in format above, to Editor, *GSA Today*, P.O. Box 9140, Boulder, CO 80301.

GSA *BULLETIN* and *GEOLOGY* contents

The Geological Society of America
BULLETIN
Volume 103, Number 5, May 1991

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GEOLOGY
VOLUME 19
NO. 5
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MAY 1991

GSA ANNUAL MEETINGS

■ 1991

GSA Annual Meeting, San Diego, California
October 21–24

SanDiego
GLOBAL PERSPECTIVE

General Chair:
R. Gordon Gastil, Dept. of Geological Sciences,
San Diego State University, San Diego, CA 92182

Call for papers: *April 1*
Abstracts due: *July 3*
Program, housing, registration information: *August 9*
Joint Technical Program Committee meeting: *August 2–3*
Preregistration due: *September 20*

For information: GSA Meetings Department, P.O. Box 9140, Boulder, CO 80301; (303) 447-2020

■ 1992

GSA Annual Meeting, Cincinnati, Ohio
October 26–29

Call for short course proposals:
GSA members and nonmembers are encouraged to submit short course proposals to be reviewed by GSA's Short Course Committee. All proposals are due by *December 1, 1991*. For short course proposal guidelines contact: Edna Collis, Short Course Coordinator, GSA, P.O. Box 9140, Boulder, CO 80301; (303) 447-2020

■ FUTURE

Cincinnati	October 26–29	1992
Boston	October 25–28	1993
Seattle	October 24–27	1994
New Orleans	November 6–9	1995
Denver	October 28–31	1996

For general information on technical program participation (1991 or beyond) contact: Sue Beggs, Meetings Manager, GSA headquarters

GSA SECTION MEETINGS

■ 1992

South-Central, Houston, Texas
Rice University, February 24–25

Hans G. Avé Lallemant, Dept. of Geology and Geophysics, P.O. Box 1892, Rice University, Houston, TX 77251; (713) 527-4889

Southeastern, Winston-Salem, North Carolina
Stouffer-Winston Plaza, March 18–20

Paul D. Fullagar, Dept. of Geology, CB 3315 Mitchell Hall, University of North Carolina, Chapel Hill, NC 27599-3315; (919) 962-0677

Northeastern, Harrisburg, Pennsylvania
Harrisburg Hilton, March 26–28

Donald M. Hoskins, Pennsylvania Geological Survey, Dept. of Environmental Resources, P.O. Box 2357, Harrisburg, PA 17105; (717) 787-2169

North-Central, Iowa City, Iowa
University of Iowa, April 30–May 1

Raymond R. Anderson, Iowa DNR, Geological Survey, University of Iowa, 123 N. Capital St., Iowa City, IA 52242; (319) 335-1575

Cordilleran, Eugene, Oregon
Eugene Hilton Conference Center, May 11–13

A. Dana Johnston, Dept. of Geological Sciences, University of Oregon, Eugene, OR 97403-1272; (503) 346-5588

Rocky Mountain, Ogden, Utah
Ogden Park Hotel, May 14–16

Sidney R. Ash, Dept. of Geology, Weber State University, Ogden, UT 84408-2507; (801) 626-6908

CLASSIFIED ADVERTISING

Published on the 1st of the month of issue. Ads (or cancellations) must reach the GSA Advertising office 1 month prior. Contact Advertising Department (303) 447-2020, 1-800-472-1988, fax 303-447-1133.

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Positions Open

SEDIMENTARY GEOLOGIST.
The Department of Geology at Lawrence University seeks to fill a tenure-track position in sedimentary geology at the assistant professor level beginning September 1, 1991. Appropriate areas of specialization include, for example, carbonate petrology, clastic sedimentology, glacial sedimentation, or biostratigraphy. Teaching duties include: sedimentary petrology, environmental geology, and invertebrate paleontology along with participation in introductory courses. The successful candidate will be expected to share the department's strong commitment to teaching and research with undergraduates. Applicants should have completed all requirements and expect to have the Ph.D. degree in hand by September 1, 1991. Please submit letter of application, resume, undergraduate and graduate transcripts, and three letters of recommendation to Professor John C. Palmquist, Department of Geology, Lawrence University, Box 599, Appleton, WI 54912. Lawrence promotes equal opportunity for all and encourages applications from women and minorities. Our review of applications will begin April 2, 1991 and the search will continue until the position is filled.

POSTDOCTORAL POSITIONS
The Geologic Division of the U.S. Geological Survey is soliciting applications for postdoctoral positions as temporary Guest Researchers in the following areas of research: Surficial Geologic Mapping; Seismic Ground Motion; Lower Crust High-Pressure and Temperature Metamorphic Petrology; Geodetic Measurement of Fault Strain Accumulation; Rock Mechanics of Faults; Magmatic Volatiles in Igneous Systems; Quaternary Sea-level Studies; Mineralogic Remote Sensing; Economic Geology of Turbidite-hosted Gold Deposits; and Sulfur Geochemistry in Sediments and Ores. Possible locations may be: Anchorage, AK; Menlo Park, CA; Denver, CO; Hawaiian Volcano Observatory, HI; Reston, VA; and Vancouver, WA.

Applicants should be outstanding scientists who have recently completed doctoral-level research and have a record of demonstrated ability or outstanding potential for basic and applied research. Positions will be at the GS-12 ($37,294) level. Appointments will be limited to 1 year and upon management recommendation, may be extended for 1 year. For specific information and Application for Federal Employment, SF-171, call (703)-648-6633, or send application to Mr. Reginald Mervine, Office of Personnel, 215 National Center, Reston, VA 22092. Applications accepted through May 31, 1991. The U.S. Geological Survey is an equal opportunity employer. U.S. citizenship isrequired.

STRUCTURAL SEISMOLOGISTS
The Institute for the Study of the Continents (INSTOC) is searching for structural/crustal seismologists and/or structural geologists to be part of the COCORP and Tibet projects at Cornell University. Ph.D. is required.

Though the applicants have, in general, specific area of expertise, we expect these scientists to analyze and integrate all available geological/geophysical observations to understand lithospheric-scale problems. Extensive knowledge or familiarity with processing or interpretation of deep seismic reflection profiling is desirable, but not required. However, we require enthusiasm to better understand the evolution of the continental lithosphere. The position may be filled at a postdoctoral associate or research associate level based on experience.

Send a C.V. and very brief statement on your research interests as soon as possible to: Professor Larry Brown, INSTOC, Snee Hall, Cornell University, Ithaca, NY 14853. Cornell University is an Affirmative Action/Equal Opportunity Employer.

UNIVERSITY OF WYOMING
Structural or Economic Geology
The Department of Geology and Geophysics invites applications for a tenure-tack position at the assistant professor level in the broad fields of structural or economic geology. We are looking for a creative scientist who can combine the strengths of theoretical or experimental studies with solid field-based observations.

The successful candidate is expected to teach at the graduate and undergraduate level, supervise graduate students, and establish a vigorous research program. A Ph.D. is required before beginning employment. This position is subject to available funds but is scheduled to begin August, 1992. Interested persons should send a resume, a statement of research interests, and the names and addresses of at least three references to Dr. B. Ronald Frost, Search Committee Chair, Department of Geology and Geophysics, P.O. Box 3006, University of Wyoming, Laramie, WY 82071-3006. Closing date for application is November 15, 1991 or until the position is filled. The University of Wyoming is an affirmative-action/equal-opportunity employer. We strongly encourage applications from women and minorities.

STATE COASTAL CONSERVANCY
REQUEST FOR QUALIFICATIONS
The State Coastal Conservancy anticipates a need for environmental consulting services over the next twelve months including architectural and landscape architectural services.

The California State Coastal Conservancy seeks statements of qualifications from individuals and firms providing these services. The conservancy acts to preserve, restore and enhance California's coastal resources and to solve land use problems on the coast and around San Francisco Bay. The conservancy undertakes projects in the following areas: (1) public access (e.g., trails; bridges; whole access; parking, recreational and interpretive facilities); (2) urban waterfronts (e.g., pier restoration; commercial fishing; waterfront access; waterfront revitalization; shoreline facilities); (3) resource enhancement (e.g., restoration and enhancement of wetlands, estuaries, coastal dunes, streams, watersheds, riparian environments and endangered species habitats); (4) coastal restoration (e.g., lot consolidation; transfer of development rights; coastal land acquisition); and (5) agricultural land preservation (e.g., acquisition of interests in coastal agricultural land and resolution of agricultural problems).

For further information please write to Tyronea Marshall, State Coastal Conservancy, 1330 Broadway, Suite 1100, Oakland, CA 94612.

PETROLEUM GEOLOGY
THREE POSTDOCTORAL POSTS
Palynology, Sequence Stratigraphy, Isotope Diagenesis
Elf UK is supporting a major research initiative to develop an integrated sequence stratigraphic, diagenetic, and poroperm model for exploration in the Upper Jurassic of the North Sea Central Graben. Posts are for a minimum of two years, and will involve close working collaboration with Elf UK and Elf Aquitaine Pau. Salary ranges £11.4k–£18.1k. Publication of results is expected. Letters of application by end May with full CV and names of 3 referees to: PALYNOLOGY: Dr. Bruce Tocher, Inst. of Earth Studies, Univ. College Wales, Aberystwyth SY23 3DB, UK Tel + 44-970-622611. SEQUENCE STRATIGRAPHY: Dr. Steve Flint, Dept. Earth Sciences, Univ. Liverpool, Liverpool, L69 3BX UK Tel + 44-51-794-5192; fax + 44-51-794-5170. ISOTOPIC DIAGENESIS: Dr. Stuart Haszeldine, Dept. Geology, Univ. of Glasgow, Glasgow, G12 8QQ, UK Tel + 44-41-339-8855; fax + 44-41-339-4817.

Services & Supplies

WANTED: Worden Gravimeter. Buy or lease. Warren Shepard, P.O. Box 1353, Billings, MT 59101, (406) 252-1625.

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

Opportunities for Students

GRADUATE ASSISTANTSHIPS FOR M.S. DEGREE STUDY in field of Quaternary Geology. Assistantships consist of 12-month funding obtained for studies of geochemistry, stratigraphy, geomorphology, and neotectonics in the central Mississippi Valley. Contact Dr. June Mirecki, Department of Geological Sciences, Memphis State University, Memphis, TN 38152, (901) 678-4358.

Identify rock colors accurately with a GSA Rock-Color Chart!

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*Inter Society Color Council-National Bureau of Standards.

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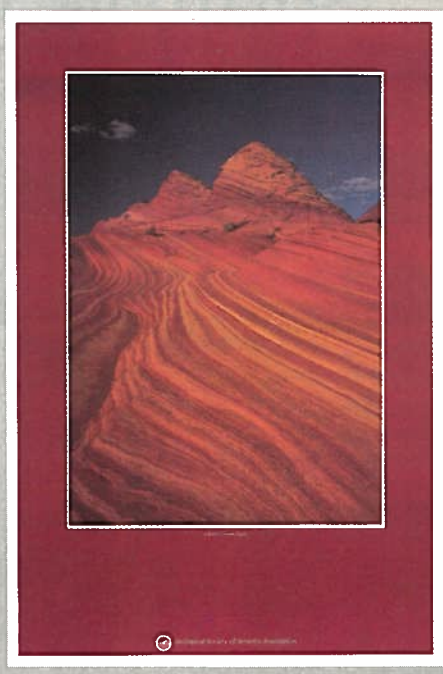

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