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Mapping the Magnetic Field at the Core-Mantle Boundary: Constraints on the Geodynamo

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ABSTRACT

Despite several centuries of conjecture and study, the details of the dynamo process in Earth's fluid outer core, which maintains the magnetic field against ohmic dissipation, remain elusive. Although recently there has been renewed optimism that numerical models might provide insight into the dynamo process, currently such models are severely restricted, even with the most powerful supercomputers. However, valuable insight can be gained from observations of Earth's magnetic field made at the surface, especially for time periods with sufficient density of observations to permit mapping of the field at the core-mantle boundary. From these observations, a time-dependent map of the magnetic field at the core-mantle boundary spanning the period 1690–1990 shows that the evolution of the field at the core-mantle boundary is highly variable, both spatially and temporally. To unravel this complicated signal it is necessary to proceed in stages. First, we examine the time-averaged, or steady, ingredient of the field. This part is nearly antisymmetric about the geographical equator and is dominated by concentrations of flux at high latitude in each hemisphere which account for the predominantly axial dipolar nature of the surface field. Surprisingly, the flux at the geographical poles, where an axial dipole field has maximum flux, is near zero. The remaining field—that is, the time-dependent part of the field left after removing this time-averaged field—is explained largely by a simple, steady-fluid-flow model at the core surface. This flow is almost symmetric about the geographic equator, a symmetry that is consistent with the antisymmetry of the steady field. Paleomagnetic data give further evidence of the importance of these symmetries in the dynamo process, both during intervals of normal secular variation of the field and during geomagnetic reversals. This simple field and flow morphology is consistent with a simple heuristic dynamo model based on the combined effects of Earth's rotation and the geometry of the outer core. A small unexplained signal remains after removing the effects of this steady flow. Part of this remaining signal is explained by time-dependent flow at the core surface. This flow can be used to calculate changes in the angular momentum of the core. The calculated changes agree well with observations of decadal variations in the length of day (rotation rate of the mantle), providing a clear demonstration that decadal variations in Earth's rate of rotation result from the exchange of angular momentum between the mantle and the core. Furthermore, this agreement provides an independent verification that time-dependent flow can be resolved, even though most of the field is explained by the steady-field model and the effects of steady flow.

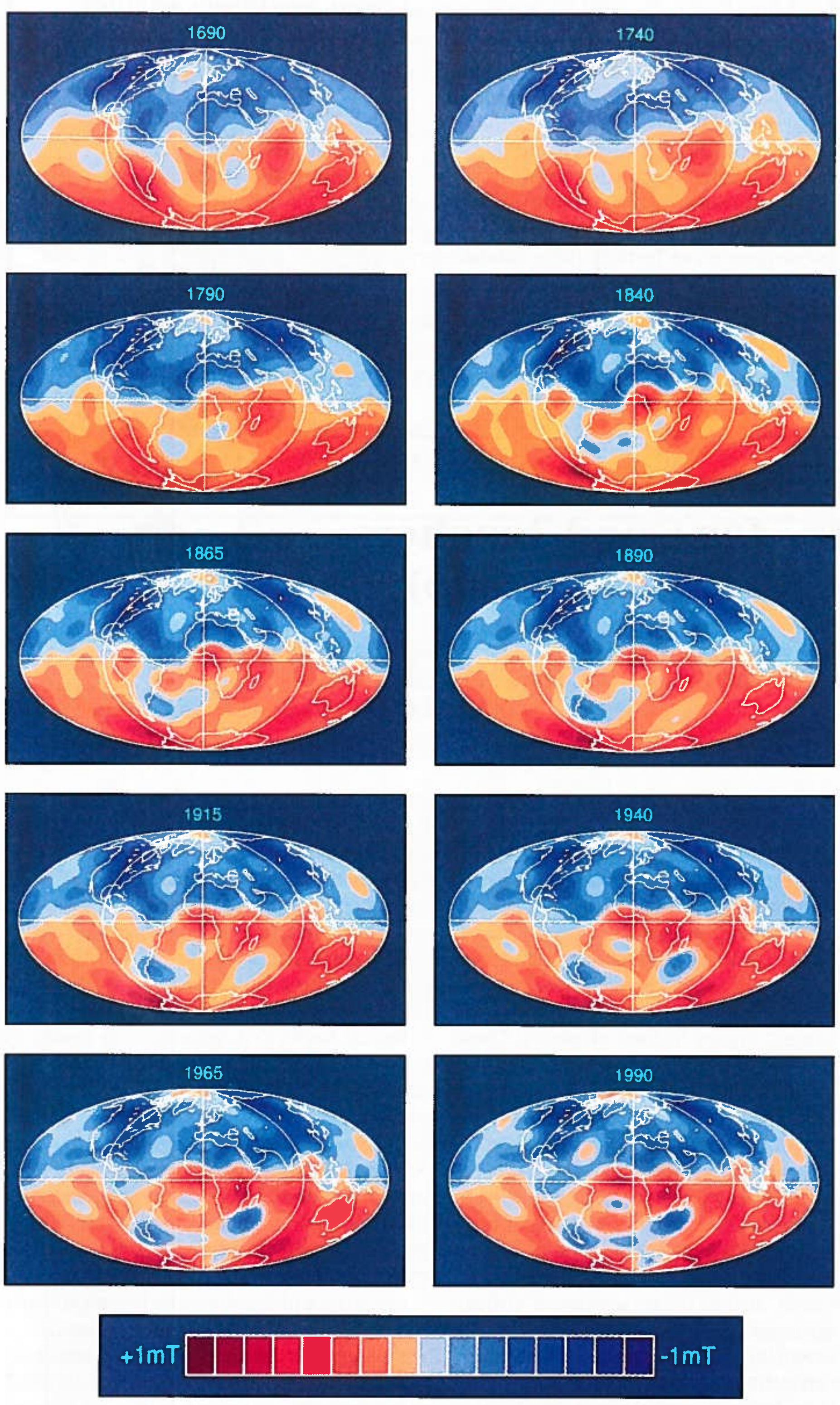

Figure 1. The radial component of the magnetic field at the core-mantle boundary calculated from models ufm1 and ufm2 of Bloxham and Jackson (1992). The contour interval is 100 μT. Hammer-Aitoff equal area projection.

INTRODUCTION

Understanding the mechanism responsible for the generation of Earth's magnetic field is one of the most longstanding problems in science; indeed, Albert Einstein once ranked it among the three most important unsolved problems in physics. The internal origin of the field has been recognized since the famous experiments of William Gilbert in 1600, but attempts at explaining its origin within Earth have encountered formidable obstacles. Although self-exciting dynamo action, originally suggested by Sir Joseph Larmor in 1919, is now widely accepted, it too once appeared to face insurmountable problems, given Cowling's (1934) demonstration that axisymmetric magnetic fields cannot be maintained by dynamo action. Cowling's result had an impact beyond the rather restrictive conditions of its applicability, in part because Earth's field is predominantly axisymmetric (at least at Earth's surface) but also because it was believed likely that his analysis was the first step in a more general antidynamo theorem. However, Backus (1958) and Herzenburg (1958) independently demonstrated that homogeneous self-exciting dynamos do exist, thus opening the way to the development of dynamo theory as an explanation of Earth's magnetic field. In the 35 years following their work, our understanding of the dynamo process has remained sketchy at best; such fundamental quantities as the strength of the magnetic field within the core are still unknown to within an order of magnitude.

The problem of understanding Earth's dynamo may be likened to attempts at understanding the dynamics of the atmosphere, but with several added difficulties: the magnetic field in the core plays an active role in determining the global circulation in the core, which adds considerably to the complexity of the governing equations; the core can only be observed indirectly, thus providing a much less immediate indication of the circula-

Geodynamo *continued on p. 224*

Editor's Note:

Each year the David and Lucile Packard Foundation awards 20 Fellowships for Science and Engineering in a national competition to promising young scientists and engineers working in fields that receive relatively less popular attention than high-energy physics, space, and medicine. Each Packard Fellowship provides $100,000 per year for five years to the Fellow's institution, $90,000 of which is for use of the Fellow to support his/her research work. These young researchers are truly among the "best and brightest" in the United States. The science article in this issue is one of several in which Packard Fellows in earth science report on research in their field.

IN THIS ISSUE

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Penrose Conference Scheduled

Triple Junction Interactions at Plate Margins

April 21–26, 1994

A Geological Society of America Penrose Conference, "Effects of Triple Junction Interactions at Convergent Plate Margins," will be held April 21–26, 1994, in Eureka, California, near the site of the Mendocino transform-transform-trench triple junction.

The typical view of subduction of oceanic lithosphere is a two-dimensional process dominated by the underflow of oceanic lithosphere, refrigeration of the fore arc, and concentration of calc-alkaline magmas along a linear chain situated 70–150 km above the downgoing plate. However, during the history of any ocean basin, trenches must ultimately interact with a spreading center, and where such interactions occur, there are major changes in plate motion which should produce a distinctive geologic "event" along the convergent margin. Analogies with modern systems imply that the consequences of three-plate interaction should produce distinctive structural, metamorphic, and igneous effects, yet there is no consensus on what these effects are.

The analysis of three-plate interactions was one of the first clear descriptions of relative-motion effects in plate interactions. Indeed, the quantitative description of the history of the Mendocino junction and its relation to the San Andreas fault is one of the outstanding early examples of plate-tectonic predictions that resolved long-standing geologic problems. Despite these early triumphs, our understanding of the consequences of three-plate interactions has lagged far behind other aspects of tectonics. This lack of understanding does not result from a lack of information, but more likely from the geological community's lack of attention to these problems, or dismissal of such problems as a minor component of the geologic record. However, despite the unequivocal requirement for ancient triple junction interactions, there are few examples of pre-Mesozoic geologic features that have been interpreted as the products of triple junction interactions. This is undoubtedly not a true representation of the geologic record, but an artifact of a lack of clear criteria for the recognition of ancient triple junction interactions. Thus, an important challenge for the earth sciences is recognition of characteristic features of triple junction interactions, and the fingerprinting of ancient systems.

The purpose of this conference is to bring together earth scientists from a variety of disciplines to determine what, if any, are the distinguishing features of different classes of triple junction interactions. Our primary goal is to bring together groups working on ancient systems and groups involved in the study of present-day systems, with the hope that the interaction between these groups will produce a new perspective on this problem. This plan is particularly timely because of recent completion of the Ocean Drilling Program leg that investigated the modern ridge subduction off southern Chile, completion this fall of a seismic transect across the Mendocino triple junction, and recent studies in both Japan and Alaska that document the geologic consequences of Tertiary ridge subduction events. Our objective is to bring together a panel of researchers with expertise to consider the topics of structure and kinematic analysis, metamorphic and igneous petrology and geochemistry, regional tectonics, plate motions, marine geology and geophysics, and geodynamics and thermal modeling of convergent margins.

Participation in the conference will be limited to about 80 people. Attendance for graduate students and non–North American participants may be subsidized. Scientists who can contribute to any of the topics listed above are encouraged to apply. We particularly encourage applications from individuals working on ancient systems where triple junction interactions may explain unusual "events" in the geologic record. The registration fee is expected to be under $600 and will include meals and lodging, a one-day field trip, and other conference costs. Formal invitations will be mailed in January 1994.

Co-conveners:
Virginia B. Sisson, Department of Geology, Rice University, Houston, TX 77251-1892, phone (713) 285-5234
Terry L. Pavlis, Department of Geology and Geophysics, University of New Orleans, New Orleans, LA 70148, phone (504) 286-6797
David J. Prior, Department of Earth Sciences, University of Liverpool, P.O. Box 147, Liverpool L69 3BX, UK

Application deadline: December 15, 1993.

Interested participants should send a letter of application to Virginia B. Sisson, address above. ■

SAGE REMARKS

Statement on Promotion, Tenure Decision, etc., for Good Teachers at the University Level (Grades 13–16)

E-an Zen
Based on text approved by the participants of the GSA Presidential Conference on Education, Racine, Wisconsin, January 17, 1993.

Science is a public property; it is useful for many purposes in the daily lives of our society and our citizens. Earth science is an important component of science because Earth is our only habitat. It is also the unique base from which other scientific investigations such as physics, chemistry, and biology must be carried out. Furthermore, earth resources, hazards, and environments directly determine whether human society can continue to prosper as a balanced and sustainable place for living forms. Knowledge of the earth processes must be taught broadly and in an accessible and enjoyable way at all levels of learning from K through 16.

Undergraduate instruction in the earth sciences is key to this enterprise. This is where future scientists are being prepared. Equally significant, it is at the universities, liberal arts colleges, and community colleges that our future elementary and secondary school earth science teachers get their preparation. In turn, these teachers will transmit the way of teaching they were exposed to and their emotional response to the subject matter to their students. These teachers will also be the principal means by which future citizens will be prepared to deal with societal issues. For all these reasons, it is vital that those who instruct at the college level are not only able to pass on to their students the factual knowledge, but to convey an understanding of the significance of earth science and its relevance, and to infuse a sense of enthusiasm and an attitude of inquiry, so that the prospective teachers in turn will carry the knowledge and attitude to their students and their children.

Undergraduate and especially introductory courses in the earth sciences must be taught by the best teachers.

Recognizing this connection between teaching at the undergraduate level and the future of science literacy in different sectors of society, the Geological Society of America calls upon the university faculties to address this challenge and opportunity within the university systems. Equitable and broadly applicable criteria for assessing meritorious teaching versus quality research must be formulated. Effective and inspiring teachers must be recognized, retained, respected, and rewarded. Excellence in undergraduate teaching must become as important as excellence in research and graduate teaching for purposes of tenure decisions, promotion, awards, and rewards. ■

Position Available

GSA will need an Executive Director in 1994

The Geological Society of America is seeking an *earth scientist with proven managerial experience and achievements, general familiarity with GSA programs, and a working knowledge of the publication business* to assume the position of Executive Director in June 1994 when Dr. F. Michael Wahl will retire.

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Nominations and applications must be received by **November 15, 1993**.

Proposals Solicited for 3rd Annual Environmental Forum—Seattle

Fred A. Donath, Executive Director
Institute for Environmental Education

The Institute for Environmental Education, in cooperation with the GSA Committee on Geology and Public Policy, is soliciting proposals for the 3rd Annual Environmental Forum to be held in conjunction with the 1994 GSA Annual Meeting in Seattle. Proposals should include a summary of the proposed forum subject, perspectives to be represented (including names of speakers who might present these), and names of the person(s) who will serve as organizer(s) of the forum. Although prospective speakers need not be confirmed at the time the proposal is submitted, proposed organizer(s) must be.

The IEE Annual Environmental Forum is intended to increase the awareness of geoscientists and the public of the role of geoscience in addressing environmental concerns. Although selection of the topic for the forum will take into consideration the geologic setting of the meeting place and environmental issues of particular interest there, the subject should have global significance. Speakers should be selected who will present public interest, legal, regulatory, management, and other viewpoints, as appropriate, in addition to the purely scientific.

Previous IEE Annual Environmental Forums have addressed the issues of ground-water cleanup vs. ground-water protection, and pollution and waste management in Boston Harbor and Massachusetts Bay. Because many environmental issues in the western United States are related directly or indirectly to energy issues, an appropriate subject for the Seattle forum might be some aspect of energy resource development or proposed land use. The proposed Yucca Mountain nuclear waste repository, offshore drilling on the west coast, and resource exploration on public lands are three examples of high-profile issues involving geoscience that are capable of generating substantial public debate.

Proposals should be submitted no later than November 15, 1993, to Fred A. Donath, Executive Director, Institute for Environmental Education, Geological Society of America, P.O. Box 9140, Boulder, CO 80301.

Earthquake Hazards Reduction Fellowship Announced

Under a cooperative agreement established with FEMA, the Earthquake Engineering Research Institute is offering the 3rd Annual Professional Fellowship, to provide an opportunity for a practicing professional to gain greater skills and broader expertise in earthquake hazards reduction, either by enhancing knowledge in the applicant's own field or by broadening his or her knowledge in a related but unfamiliar discipline. This fellowship is aimed at the career professional and is designed to bring together an experienced practitioner with those conducting significant research, providing an opportunity to enrich the applicant's knowledge and skills and broaden the research base with challenges faced in practice.

The fellowship provides a stipend of $30,000, commencing in January 1994, to cover tuition, fees, relocation, and living expenses for a six-month period.

Applicants must provide a detailed work plan for a research project that would be carried out in the six-month period. The Fellow will be expected to produce a written report upon completion of the project. All applications must be accompanied by a professional résumé and letter of nomination from the faculty host(s) at the cooperating educational institution(s). Faculty members should also indicate the institution's ability to provide research facilities, including library, work space, telephone, and computer access. Applicants must hold U.S. citizenship or permanent resident status.

Candidates may obtain an application form from the Earthquake Engineering Research Institute, 499 14th Street, Suite 320, Oakland, CA 94612, (510) 451-0905, fax 510-451-5411. Deadline for receipt of all application materials at EERI is September 17, 1993. Announcement of the award will be made October 15, 1993. ■

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tion; and because the time scale of the core flow is much longer than that of the atmosphere, observations of the core cover a relatively much shorter time span. I consider here how the rather limited observations that are available can be used to help constrain hypotheses of the dynamo process and, more generally, how they can be used as a probe of the structure and dynamics of Earth's deep interior.

OBSERVATIONS OF EARTH'S MAGNETIC FIELD

Direct observations of the magnetic field date back 500 years, and observations with sufficient geographical coverage to allow global mapping of the field date back more than 300 years. Although navigation has always been the overriding motivation for magnetic field observations, the importance of systematic observations of the field as a means to understanding its origin has long been recognized. At the end of the 17th century, Edmund Halley hoped that by refining his theory that the secular variation of the surface field can be described by a westward drift of contours of the magnetic declination (Halley, 1683, 1692), the origin of the field could be better understood. In this spirit, he undertook a magnetic survey of the Atlantic Ocean, perhaps the first marine geophysical survey.

Prior to the mid-19th century, most observations were made on sailing ships on trading voyages and voyages of discovery. The advantage of these observations is that they are generally not significantly contaminated by deviation, because they were made on wooden ships. However, imprecise navigation affects their accuracy; until the introduction of the marine chronometer by John Harrison in 1768, the determination of longitude at sea relied upon dead reckoning and was commonly in considerable error. Incidentally, Halley hoped that his magnetic survey of the Atlantic might also lead to a means of determining longitude at sea. In order to make use of these historical observations, we found it necessary to replot the original navigational records by relocating landfalls to their now known geographical positions and applying corrections to the intermediate positions.

Later, large-scale surveys of the field led, by the mid-19th century, to a great increase in the number of observations. Around this time, the first permanent magnetic observatories were introduced. Permanent magnetic observatories play a particularly important role because, unless relocated (an all too common occurrence), they are especially effective at constraining the time-varying part of the field.

Most recently, satellites, notably the POGO satellites in the middle to late 1960s and Magsat in 1979–1980, have provided very high quality observations with an extremely good geographical coverage.

All observations of the magnetic field are, of course, made at or slightly above Earth's surface. As a result, magnetic fields arising in the crust (and in the case of satellite measurements magnetic fields arising in the ionosphere) appear to be part of the internal field and so are indistinguishable from the core field. Fortunately, the crustal field is small compared to the core field at long wavelengths and to a large extent can be treated as a source of random noise, with an amplitude of a few hundred nanotesla. This is small compared to the amplitude of the field originating in the core, typically about 40 000 nT at Earth's surface. Ionospheric fields are even smaller in amplitude and are mostly of concern with recent high-resolution satellite observations. Statistical models of these contaminating fields can be constructed (Langel et al., 1989; Jackson, 1990) so that account can be taken when constructing field maps at the core-mantle boundary of their affect on the field originating in the core.

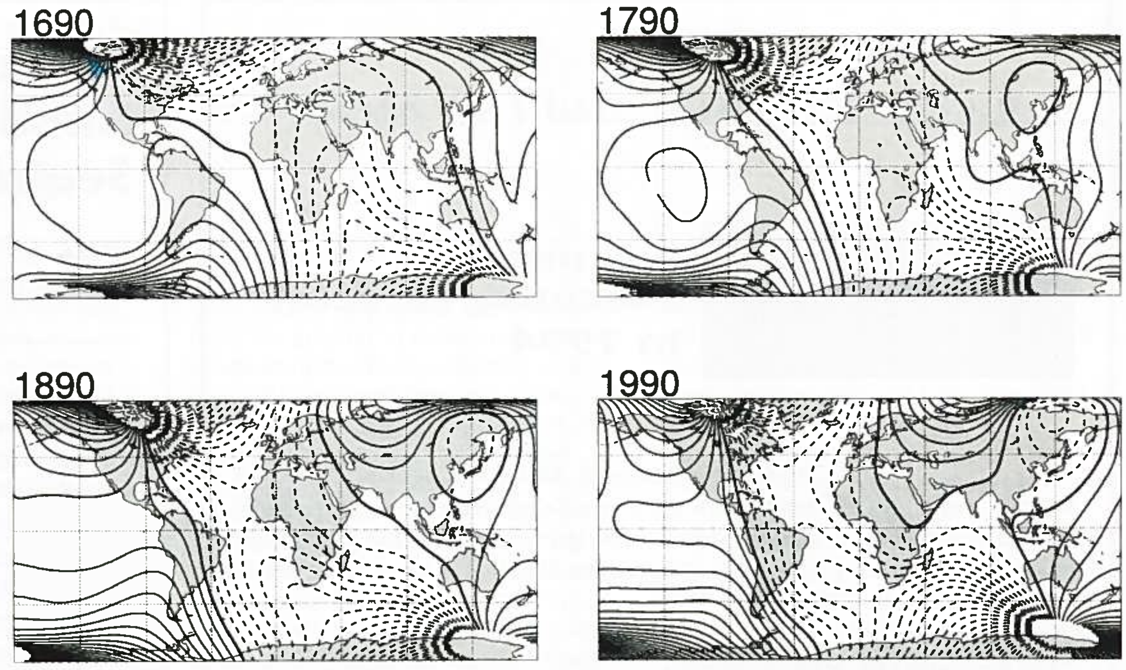

Figure 2. Magnetic declination at Earth's surface calculated from models ufm1 and ufm2. The contour interval is 5°; solid contours represent eastward declination, dashed-line contours represent westward declination, and the bold contour represents zero declination.

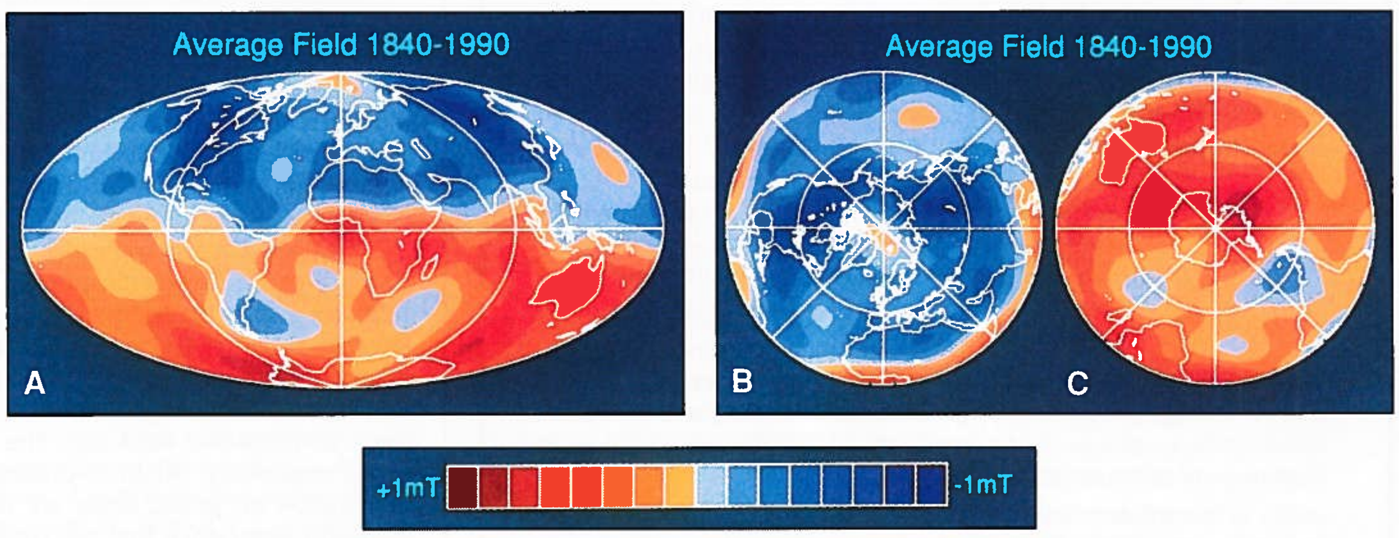

Figure 3. The radial component of the steady part of the magnetic field at the core-mantle boundary for the period 1840–1990, calculated from model ufm1. In A, the projection is Hammer-Aitoff equal area; in B and C, it is Lambert equal area centered on the north pole and south pole, respectively.

MAPPING THE MAGNETIC FIELD AT THE CORE-MANTLE BOUNDARY

This study is based on maps of the magnetic field at the core-mantle boundary rather than upon field maps at Earth's surface. One should like to be able to map the field within the core, but downward continuation is only possible through electrically weakly conducting regions (such as the mantle) and not into the body of the highly conducting outer core. Maps of the magnetic field at the core-mantle boundary do enable us to see, albeit incompletely, the magnetic field at the boundary of the dynamo region; as we shall see, maps at Earth's surface can be rather misleading when our aim is to understand the dynamo process in the core.

The discussion here is restricted to the radial component of the magnetic field for the simple reason that given the radial component, the horizontal components are uniquely determined and it is simpler to examine a single component of the vector field than all three components. The field is expanded using surface spherical harmonics to represent the spatial variations of the field and cubic B-splines to represent the temporal variations of the field; details were given by Bloxham and Jackson (1992). This expansion, which involves more than 14 000 parameters, is then fit to the observations by means of a method that finds the smoothest possible map for a given fit to the observations, so that any detail in the map is required in order to fit the observations to the particular choice of fit rather than being an artifact of the inversion procedure.

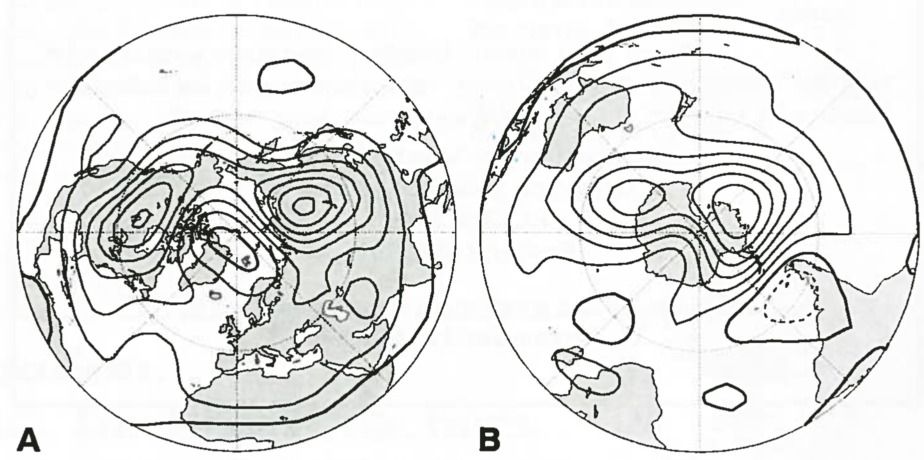

Figure 4. The function $B_r \cos\theta$ (see text) for the average field for the period 1840–1990 plotted using a Lambert equal-area projection centered on (A) the north pole and (B) the south pole.

The sequence of maps in Figure 1 shows the radial component of the magnetic field at the core-mantle boundary over the period 1690–1990, calculated from the field model of Bloxham and Jackson (1992). Although these maps are best viewed as a movie, it is clear nonetheless that the signal of the time-dependent magnetic field is rather complicated, and cannot, for example, be well described by a uniform westward drift. Beneath the Pacific Ocean the field exhibits no clear westward drift over this 300-year interval, or even any particularly obvious systematic time dependency. Figure 2 shows the declination at Earth's surface at 100-year intervals over the same period. In these maps westward drift is apparent, especially beneath the Atlantic Ocean, the region of Halley's study. This highlights the importance of mapping the field at the core-mantle boundary rather than at Earth's surface if our aim is to understand the origin of the field in the core; in particular, westward drift at Earth's surface should not be taken as an indication of a uniform westward drift of the outer core.

To move beyond the paradigm of westward drift, a more systematic analysis of the magnetic field at the core-mantle boundary is required. What is the best approach to unraveling the complicated signal of the time-dependent magnetic field portrayed in Figure 1? The analysis begins with the simplest possible first step: it is clear from Figure 1 that a large part of the field is unchanged over the time period considered, so we can begin by extracting the steady ingredient of the field—in other words, the time-averaged or

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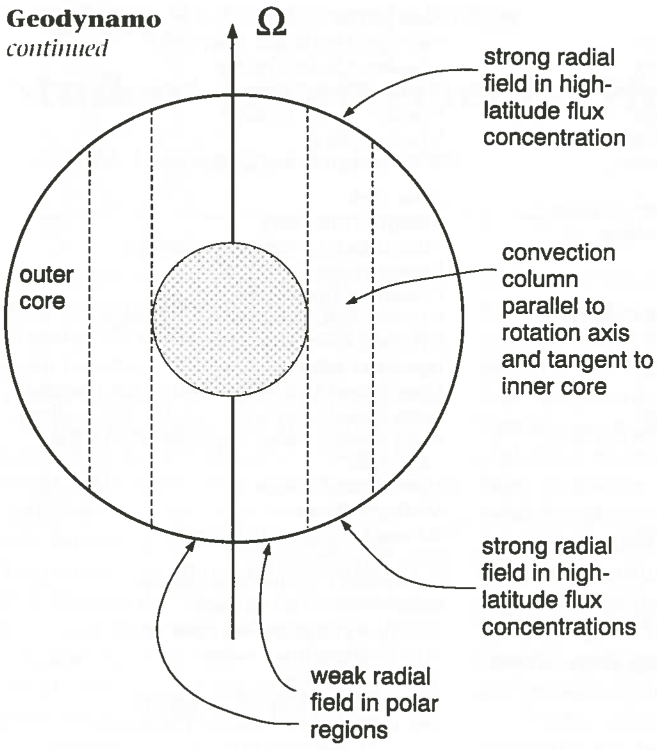

Figure 5. A model of the dynamo process in Earth's core. Dynamo action is concentrated in tall helical columns parallel to the rotation axis, the ends of which correspond to the concentrations of magnetic flux found at high latitudes. The polar regions of the core-mantle boundary, above and beneath the inner core, are regions of low magnetic field, possibly due to reduced dynamo action.

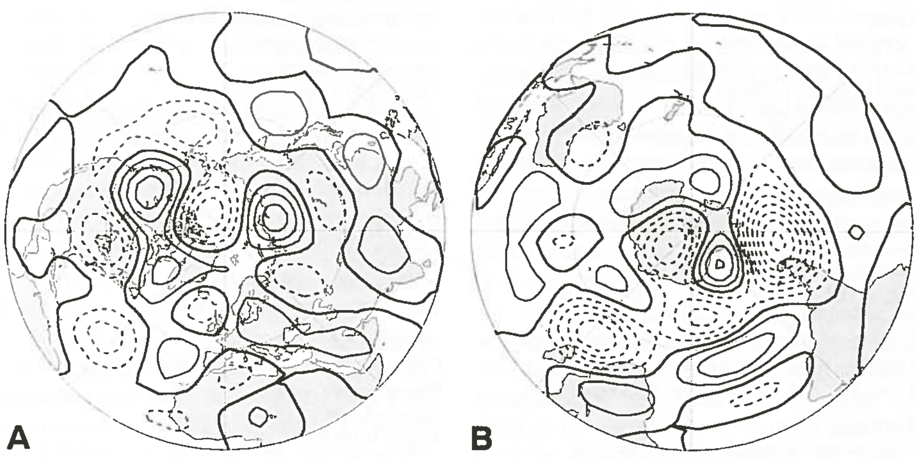

Figure 6. The function $B_r \cos\theta(t = 1990) - B_r \cos\theta(t = 1840)$ for the period 1840–1990 plotted using a Lambert equal-area projection centered on (A) the north pole and (B) the south pole.

non–time-dependent part of the field. This ingredient of the field is, most likely, the part that is best resolved, so given that we do not have reliable estimates of the true uncertainty of the maps, a conservative approach is to look first at this ingredient.

Steady Ingredient of the Field

The steady ingredient of the radial component of the field for the interval 1840–1990 (Fig. 3) accounts for approximately 80% of the variance of the radial field at the core-mantle boundary.

The dipole component of the field is due largely to two concentrations of flux in each hemisphere at high latitude and at approximately 120° longitude. The dominant contribution of these flux concentrations to the dipole is clearly seen in Figure 4, in which is plotted, using a polar projection, the contribution of the field to the axial dipole component, the quantity $B_r \cos\theta$ where B_r is the radial component of the magnetic field, and θ is colatitude (Gubbins, 1987). From Figure 1 it can be seen that these flux concentrations are nearly static. Closer to the poles the radial field is weak, and it is almost zero at the north pole, contrary to what would be expected for an axial dipole field, which would have maximum radial field at the poles.

As pointed out by Gubbins and Bloxham (1987), the steady field, including these high-latitude flux concentrations, is predominantly antisymmetric about the geographical equator, a permissible symmetry of the full magnetohydrodynamic dynamo equations, provided that the flow is symmetric about the geographical equator. This required flow symmetry is not unexpected, because of the strong role played by Earth's rotation in the dynamics of the core. An effect of rotation is to modify the form of the flow so that it is independent of the coordinate parallel to the rotation axis, resulting in columnar flow structures. But how do we explain the displacement of the high-latitude flux concentrations from the poles? Figure 5 shows one possible mechanism to explain this, on the basis of presence of the inner core. The columnar structures in the outer core are displaced from the rotation axis by the presence of the inner core, leading to flux concentrations at high latitude at the ends of these columnar structures and weak fields in the extreme polar regions within the cylinder tangent to the inner core.

Secular Variation

The next step in this analysis of the magnetic field at the core-mantle boundary is to look at the time-varying part of the field, the secular variation, which, mentioned above, varies greatly in strength over the boundary. We begin by considering the most prominent changes in the field.

The region of the core-mantle boundary that exhibits the greatest change in the field is that beneath southern Africa and the south Atlantic Ocean. In particular, a large patch of reversed flux (flux having opposite sign to that expected for that hemisphere with the present dipole polarity) has emerged and intensified in this region. What effect has the growth of this patch had on the axial dipole component of the field, which has decreased in strength by almost 10% in the past 150 years? From Figure 6, a plot of the change in $B_r \cos\theta$ (the quantity shown in Fig. 4) between 1840 and 1990 (i.e., the change in the contribution of the field to the dipole strength), we can see that the growth of the reversed flux patch and the decay of the dipole are closely related.

A simple model that explains the growth of this reverse flux patch is flux expulsion, the expulsion of initially horizontal field lines from the core by a concentrated upwelling motion (Bloxham, 1986). Remarkably, Bullard (1954) first proposed this mechanism to explain the anomalously large secular variation observed at southern African observatories, even though he had no maps available of the core field. Kinematically, this process is similar to that responsible for the formation of sunspots; by analogy, the resulting core field feature is called a core spot.

Although it is possible to account for particular features in the secular variation with simple models of this type (see Bloxham and Gubbins, 1985), to understand the secular variation globally rather than locally the magnetic field and secular variation are used to deduce maps of the fluid flow at the core surface. The secular variation of the magnetic field is described by the induction equation

$$\frac{\partial \mathbf{B}}{\partial t} = \nabla \wedge (\mathbf{u} \wedge \mathbf{B}) + \eta \nabla^2 \mathbf{B},$$

which shows how the secular variation arises from advection of the field by the flow (the first term on the right-hand sides where $\mathbf{u}$ is the fluid-flow field) and from magnetic diffusion (the second term on the right-hand side, where η is the magnetic diffusivity). In the so-called frozen flux approximation, the effects of diffusion are neglected, so that the secular variation arises entirely from the distortion of field lines by the flow. In the absence of diffusion, field lines are effectively frozen in the fluid and so act as tracers of the flow. This equation can be inverted to determine the flow at the core surface, as first

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If Your Campus is Listed Here, You Need a GSA Rep

Every college and university that has a geology program needs a GSA campus representative who can provide information about GSA services to students.

The Campus Representative Program began in 1979 in GSA's Southeastern Section. Active GSA members in the section were recruited to serve as campus representatives, establishing a communications link between GSA headquarters and present and prospective Student Associates.

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- Discount for National car rentals

All GSA sections participate in the program, and there are now 542 active campus representatives. We thank the current campus representatives now serving to keep the program growing. However, we need more volunteers. If you are a Member or Fellow (not Student Associate) and are interested in serving GSA as a campus representative for your college or university, please contact T. Michael Moreland, Manager, Membership Services Department, Geological Society of America, P.O. Box 9140, Boulder, CO 80301, (303) 447-2020, fax 303-447-1133.

The following campuses need a GSA campus representative. If yours is on the list, won't you consider serving?

CAMPUSES THAT *DO NOT* HAVE GSA CAMPUS REPRESENTATIVES:

CORDILLERAN SECTION

Arizona
Central Arizona College
Mesa Community College
Phoenix College
Prescott College
Yavapai College

California
Antelope Valley College
Bakersfield College
Barstow Community College
Cabrillo College
California Lutheran University
California Polytechnic State University—San Luis Obispo
California State University—Stanislaus
Chapman University
Citrus College
Contra Costa Community College
Cosumnes River College
College of the Desert
Diablo Valley College
East Los Angeles College
Foothill College
Fullerton College
Gavilan College
Glendale Community College
Golden West College
Las Positas College
Los Angeles City College
Los Angeles Harbor College
Los Angeles Valley College
Mendocino College
Merced College
Miracosta College
Modesto Junior College
Napa Valley College
Naval Postgraduate School
Ohlone College
Palomar College
College of the Redwoods
Riverside City College
Sacramento City College
Saddleback Community College
San Bernardino Valley College
University of San Diego
San Joaquin Delta College
San Jose City College
Santa Barbara City College
College of the Siskiyous
Sonoma State University
Southwestern College
Ventura College
Yuba Community College

Nevada
University of Nevada
Wassuk College

Oregon
Central Oregon Community College
Clatsop Community College
Willamette University

Washington
Green River Community College
Olympic College
Tacoma Community College
Whitworth College
Yakima Valley College

British Columbia
Capilano College
Cariboo College
University of Victoria

ROCKY MOUNTAIN SECTION

Colorado
Colorado Mountain College
Colorado Northwestern Community College
Pikes Peak Community College
United States Air Force Academy

Idaho
College of Southern Idaho

Montana
Eastern Montana College
Flathead Valley Community College
University of Montana
Northern Montana College
Rocky Mountain College

New Mexico
New Mexico Highlands University
College of Santa Fe
Western New Mexico University
North Dakota
Dickinson State College

South Dakota
Augustana College

Wyoming
Casper College

Alberta
Athabasca University
University of Lethbridge
Mount Royal College
Northern Alberta Institute of Technology
Southern Alberta Institute of Technology

Saskatchewan
University of Regina

NORTH-CENTRAL SECTION

Illinois
University of Chicago
Columbia University
Concordia University
Elgin Community College
College of Lake County
Lincoln Land Community College
Northeastern Illinois University
Principia College
Wabash Valley College

Indiana
Holy Cross College
Indiana University/Purdue University—Fort Wayne
Indiana University at Kokomo
Vincennes University Junior College

Iowa
Drake University

Michigan
Adrian College
Central Michigan University
Charles Stewart Mott Community College
Concordia College
Eastern Michigan University
Gogebic Community College
Henry Ford Community College
Lansing Community College
Macomb Community College—Warren
Northern Michigan University
Schoolcraft College
St. Clair County Community College
Washtenaw Community College
Wayne State University

Minnesota
Anoka-Ramsey Community College
Concordia College
Itasca Community College
Macalester College
Mesabi Community College
University of Minnesota—Twin Cities
Southwest State University
St. Cloud State University
College of St. Thomas
Willmar Community College

Missouri
Central Methodist College
St. Louis Community College at Florissant Valley
St. Louis Community College at Forest Park
Stephens College
William Jewell College

Nebraska
Kearney State College

Ohio
Ashland University
Central State University
Muskingum College
Oberlin College
Ohio University—Lancaster
Shawnee State University

Wisconsin
Milwaukee Area Technical College
Mount Senario College
Northland College
University of Wisconsin—Extension
University of Wisconsin—Madison
University of Wisconsin—Marathon County
University of Wisconsin—Platteville
University of Wisconsin—Stevens Point

Ontario
University of Western Ontario

SOUTH-CENTRAL SECTION

Arkansas
University of Central Arkansas
College of the Ozarks
Southern Arkansas University

Kansas
Cowley County Community College

Oklahoma
Northeastern Oklahoma A&M College
Northeastern State University
Phillips University

Texas
Amarillo Junior College
Angelo State University
Del Mar College
Houston Community College System
Kilgore College
Laredo Junior College
Lee College
Odessa College
Rice University
San Antonio College
South Plains College
Tarrant County Junior College
University of Texas—Pan American
University of Texas at Dallas
Texas Christian University

NORTHEASTERN SECTION

Connecticut
University of Bridgeport
Central Connecticut State University
University of Connecticut
Southern Connecticut State College
United States Coast Guard Academy

Delaware
University of Delaware—College of Marine Studies

Maine
University of Maine at Presque Isle

Maryland
Catonsville Community College
Frostburg State University
Montgomery College
Towson State University

Massachusetts
Bentley College
Berkshire Community College
Fitchburg State College
Greenfield Community College
University of Massachusetts at Boston—Harbor Campus
North Adams State College
Worcester State College

New Hampshire
New England College
Plymouth State College

New Jersey
Fairleigh Dickinson University
Glassboro State College
Trenton State College
Union County College
Upsala College
William Paterson College

New York
Adelphi University
Adirondack Community College
Broome Community College
Columbia University
Hudson Valley Community College
Jefferson Community College
Lehman College (CUNY)
Long Island University—Brooklyn Campus
Long Island University—C. W. Post College
Long Island University—Southhampton Campus
Manhattan College
Molloy College
Nassau Community College
New York University
Onondaga Community College
Roberts Wesleyan College
SUNY—College at Purchase
SUNY—Maritime College
SUNY at Albany
United States Military Academy
Utica College of Syracuse University

Pennsylvania
Drexel University
Elizabethtown College
Gannon University
Lycoming College
Mansfield University
Montgomery County Community College
Pennsylvania State University—Altoona Campus
Pennsylvania State University—Erie
Pennsylvania State University—Monaca
Susquehanna University
Thiel College
Wilkes University
York College of Pennsylvania

Rhode Island
Community College of Rhode Island
Providence College
Rhode Island College
Roger Williams College

Vermont
Castleton State College
Johnson State College
Middlebury College
University of Vermont

New Brunswick
University of New Brunswick
University of New Brunswick—Saint John

Newfoundland
Sir Wilfred Grenfell College

Nova Scotia
St. Mary's University
University College of Cape Breton

Ontario
University of Guelph
University of Ottawa
Sir Sandford Fleming College

Quebec
Concordia University
Ecole Polytechnique
Université du Quebec
Université du Quebec à Rimouski
Université du Quebec à Trois Rivières

SOUTHEASTERN SECTION

Alabama
University of Alabama—Dauphin Island
University of Montevallo
University of North Alabama

Florida
Broward Community College
University of Central Florida
Eckerd College
Edison Community College
Florida Institute of Technology
Florida Keys Community College
Gulf Coast Community College
Miami-Dade Community College (New World Center)
Nova University
Okaloosa-Walton Junior College
Pensacola Junior College
St. Petersburg Junior College
St. Petersburg Junior College—Clearwater
Stetson University
Tallahassee Community College

Georgia
Emory University—Oxford College
Gainesville Junior College
Georgia Southwestern College
Gordon College
Kennesaw College
Mercer University
Shorter College
Valdosta State College

Kentucky
Berea College

Campus Reps *continued on p. 227*

President's Student Forum in Boston

Student Involvement—The Future of GSA

Robert D. Hatcher, Jr., GSA President

An informal discussion will be held at the Annual Meeting in Boston on Tuesday, October 26, from 4:00 to 5:30 p.m. (see the meeting program for location). Student Associates of GSA (graduate, undergraduate, and any others) are invited to meet with me to discuss the ideas and suggestions of Student Associates on their perception(s) of what the Society is and where it is going, improvements that might strengthen the roles of the Society in the 21st century, and especially how they could become more involved in Society affairs. Since the Student Associate category was established in 1971, this is the first attempt, to my knowledge, to encourage students to become more involved in the workings of the Society. I hope many of you will come to the forum in Boston to voice your opinions and contribute ideas, and that even more will write comments and send them to me in Boulder—or both. I see the Student Associates as an important segment of the membership that could contribute fresh ideas and perspectives that could have a strong influence on the future of the Society.

Student Associates of the Geological Society of America receive reduced membership dues and registration fees at annual and section meetings, receive *GSA Today,* are offered the opportunity, like other members, to subscribe at reduced rates to the other periodicals of the Society, and receive member discounts on all Society publications. A forum, entitled "Future Employment Opportunities in the Earth Sciences," is held each year at the annual meeting, and published proceedings of this forum are available to students at no cost. Employment and graduate school interviews are also conducted at annual and some section meetings. GSA sections and some divisions also provide funds for student travel assistance programs to enable more students to participate in annual and section meetings. Most sections also sponsor "Best Student Paper Awards." Additional benefits for students are summarized in the accompanying box.

Unlike all other members, Student Associates are not allowed to vote in Society elections. They made up 17% of the GSA membership in 1992, and, while regular Members and Fellows are afforded no special representation, the Council has made a conscious and successful effort during the past decade or longer to include women and minorities on the Council and on committees. Yet we have made no provision to include this 17% in the major functions of the Society.

Many universities for a number of years have had student participatic on department, college, and university committees, and student representatives participate in faculty meetings in most geology departments. So, how can GSA enlist better representation of Student Associates in Society activities? Should there be special symposia or theme sessions at meetings for student presentations? An attempt is being made to effect this in Boston. Would you like to be able to vote in Society elections? Should there be a separate student group that makes recommendations to Council? If so, how should representatives be chosen and for what term of office? Would you like to participate in the GSA committees where all members are not required to be either Fellows or present or former Councilors? If so, should these committees be expanded to include a Student Associate, or should a regular slot be filled with a student as slots become available? In a time when the Society is already attempting to hold down costs, addition of a Student Associate to any committee should probably be done only where costs of committee operations will not be increased.

I raised the question of greater involvement of Student Associates in Society affairs at both the October 1992 and May 1993 Council meetings. During a lengthy discussion in May, we explored a number of possibilities for greater student participation in the Society. We decided that, before any specific recommendation is entertained by the Council, we should explore directly with the Student Associates the question of whether or not they would like to have greater involvement in the Society, and, if so, what form the involvement should take.

I see this as an opportunity to expand the role of a major underutilized segment of the GSA membership, perhaps the most important segment—the one that will be leading the Society during the 21st Century. I look forward to meeting more of you and listening to your ideas and suggestions in Boston. Please give this some thought before the informal meeting in Boston on October 26. Students who are not Student Associate members and any others will also be welcome. If you are unable to come to Boston and have ideas or suggestions you would like to contribute, please address them directly to me at GSA Headquarters in Boulder by November 1. You may wish to photocopy, fill in, and mail comments on the form below, if you find it more convenient.

We feel this is an opportunity to hear the views of a major segment of the membership that rarely, if ever, is heard. I hope that this appeal will tap a segment of the membership that wants to be heard and that the response will be quite vocal. Please respond to this opportunity. ■

STUDENTS—
Did you know about these GSA programs?

- Campus representatives in almost all geology departments on campuses in the U.S. and Canada have information available about GSA programs and activities.
- Reduced registration fees for annual and section meetings.
- Additional meeting registration discounts for students joining GSA at the annual meeting. Discounted membership fee includes *GSA Today.*
- Travel grant program to assist Student Associates traveling to annual and section meetings.
- Research grants program.
- Student best paper awards presented by most sections and divisions (the Planetary Geology Division program offers a cash prize).
- Limited assistance to attend Penrose Conferences including reduced conference fees.
- Forums on careers in the geosciences conducted at annual and some section meetings.
- Graduate school information services at the annual meeting
- Student Associate discount for GSA Employment Service application.
- Reduced subscription rates to GSA *Bulletin* and *Geology.*
- Discounts on GSA books, maps, and charts.

Requirements for programs vary; some require GSA membership.

STUDENT ASSOCIATE QUESTIONNAIRE

NAME *(optional)* ______________________________

COLLEGE OR UNIVERSITY *(optional)* ______________________

How can GSA enlist better representation of Student Associates in Society activities?

Should there be special symposia or theme sessions at annual and section meetings specifically for student presentations? (An attempt is being made to effect this in Boston with a Theme Session on World Environmental Problems.)

Would you like to be able to vote in Society elections?

Should there be a separate student group that makes recommendations to Council? If so, how should representatives be chosen, and for what term of office?

Would you like to participate in one or more GSA committees as a Student Associate? If so, should these committees be expanded to include a Student Associate, or should a regular slot be filled with a student as slots become available?

In what other ways could the Society better serve student interests?

Photocopy, clip along dotted line, and mail to:
President Bob Hatcher, Student Associate Forum
Geological Society of America
P.O. Box 9140
Boulder, CO 80301

Reps Needed *continued from p. 226*

Henderson Community College
Morehead State University
Northern Kentucky University

Louisiana
Louisiana Tech University
Northwestern State University

Mississippi
Millsaps College

North Carolina
Catawba College
University of North Carolina—Asheville
North Carolina Agricultural & Tech State University
North Carolina Central University

South Carolina
Coker College
Wofford College

Tennessee
Rhodes College

Virginia
Emory & Henry College
Hampton University
Lynchburg College
Northern Virginia Community College
Virginia State University
Virginia Western Community College

West Virginia
Glenville State College
Potomac State College
West Virginia University—Parkersburg ■

FORUM

Bruce F. Molnia

Forum is a regular 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: Ground-water Cleanup vs. Ground-water Protection—Where Should the $$$ Go?

This Forum is the second of two parts that, collectively, are a condensation of the IEE Annual Environmental Forum presented at the 1992 GSA Annual Meeting. Part 1, which appeared in the July issue of *GSA Today*, presented the viewpoints of two environmental scientists and an economist, on several key issues: the large volume of unregulated hazardous waste, real vs. perceived health risks, and the costs and benefits of protection vs. cleanup of ground water. Part 2 presents an historical and international perspective of the problem and viewpoints on what can be done by local government, the geoscientist, and the public in consideration of the causes and character of ground-water contamination.

PERSPECTIVE 4: Ground-Water Contamination: An Historical and International Perspective

Andrew W. Stone,
American Ground Water Trust

I represent a group that has concern about public education in ground water. It is our fundamental belief that unless the public is informed about the underlying science, we don't stand much hope of making progress in getting good legislation and intelligent decisions that affect ground water. In the United States, liability, cleanup, and protection policies related to ground water have had far-reaching effects on industry and the environmental professions, and lesser, but ongoing, impacts on aquifers. But ground-water contamination is not a problem unique to the United States. In many parts of the world, environmental perceptions and priorities have changed over the past 20 years, and public pressure has forced a legislative and administrative response.

The term "ground water" broadly describes all subsurface waters, but the major concern regarding contamination issues is with ground water that has economic supply potential or ecological significance. Nevertheless, the contamination debate needs to maintain a perspective of the entire integrated hydrological system, of which ground water is only a part. But what is contamination? A dictionary definition is "to render impure by mixture or contact." The definition begs the question of what is meant by purity, a particularly difficult issue in water resources, with the constantly moving target of changing drinking-water standards being advanced by regulators, environmentalists, or individual perceptions. In recent British water legislation, the term "pollution" is used when the levels of contamination are such that harm may be caused. Harm is seen usually, but not exclusively, in terms of risk to human health. In virtually all instances, ground-water contamination is associated with human activity in agriculture, mining, industry, transport, or urban development.

Increased health risk from contaminated water is a problem for any society. In addition to health costs, ground-water contamination can result in the total loss of the economic value of the resource, in increased costs of water treatment, and in environmental damage resulting from the perturbed hydrogeological system. Although the risks to health from contamination have been known for thousands of years, each society seems to need to go through a relearning process.

Different societies have at different times had varying engineering and regulatory responses to reduce risk. The Bible's Book of Deuteronomy, Chapter 23, provides an early example of environmental advice, "...it shall be that when thou will ease thyself ... thou shall dig ... and turn back and cover that which cometh from thee." More than 4000 years ago in Harappa, in the Indus Valley, houses had both water supply and drainage systems. In 500 B.C., Athens had a policy of no dumping within a mile of the city. However, the sophisticated water engineering of early societies stands in sharp contrast to the almost total lack of hygiene and environmental awareness in cities of Europe during the Middle Ages.

In 17th century America, a 1610 proclamation by Governor Gage at the military fort at Jamestown conveys a timeless message and comment on ground-water contamination: "There shall be no man or woman dare to wash any unclean linen, wash clothes, ... nor rinse or make clean any kettle, pot or pan, or any such like vessel within twenty feet of the old well or the new pump. Nor shall anyone aforesaid within less than a quarter of a mile of the fort, dare to do the necessities of nature, since by these unmanly, slothful, and loathsome immodesties, the whole fort may be choked and poisoned." From this first recorded American ground-water contamination regulation, one may conclude that:

- Unpolluted drinking water is vital for health.
- The activities of man are a major cause of pollution.
- Separation by distance is a way to protect a ground-water resource.
- Responsible behavior is the solution to collective well-being.

These four principles could serve as a reference for considering any contamination issue, ranging in scale from the worst chemical cauldron at a Superfund site to a single malfunctioning septic system.

Most contamination problems are caused by the concentration of people and activities, which creates wastes beyond the capacity of natural chemical and biological processes to neutralize them. Early settlements benefited from pristine natural conditions. For example, springs near London were described in 1180 as "... excellent[,] the water of which is sweet, clear and salubrious." An account some 700 years later comments, "I have never seen anything so ghastly ... as the slow stealing of reckless and indolent neglect ... than the insolent defiling of those springs."

We are representatives of the first generation in the earth's history that has clearly, radically altered our environment. Things have gone wrong in the past, but demographics and technology have made us part of what is a very fundamental change in the whole global environment. Part of the industrial contamination problem can be related to a resource exploitation mentality based on the Cartesian philosophy that man should harness nature and make it serve his needs. Indeed, as Genesis will tell us, there was almost a requirement that man should control nature. Winston Churchill, commenting on the completion of the first dam on the Nile, said that he looked forward to the day when technology would be able to stop every drop of water from being wasted on its way to the ocean. In the United States, an additional influence on environmental attitudes was the "frontier mentality" of the developing West, whereby territory and resources were seemingly limitless, and you merely moved on when you were finished where you were. Such historical perspectives have very much influenced our attitudes and our reactions to contamination issues.

There are many other historical aspects on which one can comment, most of which indicate that we have known all along what is wrong. However, we've lacked the will, the political will, or the infrastructure to put it right. One thinks of the 1854 statement by Snow, that famous doctor who solved a disease problem in London: "Take away the handle from the pump and you'll solve the problem." He identified immediately the relationship between water and disease. Indeed, our focus must remain on people. We are concerned with health, and we are concerned with water-quality issues as these affect the human environment. Nearly 40% of the world's population does not have adequate access to healthful water. There are 35 deaths per minute throughout the world related to poor water quality—35 per minute! According to the United Nations, the United States is one of only 18 countries in the world whose populations have 100% access to pure water. We are rightly proud of our record—in many places, we erect signs stating "Public Water Supply Approved." But 18 out of 181 countries is not very good.

The current environmental paradigms of "self sustaining," "equilibrium," and "balance" show a change in philosophy which public pressure has now forced many governments to espouse. These modern philosophies are very similar to the traditional beliefs and rules of indigenous peoples such as the North American Indians. The United Nations 1992 Rio Conference confirmed that environmental issues, such as ground-water contamination, are part of the world political agenda. The profit-oriented motives of capitalist western industry have in the past been as guilty of negligent contamination as have been the crass inefficiencies of factories of the former socialist systems of eastern Europe. However, too often the environmental issue has been simplified to the point where it is seen as business vs. the environment. Those of you who have read Charles Dickens will appreciate some of the satanic laws and the early industrial environments in which Britain emerged—and, of course, the United States as well. But business vs. environment is not a very sensible or useful way of looking at issues that are infinitely more complex and require a far more sophisticated approach than an "either/or" type of investigation.

Concerns in Europe and in the United States over the past 20 years have been driven by ever-increasing public environmental awareness, prompted in part by media attention to a succession of serious contamination incidents. With 53% of the U.S. population using ground water for drinking—obtained from 13 million private wells and 200,000 public supply systems—the nation has an enormous vested interest in preserving and protecting its ground-water resources. In Europe, ground-water use is even greater—for Italy, 97%, the Netherlands, 70%, and Switzerland, 84%—and, with a higher ratio of population to land area, contamination has the potential to be more serious.

Although some lone voices were raised about contamination, it was not until the 1972 United Nations Conference on the Human Environment in Stockholm that there was an international declaration on the obligation of states to protect the environment. International standards developed by the World Health Organization, although controversial in terms of their toxicological relevance, have served to spread world-wide awareness of ground-water quality and contamination risks. The European Economic Community attempt to create a single set of drinking-water standards has further sharpened the contamination debate in and among member countries.

In all parts of the world there are reasons to explain instances of failure to protect ground water from contamination. The legacy of many years of few or inadequate safeguards, lack of funds for enforcement, regulations drafted in partial ignorance of hydrological and hydrochemical processes, inappropriate administrative organization, political upheaval, and a low budget priority for environmental issues in comparison with industrial growth targets are reasons, but not excuses, common to many countries.

"Prevention is better than cure" is a glib saying that does little to comfort the sick! In terms of aquifer contamination, both remediation and prevention are needed, although in the United States, largely because of political decisions about funding, an enormous investment has been made in cleaning a small portion of the contamination problem, whereas a much more limited investment is being made in the critical area of public education and prevention. In Australia, to manage and remedy the cause of pollution problems is accepted as more effective than to provide capital-intensive treatment of the effects. German law gives ground water the same protection rights provided for humans and animals. India has an imaginative system of ground-water protection whereby the cost of pollution control for each industry is linked to annual activity. In Korea, environ-

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mental conservation is a national obligation because the right to a clean environment is provided in their constitution.

From the perspective of public awareness and education, I have attempted to add a few cameos to the debate about how to deal with ground-water contamination. My main points are the following.

- We should recognize that concerns with water quality are part and parcel of the total environmental issue. We cannot and should not separate concerns about ground water from other environmental concerns.
- Issues about ground-water contamination are fundamentally issues of hydrology, of the hydrologic system and geology. It is most important that ground-water protection laws recognize the higher laws of physics which apply to the flow of ground water.
- Regulations at federal, state, and local levels will be an ever-present component of ground-water protection. Public education is required to help formulate effective legislation, to help gain public support for the costs of ground-water protection, and to promote individual behavior patterns that will reduce contamination.
- The United States and North America are part of a global environmental concern. In formulating cost-effective and workable legislation, much can be learned from other countries and from historical perspectives. We cannot afford the time nor the expense of "blinkered" isolation in dealing with our contamination problems.
- We respond in the context of our perceptions. Perceptions are framed within our understanding and experience. Understanding follows from interest, awareness, and information. Public awareness and education about correct concepts of "cause and effect" in hydrology is therefore a major challenge in dealing with ground-water contamination.

The country is concerned, communities are concerned, and people want to do something about ground-water contamination. They are depending on the scientists to advise them about what they should do. Concern is not only about health risks. The economic and ecologic value of ground water and the costs of preserving ground-water quality and integrity are associated problems for the nation's 13 million homeowner wells, for major metropolitan area water supplies, and for regional irrigation systems.

The level of public understanding and education about ground-water contamination will be a powerful influence on the amount of money that society is prepared to invest in providing solutions. Therefore, the better we as professionals inform people, the better the chance that they will be prepared to do what is needed to get the results we all are seeking.

PERSPECTIVE 5: Making the Transition from Cleanup to Prevention—Dayton's Approach to Well Field Protection

Douglas "Dusty" Hall,
Environmental Protection Manager,
City of Dayton, Ohio

The title of this presentation is intended to send the message that in Dayton, Ohio, we are making the transition from cleaning up ground-water contamination to preventing contamination. We're not simply talking about it, we are doing it. A famous saying is very apropos here: everything is political, and all politics are local. My presentation concerns the role of local government and its capabilities relative to ground-water management. Much has been said about federal regulations and what they do and don't accomplish. Here I give examples of what, in fact, can be done at the local government level.

Dayton is about 60 miles north of Cincinnati, on Interstate I-75. The city sits directly above a buried valley aquifer system generally referred to as the Great Miami Buried Valley Aquifer system. Knowing that the region is characterized by glacial outwash and that this is simply an ancient valley filled with lots of sand and gravel, one can appreciate the sensitivity of the aquifer situation with which we're dealing. There are no protective layers above the aquifer system—the entire city was built virtually right on top of the aquifer. The city's economy is based primarily on manufacturing, so, in 1926, when the first land-use plan was established for the city, we all know where the industrial zoning went! I have a theory that, somewhere along the line, a clandestine hydrogeologist actually wrote the land-use plan to ensure future employment for hydrogeologists!

Potential Sources of Contamination

We now operate 2300 acres of well fields among that industrial zoning, and a quick tour of our well-field areas shows the types of challenges we deal with. Some of these are the same old "horror stories" with which you're all too familiar. Underground storage tanks seem to be on every corner, for example. But, we don't put them all underground in Dayton; we also have bulk petroleum storage tanks above ground. This can be intriguing because, instead of using sophisticated analytical methods, one can measure contamination with a yardstick.

We have a number of Superfund sites near our well fields. The Powell Road Landfill, for example, is in our well field protection area. Another Superfund site is Wright-Patterson Air Force Base, which has about 63 contaminated sites on base. Something to keep in mind as we continue on this tour is that Wright-Patterson is Ohio's single largest employer at one location. So, there are also economic and political issues to be considered.

Our well-field areas include some agricultural activity in addition to a large number of manufacturing facilities. It can be a rude awakening to drive by a manufacturing facility and see a drill rig out in front with people in level C chemical protective clothing. If that happens, you can definitely add them to the list of potential pollution sources.

Another potential contaminant source is a Federal- and State-permitted hazardous waste treatment and storage facility. Attempts by local government to regulate this type of facility can be especially difficult because of preemption by state law. One such facility had been granted an expansion permit under Lee Thomas's administration at the EPA. We appealed to him on the basis of the hydrogeologic sensitivity of the location and its proximity to our well field. He subsequently remanded the permit for additional consideration. So, this is one situation in which the federal government was responsive to local government efforts to protect ground water.

Our well-field protection area is also host to a large number of infiltration galleries for storm water. Unfortunately, storm sewers are not always present everywhere that development exists. One industrial laundry spilled dry cleaning solvent in the parking lot during a rain storm. The contaminated rain water entered an infiltration pond. Contamination of the ground water and a very expensive cleanup resulted.

Of course, transportation of hazardous materials is one of the most difficult of all potential sources of contamination to deal with at the local level.

One of my favorite stories is about what we call a "lulu," which stands for locally undesirable land use. It involves a paint distribution facility located fairly close to drinking-water production wells. With state-of-the-art engineering, nothing could, of course, ever go wrong. But five weeks after I took the job as Dayton's environmental manager, something went wrong. On May 27,1987, the facility went up in flames. The facility was always controversial, and that controversy now really heated up. We noted two important principles from this experience. The first is that if you have sufficient technical resources and enough money to throw at a problem, you can work miracles. In fact, five years later we are prepared to declare this site clean. The site is uncapped, and the well field is in full use. It's a miracle story that can be repeated elsewhere—provided, of course, that you've got $10 million lying around with which to take very aggressive remedial action. The other principle is that what can happen will happen. The paint warehouse had state-of-the-art engineering technology, with secondary containment, full fire suppression, and a trained fire brigade. The facility still burned up. So, the principle that we carried into our well field protection program is *proper siting*. Rather than trying to design around new potential sources of contamination, identify better locations for them.

That kind of common-sense approach is what one uses to develop and implement well-field protection programs. Deal with existing risk and prevent new risk, and that's about as complicated as it gets.

Approaches to Risk Prevention

What mechanisms are available at the local level to address the needs for risk prevention? One tool is land use control zoning. The trick to this is to adjust zoning in a way that it serves ground-water protection, which it typically does not do at present. In Dayton, we established a new zoning overlay district concept, based on the volumes and types of hazardous chemicals associated with a type of existing or proposed business activity, rather than the typical zoning approach that looks only at categories of business. Many zoning decisions include plan review processes. So, if a zoning district is in place and a company that wants to be in a district doesn't meet the protective standards of the district, the reviewer simply doesn't sign off on the plans and the company doesn't go in.

As mentioned, Dayton's overlay district concept is based on the volumes and types of hazardous chemicals, which we call regulated substances. However, we define *regulated substances* so as to parallel the definition of chemicals that are health hazards under the Occupational Safety and Health Act. This not only defines a comprehensive set of chemical threats, but, because it is not a list of chemicals, it evolves with the production of new chemicals. This is an important aspect of this kind of prevention program.

All businesses operating within our well-field protection area that do not conform to specified regulated substance limits must submit Regulated Substance Activity Inventory Reports. We have excellent compliance with this requirement because if we don't receive a report from a business, then we may designate that business to be *conforming*. That can have a significant impact on subsequent use of the property, inasmuch as only conforming uses may replace conforming uses. As a result, we have essentially 100% reporting compliance in our program, which is unique among environmental regulatory programs.

When a zoning district is established and zoning is implemented, decisions have to be made about the well-head protection area method and the delineation threshold. This is where most programs in the United States are getting bogged down. Existing approaches include everything from an arbitrary fixed radius through numerical modeling. We selected a rather sophisticated time-of-travel model and designation. One thing to remember about delineation and the subsequent designation of a protection area is that, regardless of the sophistication of the method, when planners start drawing district boundaries on maps, they will use property boundaries and roadways. The lesson to be learned from this is that one shouldn't argue for years and years over what delineation method to use—just use the one that makes sense, and get on with it.

Another issue that frequently arises when considering designation of a protection area, which also happens to be one of the most prevalent excuses not to do well field or aquifer protection, involves jurisdictional control over the area that needs protection. "It's not in my jurisdiction" is an often heard proclamation. So what? Just call your

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regional planning commission and request a meeting of the appropriate jurisdictions. Sit down together and talk through the issues. In our case, six local political jurisdictions and Wright-Patterson Air Force Base had to cooperate to provide geographically complete coverage.

We have established a multi-jurisdictional coordinating committee to maintain communication among participating jurisdictions. All of the jurisdictions retain their land use control authority, and for implementation consistency we meet regularly to discuss program issues. In the past the City of Dayton had an adversarial relationship with one of the townships that now participates cooperatively in the program. Dayton had commenced an effort to unilaterally annex the township, then stopped the process because of overwhelming opposition. Despite the tension which this created between Dayton and the township, the township representatives were steadfast in their commitment to the protection of drinking-water supplies. Jurisdictional issues should not be allowed to be an excuse—or perhaps they are nothing more than an excuse—to stall efforts to protect public health.

Risk Identification and Reduction

In the risk-reduction arena, we must consider about 350 businesses that are handling 200 million pounds of hazardous materials on a daily basis. Consequently, we must take an aggressive approach to address existing threats while we endeavor to prevent new ones. We inspect facilities, participate in emergency response actions, monitor ground water, and promote voluntary risk reduction in the business community.

We have five full-time inspectors in the field. These are all technical professionals. During facility inspections the inspectors verify inventory reports and look for obvious problems at facilities. Chemical inventories are monitored for inventory growth or increased toxicity, neither of which is allowed under our program. General characteristics of the chemicals on site must remain pretty much the same, or decrease in volume and toxicity.

Unfortunately, despite our preventive measures, we still find ourselves engaged in emergency-response activities at times. One point that I want to make about preventive measures can be illustrated by the case of a tanker-truck wreck. If a ground-water professional is available at the scene of a tanker-truck spill and advises the fire department's officer-in-charge that it would be inadvisable in this area to wash the petroleum off the road onto the ground (a typical response), then you have likely accomplished some relatively inexpensive and effective pollution prevention. Throwing sand or, better, throwing absorbent material on the spill and then removing the material from the scene might avoid the need for another ground-water cleanup.

Posting signs at the boundaries of a well-field protection area, as we have done, is a good way to keep people educated. This not only works for fire officials with emergency response duties, but it keeps everybody alert to report spills, leaks, or illegal dumping. The signs have thus turned out to be another simple but effective tool for pollution prevention.

We do a lot of ground-water monitoring and have an early-warning monitoring system composed of approximately 130 wells. There are two aspects of this monitoring worthy of mention. The first is the obvious role of monitoring the quality of raw water that's approaching the production areas. These wells are in various locations around our two well fields, including old landfill sites, agricultural areas, and any other areas where we believe hazardous materials are managed and might eventually be released.

The other significant aspect of a monitoring-well system is that the system tends to keep people honest. We have a spill-reporting requirement of which our regulated facility managers are aware. If they are not sure whether they should report an incident, they generally report. Every day they drive to work past monitoring wells, which remind them that they might get caught if they don't report. Generally, people would rather report than get caught later.

The concept of "early warning" and how that relates to monitoring wells and well-field protection in general, are worth considering. The word "early" begs the questions of who responds, and how fast. You might want the monitoring wells 20 years away from your well field, in contaminant-travel time, depending on who is expected to respond. So, when thinking about early warning from ground-water monitoring and how to incorporate that in a well-field protection program, you need to give careful consideration to who will respond and how fast corrective action will be taken.

In Dayton's case, we're managing a fairly small area geographically with a large number of potential sources. Consequently, we respond ourselves and do it very quickly. One of the advantages of local government is that we own land everywhere. Where there's a public road, we own a right-of-way associated with that road. We can generally provide access for a drill rig to get in to a business's front yard without their permission, if necessary. Remedial investigations move a lot faster using this approach, than if we had to work with attorneys on access agreements.

In addition, we maintain a blanket contract with an environmental engineering-consulting firm which requires that drilling and laboratory equipment be available at a specified location within 48 hours of request. During such a response, we typically proceed with plume characterization using a slotted lead auger with which we can both bore holes and obtain water samples for on-site laboratory analyses. We don't send our samples off to a certified laboratory and wait six weeks for the results. We can drill a hole in a day, with collection of samples through the slotted auger, and complete the analytical work on site. This allows us to generate information regarding the horizontal and vertical distribution of contaminants in a very short time. I should also mention that we have air-stripping towers, which can be erected on a moment's notice, for treatment of volatile organics when that is necessary. If a regulatory agency or a responsible party wants to come in later, after the problem is under control, and put in stainless steel wells and send their data off to certified labs, they are welcome to do so. Our approach enables us to characterize a plume of contamination and implement a hydraulic gradient control well within about 100 days of first discovery—and all at a bargain price of around $350,000.

As a counterpoint to the response policy that I just described, I mention another response action that we were involved in near our local federal facility. We were conducting exploratory drilling near Wright-Patterson Air Force Base in search of the source of some contamination that was impacting one of our monitoring wells. We drilled about as near to the base as possible without fear of having F-15's strafe our drill rig. We found a contaminant plume, and characterized it horizontally and vertically. Then, we turned it over to the federal and state governments to address. With lots of regulatory assistance, after two years and $10 million, this plume of VOCs is almost under control. So, the choice can be $350,000 in 100 days or $10 million in two years.

This comparison of response policies poses questions that relate very directly to the title of this forum. Just how cost effective are typical remedial measures? Is it appropriate to compare pollution prevention costs with typical remedial measures or with cost-effective control strategies? Can we advance the application of cost-effective remedies *and* prevent new problems at the same time? It seems to me that we are probably spending more money then we need to be spending, and that we need to take a closer look at some of those issues.

Dayton's RIDRED Program

Dayton is about to begin a new program called RIDRED, which stands for Risk Identification and Reduction. We have just produced an audit guidance document targeted to identify those activities of a business that might lead to ground-water contamination. The document was produced to facilitate audits of the *nonconforming* facilities in our well-field protection area. We won't actually fund the audits because if we were to do so, the product of the audit would become public information. Most companies object to having their "dirty laundry" displayed on the front page of the newspaper. The approach that we are trying is somewhat creative. First, we will prequalify consultants to do these audits. A business can then contract directly with one of those consultants and can audit itself in terms of what its ground-water threats might be. Then, the company and consultant can come to us, verify the conduct of the standard audit, and identify their top-priority problem. If the project receives a favorable review, the company can apply for two times the cost of its audit as a project grant toward correcting the problem. The remaining money for the project may be obtained though a 0%-interest loan.

RIDRED is a clear indication that we're serious about pollution prevention. Even with the cost effectiveness that we have demonstrated, it's difficult and very costly to deal with ground-water contamination. We'd like to prevent some accidents, and we have about $3 million a year from our Well Field Protection Fund to do it. This fund contains a $5 million reserve for emergency response in addition to providing incentives for voluntary risk reduction under RIDRED. The fund is derived from a surcharge on water customers of $1 per thousand cubic feet of use. It is notable that this surcharge was unopposed as a method for funding measures to protect the region's drinking water.

The Dayton Well Field Protection Program has been referred to by some as a "Cadillac-type" program. We serve 400,000 customers, and we want to provide the level of protection they desire. We funded the development

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of a numerical model to support our delineation and well-field protection area designation. To enhance the modeling and provide for our early warning system, we have installed a large number of monitoring wells. Annual administrative costs for our inspectors include not only direct personnel costs, but also some contract expenses because the inspectors who work in the areas outside of the city's incorporated area are employed by our health district under contract to the program. Despite the costs of a comprehensive and technically sophisticated protection program, as well as the costs of emergency response activities, the fund has been adequate to cover implementation costs and to provide a substantial incentive for voluntarily initiated pollution prevention projects within the regulated community.

Regarding the issue of how much money is being spent to deal with contamination and what that means from a public health point of view, I am fortunate in not having to debate the value of a human life or to quantify the risk to life or to health that results from exposure to cancer-causing chemicals, relative to the cost of preventing such exposures. It is much easier to take the perspective of a business that provides a product to consumers who, quite simply, don't want the product contaminated by industrial chemicals. I recently tested the validity of this perspective by asking my greatest critic, my wife, a former medical professional and personal fitness trainer, whether she would accept drinking water with eight or ten parts per billion of industrial solvents, if I told her that that level of contamination was okay. She said "No." Then I said, "Well, why not?" And she said, "Well, I don't trust you." Then she added, "Well, I trust you as a person, but you know what I mean. I don't trust you as a scientist." I suppose I should have been insulted, but, as a scientist, I know that we've changed our minds and wavered a lot over the years, particularly in our efforts to bring objectivity to inherently subjective terms such as "safe." People are very aware of that. Now, they tend to be more skeptical and to react in ways deemed more prudent. This seems especially true when someone is told that it's okay to be *involuntarily* exposed to risk, whatever the level.

I think it's going to be a long time before we can rely solely on pollution prevention to protect public health. Some gradient control and water-quality control measures will still have to be undertaken, and those measures aren't perfect. We can generally be assured that they provide additional opportunities to control the quality of raw water arriving at drinking-water production wells. As I mentioned, we can implement these measures more cost effectively than we have been. However, I am also compelled to say that any money spent on such measures might be tantamount to pouring money down the toilet if you don't have a pollution prevention program. Even today, most local governments will not do a thing to prevent new development in a sensitive aquifer area even when the development is a potential contamination source. Without a program that incorporates environmental considerations into land-use decisions, you might be caught up in a continuous application of corrective measures for problems that could have been prevented.

Because of the importance of land-use controls as a tool for aquifer protection and pollution prevention, local officials will be the key in this endeavor. These officials need to have the political will to utilize local tools for pollution prevention. If these officials don't currently have the will, then additional public education is needed to develop that political will. During the development and implementation of Dayton's program, the mass media were very effective partners with us in the public education process that occurred. What's more, if media representatives are kept involved and informed, they can help to sustain the program once it's established. It is an unfortunate irony that programs which effectively protect public health often run the risk of creating public apathy, where formerly a perceived threat existed that sustained public interest and support. This apathy does little to stop the erosion of sound regulatory programs during tough economic times, but the electronic and print media can very effectively remind the general public of the critical importance of maintaining the success of such programs. You, as experts, must work with the media representatives to keep them informed and educated, and you should accept this responsibility recognizing that, as a partner, they can be invaluable.

PERSPECTIVE 6: Clarifying the Scientist's Role in the Ground-water Remediation Process

Fletcher G. Driscoll, Geraghty & Miller, Inc.

The role of a consulting scientist performing environmental work has broadened significantly in recent years, and adjustments to new demands have not been easy. Because certain conditions in both consulting firms and government agencies have made environmental cleanups more difficult and expensive than they need to be, I offer some recommendations for change on the basis of 23 years of consulting experience.

Two points serve as the basis for my analysis. The first can be illustrated by two quotations: "In six days, the Lord made heaven and earth, the sea, and all that in them is" (Exodus, in the Bible), and "If God had consulted me before embarking on the creation, I would have suggested something simpler" (Alfonso of Castile). In addition to the normal complexity of geologic materials, the multidisciplinary nature of environmental work increases greatly the usual challenges of working in the ground.

The second point is based on a conversation with an undergraduate geology student, who complained that her professors would not provide the assistance she needed. She attributed this lack of attention to the fact that she was "only a B student." This young woman was a class officer, played two college sports, was socially active both personally and on behalf of the college, and possessed a delightful personality. In brief, she had already developed skills in working with people to accomplish common goals. These skills are not recognized in college—the only way a student is judged is by academic standing. Yet, in the real world, an individual's effectiveness is based as much, or more, on social skills as on academic skills. Under current consulting conditions, successful relationships must be forged carefully with governmental agencies, clients, consulting firms, and service companies, all of whom will take a different viewpoint on the same project.

It would be fair to say that no entity—the government, the general public, special-interest groups, polluters, and the scientific and engineering communities at large—truly appreciated at the outset the monumental difficulties of creating successful cleanups under RCRA and, especially, Superfund programs. Yet, from a technical viewpoint, given sufficient time and economic resources, most aquifers of a reasonable size can probably be cleaned up. Successful remediation requires proper application of scientific principles, aggressive engineering techniques—which in some cases can enhance the hydraulic character of the aquifers—and the creative mix of appropriate chemical, physical, and biological treatment technologies. Fortunately, most of these technologies already exist, although many might not have been applied to aquifer restoration as yet. Development of truly innovative methods will make the job much easier. But, most of all, successful remediation requires a rational discourse among those responsible for the cleanup.

Although experienced environmental scientists and engineers have become familiar with the myriad challenges of working in the ground, the regulatory, economic, legal, and political aspects of ground-water remediation have exacerbated purely scientific and engineering problems enormously. Demands are now placed on consulting scientists to perform state-of-the-art work under less-than-ideal conditions that include inadequate funding, rigorous regulatory oversight, often unreasonable time limits for compliance, and poorly trained and inexperienced staff. In addition, scientists are often called upon for duties that go far beyond their formal training, such as providing expert testimony in cases where hundreds of millions or even billions of dollars are involved, or where they must manage 100 or more scientists and engineers at highly sensitive CERCLA ("Superfund") or RCRA sites. Over the past few years, some scientists with only three to six months' experience have been asked to manage million-dollar projects.

Successful implementation of ground-water remediation programs hinges on much more than producing enlightened site characterizations and applying good engineering solutions. Important technical and administrative factors that affect overall success in federal cleanup programs include:

1. *Quality of site characterization that describes the physical, chemical, and hydraulic character of the aquifer.* Locating and removing DNAPLs (dense non–aqueous-phase liquids), for example, is essential for effective and timely remediation, but this requires a much more insightful site characterization than is required for contaminants that have approximately the same density as water and readily dissolve in it.
2. *Ability to predict the physical and chemical nature of contaminants within ground water, and how reactions between contaminants and the natural environment will affect migration of the plume.* Accurate initial estimates of plume geometries and strength of the contaminants at a point can reduce the cost of monitoring significantly, as well as shorten the time required to reach the remediation stage.
3. *Reasonableness of the regulations, as enforced.* Attempts to improve on nature at a specific site may be less cost-effective than remediating dangerous levels of contaminants at numerous other sites. Setting unreasonably high goals for environmental protection should be avoided, thus permitting a more appropriate allocation of limited funds.
4. *Cooperation among geologists, hydrogeologists, biologists, and engineers in charge of the cleanup.* Because solutions for successful remediation require a multidisciplinary approach, all scientists and engineers involved in the remediation must cooperate constructively. When one discipline dominates, the effectiveness of the solution is often found to be deficient.
5. *Cleanup method chosen and the scale on which the method is carried out.* Both method and scale decisions are guided by information derived from the site characterization.
6. *Cleanup standards as reasonable or unreasonable in consideration of hydrogeologic reality.* If aggressive and appropriate cleanup measures do not reduce contaminant concentrations to agreed-upon levels, some rational renegotiation of the standards should occur.
7. *Determining whether nature is contributing to the cleanup process, and to what degree.* Processes driven by nature can assist the rate at which engineered remedial solutions proceed. These include high rainfall, degradation of the contaminants by bacterial action, sorption of the contaminant by geologic materials, and reduction of contaminant strength by advection and dispersion.
8. *Effectiveness of the company or consulting team in negotiating with the*

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EPA. Often, remedial problems caused by site diversity cannot be adequately accommodated by strict application of the appropriate regulations. Thus, reasonable variances from the regulations must be negotiated between the agencies and consultants for the companies.

9. *Professional skills and experience of the EPA staff, as well as their negotiation skills.* Understanding all of the ramifications of Superfund or RCRA law places high demands on agency scientific staff. As a result, staff ability to keep up with scientific advances may suffer.
10. *Management objectives of the EPA with regard to criteria for success in the ground-water cleanup programs.* Multiple interim goals for cleanup may be viewed as being just as important as final cleanup.
11. *Economic factors affecting the ability of polluters to afford adequate cleanups.* The cost of remediation is so high that general economic conditions play a major role in both the time required and the effectiveness of cleanup procedures.
12. *Omnipresent threat of litigation.* Litigation involving company against company, government agencies against companies, and companies against insurance firms reduces the pace at which cleanup proceeds.

Another consequence of the litigation threat is to increase the cost both of the site investigation and of the remedial phases. There are ten broad areas in the above list in which scientists can play a key role in performing successful ground-water remediation under federal regulations. In my view, the ability of scientists to function adequately in these areas has not kept up with the new challenges. In part, that is because many scientists are being asked to do more than pure science, and they have not been trained to handle these new elements of their job. Certain problems, however, are more familiar and can be traced to factors that are well within our control to remedy because they originate primarily in the way scientists are trained.

With respect to the consulting aspects, many of the problems arise because the environmental field is dominated by individuals with less than five to seven years' experience. Most of these individuals do not have advanced degrees, even though the demands placed on them are great. The challenges they face are daunting for even the most senior scientist.

Unfortunately, the consulting community is not meeting its responsibilities to these young scientists. For example, consulting firms do not provide adequate training programs for new employees, and most field work is performed by junior staff. Moreover, field supervision of scientific work by managers is sporadic at best, and nonexistent at worst. And, if it occurs at all, peer review of reports is inadequate—in spite of management protestations to the contrary! Opportunities for continuing education in both science and associated management skills are not always offered, and when they are, these are likely to be inadequate to meet current challenges. Furthermore, many companies fail to install rigorous quality assurance and quality control (QA/QC) programs that would provide benchmarks for the achievement of high-quality scientific work. Finally, mentor programs do not exist in most companies on a formal basis; thus, newcomers do not know where to seek help. As a consequence, scientific standards are sometimes set by the least experienced personnel. Learning is often achieved on a "monkey see, monkey do" basis, with the corresponding inevitable loss in quality.

A review of consultant reports and other personal experience suggests that some of these problems were endemic from the mid-1970s up to the late 1980s. Since about 1988, however, the quality of scientific work has improved remarkably with increased maturation of the work force. Part of this improvement can also be attributed to a clearer definition of the goals of the federal cleanup programs.

As with the consulting community, one can list similar deficiencies originating in the government sector. Again, some of the problems result from the overall youth and inexperience of the regulatory staff, but many may originate in the complexity of the regulations these staff are asked to enforce while working with a diverse community of industrial companies and other potential polluters.

With respect to regulatory aspects, specific causes for problems in the cleanup arena include the following factors.

- The emphasis on science at EPA seems subordinate to purely administrative functions. As a consequence, the role of science becomes minimized in the decision-making process that should, in fact, be guided primarily by science.
- In many instances, regulatory personnel have never held a position in nongovernmental service and therefore have not become accustomed to the "give and take" of the nonregulatory world.
- Idealists who are unaware of the constraints of the physical systems, available technologies, and economic resources can retard or even halt cleanup negotiations.
- Turnover of good government personnel (e.g., because of low salaries) is destructive to progress in cleaning up sites. Consultants and companies are faced with educating new cadres of bureaucrats every few years for the same site, thereby slowing the cleanup process and raising costs.
- Performance objectives and rewards for EPA personnel were, and still may be, based on interim objectives—for example, the number of sites being investigated, not the number of sites cleaned up. The process therefore becomes the dominant factor in performance and rewards, not the fact that a cleanup has been achieved.
- Inability of the EPA to set priorities has caused huge dollar expenditures on small sites in remote areas, whereas massive cases of ground-water contamination in urban areas are sometimes ignored.
- Although EPA staff attend scientific and engineering training sessions on a regular basis, most individuals

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seem reluctant to use their peer contacts later on to help them develop better approaches for their regulatory work.

These and other factors have reduced the scientific and regulatory effectiveness of government staff in their negotiations with consultants and companies over cleanup goals and actions. At least three of the items indicated in this list relate directly to science; the others are related more to management and institutional issues.

Given the current conditions cited, what changes are necessary in how scientific site investigations are accomplished in order to make the ground-water remediation process run more effectively? The answer lies in (1) strengthening the academic training that scientists and engineers receive—especially as it relates to the formation of aquifer systems, understanding aquifer hydraulics, and the use of appropriate field methods; (2) returning to fundamental investigation procedures; and (3) training those scientists already in the professional arena so that they can meet the nonscientific challenges of ground-water remediation.

The consequences of ignoring these issues will be significant. In the past, for example, poorly prepared site characterizations for contaminated sites were often not recognized as such by the regulators or even by the companies for which these were prepared. This occurred because most scientists were involved only in the investigation phase of site remediation. Flaws in characterizing basic geologic conditions, hydraulic characteristics of the ground-water system, and the fate of contaminant chemicals went undetected because most data and report conclusions were left untested by engineers. As the emphasis has changed from investigation to remediation, it has become obvious that site characterizations were deficient —thus causing unnecessary expenditures of time and money. Inadequate scientific investigations lead to significant delays in implementing remedial efforts.

The second area in which improvement must take place is in how scientific investigations are to be carried out. Long ago, qualified field geologists realized that investigations—whether for oil, gold, or ground water—had to be focused to be successful. Predictions on site conditions had to be made before field activities commenced, in order that the investigation could yield accurate results on a timely and economical basis. These geologists used as a guiding principle the theory of "multiple working hypotheses." In this method, the field geologist (or hydrogeologist) uses his or her expertise and training and a site visit to prepare various possibilities for the origin of the site and, thus, its physical and chemical character. Appropriate investigation techniques are then selected to test thoroughly the proposed hypotheses so that the character of the site can be established. Even though field geologists used this principle extensively in the past, it appears to be a methodology that is not used today by most hydrogeologists and geologists in the environmental field. Inexperienced scientists with a poor foundation in hydrogeology often attempt to overwhelm the investigation with costly technology, resulting in confusing and contradictory data that lead to site mischaracterization and the inevitable misapplication of remediation technologies.

The third area in which scientists must improve involves enhancing their interpersonal and management skills. Superfund law is based on fixing responsibility and recovering costs for cleanup. Under this set of operating conditions, scientific and engineering conflicts are inevitable when agencies attempt to enforce regulations. Scientists and engineers are ill equipped by training to cope with the inevitably complicated and adversarial nature of the regulation process that characterizes the investigation and remedial phases of Superfund work. Moreover, the complexity of managing large remedial investigation or feasibility study projects provide rigorous tests of the natural skills of the scientist or engineer. Few scientists have received extensive training in all phases of project management, including planning the project, establishing the project schedule and budget, monitoring and controlling budgets, managing the project team, and maintaining client relations. Fortunately, engineers normally receive such training.

Because we cannot wait for the development of some miracle innovative technique to help us solve our current scientific deficiencies, not to mention our management deficiencies, several steps need to be taken now to enhance the quality of science practiced by those involved in ground-water remediation. These steps are as follows.

1. Consulting scientists should help their local university or college expand the scope and depth of its environmental course offerings, placing particular emphasis on those subject areas that will facilitate the successful entry of graduates into professional environmental work.
2. Both government and consulting firms need to install rigorous QA/QC programs and mentor systems.
3. Consulting firms and government should offer continuing education in relevant science and in management (e.g., negotiation skills, personnel management, project management, conflict resolution, and time management) to all technical staff members at an appropriate time.
4. Ideally, scientific personnel should build professional and personal relationships before entering into the highly complicated, and often highly contentious, cleanup process, and subsequently strengthen peer relationships by jointly publishing the results, even the interim results, of cleanup activities.

Only recommendations 2 and 3 require a monetary investment. Even that investment is small compared to the value of the benefits. The other two recommendations require becoming involved personally in enhancing the effectiveness of scientific training and the remediation process. This involvement will occur if scientists will assume a larger role in meeting their fundamental obligations to their profession.

The national EPA regulations governing the remediation of contaminated ground water offer scientists significant challenges in terms of the development of comprehensive site characterizations, the selection and use of appropriate remediation technologies, and the opportunity to work with other scientists and engineers from regulatory agencies and industrial firms to enhance the quantity and quality of ground-water resources. In my view, these challenges offer geoscientists one of the greatest professional growth opportunities that has ever existed in the history of geological science.

PERSPECTIVE 7: Who Is To Blame And What Can Be Done?

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From a little-known problem in the 1960s and 1970s, ground-water contamination has become a major environmental issue and water resource management problem of the 1990s. In the United States, ground-water contamination was ignored in the Clean Water Act of 1972, and largely ignored again in 1976 in the first authorization of the RCRA (Resource Conservation and Recovery Act). However, as a consequence of having found organic industrial contaminants in numerous municipal water supply wells in the United States in the late 1970s, and also because of the impact of Love Canal on public perception, the Comprehensive Environmental Response, Compensation and Liability Act ("Superfund") and an expanded reauthorization of RCRA came into existence in 1980. This powerful legislation put the United States far ahead of Canada, Mexico, and Europe in the movement toward restricting industrial impacts on ground water. The legislation and its associated regulations have led to the installation of millions of monitoring wells, and to the analysis of ground-water samples at thousands of industrial sites across the United States for an exceptional variety of contaminants. Monitoring at Superfund and RCRA sites in the 1980s showed, quite unexpectedly, that organic chemicals of industrial origin are common in ground water at sites where manufacturing and/or waste disposal now occurs or has occurred in previous decades.

The number of identified organic chemicals in ground water at these sites is small, generally limited to several chlorinated solvents (such as trichloroethylene, tetrachloroethylene, and trichloroethane) and some nonchlorinated compounds (such as benzene, toluene, and xylenes) derived from common petroleum products. However, the chlorinated organic chemicals are generally quite mobile and persistent in ground water, and, having entered the ground water in past decades, they have gradually created large plumes of contamination. At many sites, this has caused water supply wells to be shut down and substantial portions of aquifers to have water unfit for human consumption.

Historical Perspective

Most of the plumes that are now major problems at sites under Superfund or RCRA, or under similar types of legislation at the state level, have their origin in industrial or municipal activities that took place between the 1940s and the 1970s. In these earlier times, government, industry, and the public at large gave little thought to the potential consequences of spills, leakages, or in-ground disposal of these chemicals. This is not surprising when we consider that these chemicals were not regulated in a water-resource or environmental context at the time. The U.S. Environmental Protection Agency first issued its Priority Pollutant List in 1978. Among the more than 100 chemicals included on this list were the chlorinated solvents now so commonly found in ground water. And it wasn't until 1978 that the first drinking-water standards included maximum concentration levels (MCL's) for some of the common chlorinated solvents—and then only in the state of New York.

These chemicals were not added to the federal drinking-water standards (EPA) until 1984. In Canada, organic chemicals relevant to ground-water contamination were not added to drinking-water standards until the late 1980s. A Canadian equivalent of the Priority Pollutant List has not yet been issued but is expected soon.

In many hydrogeological circumstances, plumes of contaminated ground water travel considerable distances and ultimately cause water supply wells to be shut down or springs to issue degraded water. For aquifers, plumes are the symptoms but not the disease. The disease for organic contamination is usually the presence of oily industrial liquids that reside, immobile, at various depths below the water table. Many of these oily liquids are heavier than water, and therefore often sink deep in aquifers. Examples are chlorinated solvents, creosote, coal tar, PCB oils, various mixed industrial wastes and some types of pesticides. However, others are lighter than water and do not penetrate much below the water table. Examples are gasolines, jet fuel, and heating oils.

In aquifers, the oily liquids, regardless of their density, generally exist directly beneath or close to the property where they have been spilled, leaked, or disposed. Over years and decades, part of the subsurface mass of oily liquid dissolves, contributing mobilized contaminants to ground water and causing the growth of plumes in the direction of ground-water flow. As long as some oily liquid resides in the aquifer, the plumes persist and, in general, expand. However, at most sites, the plumes, even when they are large, constitute only a small percentage of the total contaminant mass in the aquifer. The remaining oily liquid has most of the mass. At many industrial sites and landfills where contamination is caused by oily liquids that are heavier than water, considerations of mass flux and mass balance indicate that these oily liquids will feed the plumes for centuries or even millennia, if human intervention fails to effect nearly complete removal of the oily liquid mass. Unfortunately, nearly complete removal is beyond the capability of today's technologies for almost

Forum *continued on p. 234*

Forum *continued from p. 233*

all such sites; most of the oily liquid goes unlocated because of geologic complexity and because of inefficiency of removal technology.

The existence of, and even the potential for, this widespread and persistent contamination of ground water by industrial organic chemicals heavier than water was unknown until the 1980s, even in that part of the scientific community focused on ground-water management and research. Today, the majority of Superfund sites have significant ground-water problems caused by heavy oily liquids; many thousands of other sites have these problems as well. Thousands of water supply wells have been shut down as a result of this type of contamination, and thousands of other wells are now equipped with expensive water-treatment systems to remove the contaminants so that the water can be used. Driven by Superfund and RCRA, billions of dollars have been spent attempting to ameliorate ground-water problems at industrial sites, and no end to this financial hemorrhaging in the name of aquifer cleanup is in sight. The financial burden is being carried by the manufacturing sector of Corporate America and by U.S. taxpayers at the federal and state level. Increasingly, the insurance industry is contributing, and funds are also being increasingly extracted from municipalities.

Other Parts of the Ground-Water Problem

Ground-water monitoring and cleanup activities at Superfund and RCRA sites receive nearly all of the attention of government, industry, and the public at large. However, in the 1980s, ground-water quality monitoring, mandated by Superfund, created a much broader desire among the public, and hence government, for information on other types of contaminants in ground water. Recently, ground-water sampling in rural and suburban areas has shown widespread presence of nitrate (NO_3^-) in ground water, and considerable amounts of pesticides at very low concentration levels.

The significance of pesticides in ground water is not yet clear. In contrast, much is now known about nitrate. The maximum concentration level for nitrate in drinking water is 10 mg/L (as N). In many areas, shallow aquifers have contaminant levels approaching or exceeding this limit. Part of the public-health community now believes that nitrate in drinking water may be more hazardous to humans than was previously thought. Removal of nitrate from well water is exceptionally expensive, and such contamination usually means loss of use of the water resource for human consumption. Essentially all nitrate in ground water originates from human sewage, primarily septic systems, and from agricultural practices, primarily the use of fertilizer. The accepted design of septic systems used across the continent results in soil-zone processes that remove nearly all of the contamination, with the exception of nitrogen. The nitrogen, in various forms and derived mainly from human waste, is converted in the shallow subsurface to nitrate, which then typically travels in ground water with little attenuation. Since the 1950s, tens of millions of homes constructed in the United States and in Canada have septic systems that cause nitrate contamination of ground water. Also, since the 1950s, agriculturists have applied millions of tons of nitrogen to cropland, causing much nitrate contamination of ground water.

Where Are We Now?

I have focused on two major causes of ground-water contamination: organic chemicals, primarily chlorinated solvents; and nitrogen loading to the ground, primarily nitrate from septic systems and agriculture. Nearly all Americans and Canadians eat food produced in a manner that causes nitrate contamination of ground water. Nearly all Americans and Canadians have homes or cottages connected to septic systems or stay in motels or eat in restaurants connected to septic systems that cause ground-water contamination. Nearly all Americans and Canadians wear clothes cleaned at "dry cleaners" where a common chlorinated solvent, PCE (perchloroethylene), is used and often released to the environment. At hundreds of thousands of locations, manufacturing industries, from smokestack to high tech, have used, spilled, leaked, or disposed chlorinated solvents to soil and, hence, to ground water. Nearly all military bases have used large quantities of such solvents, with ground-water contamination as a consequence.

Many other types of ground-water contamination not discussed in this paper are nonetheless important. What has been discussed, although limited, is intended to demonstrate that ground water, particularly shallow ground water, now has widespread and persistent contamination. This unfortunate state of the ground-water environment is a problem that has been developing for the past 50 years, but was recognized as a major problem only after 1980. In general, broad recognition of the true magnitude of the problem did not arrive until the late 1980s. Billions of dollars were spent during the 1980s in an attempt to correct the problem. Much of these funds was spent at Superfund and RCRA sites, but very few of the contaminated aquifers at these sites have been permanently restored. However, plumes at many sites are being controlled—thus, the symptoms are being controlled, but the disease remains. For most industrial sites where chlorinated organic contamination of ground water occurs, technology does not exist to cure the disease nor are such "cure" technologies on the horizon. Control is generally accomplished by operation "in perpetuity" of pump-and-treat systems. The control of plumes, like taxation, is here to stay.

Corporate America is angry because it is paying most of the bills, either from the manufacturing sector or through the insurance industry. Politicians are dismayed because their well-intentioned legislation has not solved the problem, more than a decade after becoming law. Regulatory agencies at all levels of government are nervous because they are caught in a bind, unable to satisfy the expectations of politicians, environmentalists, industry, or the public at large. Cities, towns, and municipalities are displeased because approval of developers' plans for building homes with conventional septic systems in effect constitutes approval of ground-water contamination. Land developers are unhappy because ground-water problems are changing the old environmental rules, and new rules are hard to come by. Farmers and the agricultural chemicals industry are unhappy because they recently have had the finger pointed at them for ground-water contamination and are now widely perceived as being part of the problem rather than part of a solution. Environmental lobby groups are unhappy because the situation is so amorphous or confusing that it is increasingly difficult for them to see how they should proceed in order to bring about positive changes.

Who Is To Blame?

Nearly all of the contamination we now know of was caused, or is still being caused, by industrial, municipal, agricultural, or waste disposal practices that were formerly (generally before 1980) viewed as standard or were widely accepted. Accepted industrial practice for transportation, storage, handling, and disposal of chlorinated solvents produced sufficient leakage or spills over the years that considerable cumulative solvent volumes "escaped" to the ground-water environment. This caused problems that generally did not show up until years or decades later. The builders and permitters of septic systems thought that they were connecting homes to in-ground systems that fully removed contaminants from the sewage; in fact, these were causing nitrate contamination. The underlying cause of nearly all of the ground-water contamination constituting today's problems has been profound ignorance of the long-term consequences of normal functioning of our modern industrial society. In the context of the ground-water environment, what we take as an abnormal or even criminal activity today was an accepted, although often mindless, activity of previous decades.

In the decades prior to the 1980s, industrial discharges to rivers and lakes often caused environmental impacts so severe that "fish kills" occurred. Such immediate visual evidence of impacts caused rapid focus of regulatory and scientific attention on problems of surface-water quality, to the neglect of ground water. For this and many other reasons, ground water remained an "out-of-sight, out-of-mind" issue until long after the seeds of long-term contamination were planted in untold numbers of aquifers across the continent. The same happened in Europe.

With the benefit of hindsight, we can say that the chemical industry can be blamed for not determining, much earlier, the propensity for ground-water impacts of the chemicals it produced. The manufacturing industry can be blamed for not having corrected sloppy practices for storing, handling, and disposal of chemicals in earlier decades. Government can be blamed for not having implemented rational regulations to protect ground water in earlier decades. The scientific community can be blamed for not having done needed research relevant to these important ground-water problems prior to the 1980s, and for not predicting today's problems before they evolved to the current state of widespread occurrence.

In hindsight, it is evident that we all have contributed to ground-water contamination in one way or another. Unfortunately, the problem of this contamination is still growing. More contaminant mass is entering the ground-water environment than is being removed by the various current corrective measures, such as the extraction of contaminants from aquifers by pump-and-treat systems.

What Should Be Done?

Most ground-water contamination has been and continues to be caused by ignorance, sloppiness, and poor land-use planning. Ground-water contamination differs from contamination of rivers and lakes in that, once the human activities causing input of contaminant mass to the aqueous system cease, river water quality rapidly improves; lake water quality improves less rapidly, but nevertheless quickly when compared to water quality in aquifers. In aquifers, once the chemical input (spills, leakages, disposals) ceases, the zone of contamination continues to grow. In some contamination, particularly that caused by heavy oily liquids such as chlorinated solvents, plume growth and therefore deterioration of larger segments of the aquifer persist for centuries or longer.

Since the early 1980s, thousands of ground-water extraction (pump-and-treat) systems have begun operation in the United States to restore aquifers. The cost of construction and long-term operation of these systems is much greater than expected. Also, at thousands of industrial sites, contaminated soil is being capped, removed, or cleaned for the purpose of preventing more ground-water contamination. On the basis of dollar per unit of contaminant mass removed, the cost of pump-and-treat systems for aquifer cleanup is immense compared with the cost of adapting industrial facilities and procedures to prevent a unit mass of contamination from entering aquifers. The cost of eradicating ignorance and sloppiness in the use of industrial and agricultural chemicals is expected to be minimal compared with the long-term costs of ground-water remediation. This fact was not evident a decade ago because the true costs of aquifer remediation and the most important causes of most contamination were not then known. Most large corporations have already adapted their operations to prevent further ground-water contamination. Many smaller companies, municipalities, and farmers have not.

The improvements brought by Superfund, RCRA, and similar efforts at the state level to the benefit of the ground-water environment are considerable. However, there is no reason to expect that these efforts will reverse the current trend of increasing ground-water contamination, even if the already large annual expenditures of these programs are greatly increased. Estimates for these expenditures in the next two or three decades are in the trillions of dollars.

If the collective goal of the various regulatory programs pertaining to ground-water contamination is one of minimizing that contamination so that future generations will have access to ground water of good quality, then the focus of expenditures on ground-water contamination should be largely redirected. Rather than the current focus on restoration of a relatively small number of industrial sites by cleanup of soil and renovation of aquifers, the focus should be on the prevention of contaminant entry to the ground-water zone and on prevention of plume expansion in significant aquifers. In addition to the large corporations currently involved in such efforts, it is urgent that the hundreds of thousands of smaller industrial and municipal entities causing ground-water contamination become involved in the effort. The financial and land-use difficulties inherent in such an effort are great. However, if this redirection can be accomplished in the 1990s, the lessons learned from the many unsuccessful but expensive attempts at industrial site restoration in the 1980s will have been well learned. ■

BOSTON

Registration and housing information appeared in the June issue of *GSA Today*
1993 Technical Program Schedule is in this issue
Preregistration deadline is September 24
Call us at 1-800-472-1988 for answers, advice, and assistance

CHARGING INTO THE FUTURE

1993 GSA ANNUAL MEETING

Boston, Massachusetts ▪ October 25–28
John B. Hynes Convention Center ▪ Boston Marriott Copley Place

Join Us in Boston: The Place To Charge into the Future

Jim Skehan

A major challenge to the human race is to develop Earth's natural resources without degrading the environment and threatening the health and financial resources of us "earthlings." Beneficial environmental public policy decisions can only be arrived at by a sound interpretation of geological data as an integral part of the decision-making process. Since the natural environment is a geological environment, society must have access to those whose expertise involves an understanding of how Earth works in order to deal effectively with its problems.

Many of the technical programs, field trips, and short courses are designed to deepen the expertise of geoscientists, engineers, environmental scientists, and health care professionals by presentation of geoscience and related data on significant societal problems and to propose sound interpretations and solutions. The 1993 Local Committee, interacting with members and fellows of GSA, has designed a broadly based program on the cutting edge of basic science and its applications. We believe that this program will stimulate a high level of constructive disciplinary and interdisciplinary discussions and education.

The 1993 Local Committee chairs, on behalf of the Northeast Section of GSA and of the New England Intercollegiate Geological Conference (NEIGC), are delighted to welcome you to the first Annual Meeting in Boston since 1952, when Cornelius S. Hurlbut, Jr., was General Chairman. This meeting, then, is literally the opportunity of a lifetime to loosen your purse strings, strap on your money belt, close down and pack up your department, and make this meeting, with its field trips and short courses, a mini-sabbatical for your professionals and students alike. Where can so little tuition buy so much?!

It is an unparalleled opportunity to take a new look at classical localities under the guidance of well-known geologists. Many of these localities and geologists have been pivotal to a progressive understanding of the accretion of terranes and subsequent evolution of the Appalachian Mountain chain of the region in all of its aspects. These localities were originally studied by some of the other famous "greats" of the past 170 years or more, such as Dana, Hitchcock, Lyell, Agassiz, Hall, Dale, Crosby, Billings, and Rodgers, to name only a few.

Make time to experience the cultural and social environment and historical sites of this colonial city and region. Our goal is to ensure that the required sacrifice of time and money will be amply rewarded by your increased professional growth and heightened appreciation of the varied "treasures" that you will discover at GSA '93.

Jim Skehan, S.J., General Chairman
1993 Annual Meeting Committee

1993 GSA Annual Meeting Contributors and Sponsors

For the Boston Annual Meeting, GSA has received generous contributions to both the general meeting fund and to specific events. GSA is most appreciative of this support and thanks the following companies. Companies with bold listing have contributed $500 or more to the meeting. Those in uppercase have contributed $1000 or more.

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Special thanks to PCR Computer Rentals of Boston for sponsoring the Computer and Office Center.

While in Boston, Make Tracks to the Museum of Science!

This is a world-renowned educational institution with over 400 interactive participatory exhibits featuring live animal and physical science demonstrations, courses, traveling exhibits, a computer center, a planetarium and the Mugar Omni Theater. The Museum of Science is easily accessible on the Green Line of the T. From the Copley station, take the Lechmere train on the E line to the Science Park stop. The museum hours are Tuesday through Sunday 9:00 a.m. to 5:00 p.m. and Friday until 9:00 p.m.

Three new exhibits that should be of interest in October:

Picturing the Planet. This permanent exhibit, which opens September 30, is a display of remote sensing.

The "Big Dig". Opening mid-September, this permanent exhibit documents the lowering of the central artery into a tunnel that is now being excavated in the glacial deposits of Boston. This project will be reported on in various theme sessions and may be visited by GSA field trip #27.

The Dinosaurs of Jurassic Park. Early October to early January 1994.

1993 GSA ANNUAL MEETING—BOSTON

Overview of 1993 GSA Annual Meeting Program

OCTOBER 25–28, 1993
HYNES CONVENTION CENTER

There will be 184 technical sessions presented during the course of the meeting. Of these, symposia (invited papers) and theme sessions (volunteered papers submitted to a specific topic) are referred to by a number that precedes the title. All other sessions are referred to by disciplines, such as Geochemistry I, II. Sessions are oral unless poster is indicated.

ASSOCIATED SOCIETIES AND ORGANIZATIONS SPONSORING SESSIONS

CF	Cushman Foundation
GS	Geochemical Society
GIS	Geoscience Information Society
IEE	Institute for Environmental Education
MSA	Mineralogical Society of America
NAGT	National Association of Geology Teachers
PS	Paleontological Society
SEG	Society of Economic Geologists
SEPM	Society for Sedimentary Geology
SGE	Sigma Gamma Epsilon

Program by Scientific Disciplines

KEY: I, II, ... = Discipline session number in a series; P = Poster; S = Symposium; T = Theme Session (listed under disciplines having the majority of the abstracts); TP = Theme Poster Session.

DISCIPLINE	SUN, OCT. 24 8:00 a.m.–12:00 N 1:00–5:00 p.m.		MON, OCT. 25 8:00 a.m.–12:00 N 1:00–5:00 p.m.		TUES, OCT. 26 8:00 a.m.–12:00 N 1:30–5:30 p.m.		WED, OCT. 27 8:00 a.m.–12:00 N 1:30–5:30 p.m.		THURS, OCT. 28 8:00 a.m.–12:00 N 1:00–5:00 p.m.	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
ARCHAEOLOGY				P	I	S19				
COAL			S7		I	P				
COMPUTERS							I	P		
ECONOMIC	S10	S10	T34	S23	I	T27	P		II	III
EDUCATION			P	S20	S21	S25, I		T3	II	III
ENGINEERING			I			T16	S2	T1	T1	P
ENVIRONMENTAL		S24	S1	T6 T22, T33	T36	I	T8 T10, T11	T11	II	P
GEOCHEMISTRY, AQUEOUS		S5	I	II		III			S17	
GEOCHEMISTRY, OTHER	S12	S12	T17			I	II	P	T5, T32	III
GEOPHYSICS/ TECTONOPHYSICS				TP21	T25, P	T29, I		S14		
GEOSCIENCE INFORMATION					S22		I	P		
HISTORY			P			S18	I			
HYDROGEOLOGY			S3	I	T35	TP35, PI	T37, II	T7, T37	T42, PII	T42, III
MARINE									P	I
MICROPALEONTOLOGY					S15	P		T15		I
MINERALOGY/ CRYSTALLOGRAPHY				S11	I	P		T3	S17, II	
PALEOCEANOGRAPHY/ PALEOCLIMATOLOGY							T19	T19, P	I	II
PALEONTOLOGY/ PALEOBOTANY			T39, I, P	T30, II	S4		III	T18, IV	V	VI
PETROLEUM					I	P	T24			
PETROLOGY, EXPERIMENTAL				P		I				
PETROLOGY, IGNEOUS			I	PI			PII			II
PETROLOGY, METAMORPHIC				I			TP2, P	II	T38	III
PLANETARY/ REMOTE SENSING				P	S16	I				
PRECAMBRIAN			I			T23	T12, T23	T12	P	II
QUATERNARY/ GEOMORPHOLOGY			I	T20, T33	II, PI	III, PII	T41	S9	IV, III, PIII	V
SEDIMENTS, CARBONATE			I		P	II			III	
SEDIMENTS, CLASTIC			P	T22			T8, I	II		III
STRATIGRAPHY			T26	S8, PI	T31			I	II	III, PII
STRUCTURAL			S13	S6	T25, P	I	T40, II	T9, T40	III	IV
TECTONICS			I	T14, II	T14, III	IV	V	VI	VII	VIII, P
VOLCANOLOGY							P	I		

SYMPOSIA

S1. Geology and Health: 1993 Keynote Symposium. 1993 Annual Meeting Committee. Oct. 25 a.m.

S2. Fractal Geometry and Chaos Theory and Their Use in the Earth Sciences. Engineering Geology Division. Oct. 27 a.m.

S3. Geological Insight and Ground-water Modeling. Hydrogeology Division. Oct. 25 a.m.

S4. The Permian-Triassic Mass Extinction: Causes and Consequences. Paleontological Society. Oct. 26 a.m.

S5. Fluids and Fluid Flow in the Crust. Geochemical Society. Oct. 24 p.m.

S6. Inferring Paleoearthquakes from Fault-Rock Fabrics: Experimental and Field Evidence. Structural Geology and Tectonics Division. Oct. 25 p.m.

S7. Coalification: Metamorphic Parameters and Interpretation of Maturation Histories. Coal Geology Division. Oct. 25 a.m.

S8. Sedimentological and Stratigraphic Framework of Ground-water Resources. Sedimentary Geology Division, Oct. 25 p.m.

S9. Neogene and Quaternary Sea-level Change and Coastal Plain Evolution: U.S. East Coast. Quaternary Geology and Geomorphology Division. Oct. 27 p.m.

S10. Organics and Ore Deposits. Society of Economic Geologists, International Geological Congress. Oct. 24 a.m./p.m.

S11. Geochemical Aspects of Minerals in Physiological Fluids. Mineralogical Society of America. Oct. 25 p.m.

S12. Sedimentary Diagenesis of Nitrogen and Sulfur in Organic Matter. Organic Geochemistry Division of the Geochemical Society. Oct. 24 a.m./p.m.

S13. Evolution and Global Consequences of the Himalayan Orogenic System. International Division. Oct. 25 a.m.

S14. Deep Seismic Imaging across Continental Margins: From the Ocean-Continent Boundary to the Beach and Beyond. Geophysics Division. Oct. 27 p.m.

S15. Human Problems, Foraminiferal Solutions. Cushman Foundation. Oct. 26 a.m.

S16. The First Half-Billion Years in the Inner Solar System. Planetary Geology Division. Oct. 26 a.m.

S17. Chlorine and Fluorine as Monitors of Fluid-Rock Interaction: New Developments. Geochemical Society, Mineralogical Society of America. Oct. 28 a.m.

S18. Historical Research as a Function of Exploration Methodology. History of Geology Division. Oct. 26 p.m.

S19. Analytical Methods in Archaeological Geology. Archaeological Geology Division. Oct. 26 p.m.

S20. Beyond Student Literacy: How To Create an Earth-Literate Public. Geoscience Education Division. Oct. 25 p.m.

S21. Successfully Funded Laboratory and Field Technique Programs in the Geosciences. National Association of Geology Teachers, National Science Foundation. Oct. 26 a.m.

S22. Finding and Communicating Geoscience Information. Geoscience Information Society. Oct. 26 a.m.

S23. Metamorphic and Metamorphosed Ore Deposits. Society of Economic Geologists. Oct. 25 p.m.

S24. Annual Meeting Forum: A Crisis in Waste Management, Economic Vitality, and a Coastal Marine Environment: Boston Harbor and Massachusetts Bay. Institute for Environmental Education. Oct. 24 p.m.

S25. Geological Concerns of the Future: Geology and its Effect on Society Today. Sigma Gamma Epsilon. Oct. 26 p.m. (Posters)

THEME SESSIONS

T1. Fractal Geometry, Self-Organized Criticality, Chaos Theory, and Their Application in the Earth Sciences. Engineering Geology Division. Oct. 27 p.m./Oct. 28 a.m.

T2. Tectono-metamorphic Evolution of North and Central America. Oct. 27 a.m. (posters).

T3. Teaching Mineralogy. Mineralogical Society of America. Oct. 27 p.m.

T4. Coalification: Metamorphic Parameters and Interpretation of Maturation Histories. Coal Geology Division. *(Canceled)*

T5. Geochemistry of Large Rivers. Oct. 28 a.m.

T6. Geologic Impacts of the Gulf War. Oct. 25 p.m.

T7. Hydrogeochemistry Related to Health and Disease. Hydrogeology Division, Institute for Environmental Education. Oct. 27 p.m.

T8. The Urban Ocean Environment: Geological Perspectives. Sedimentary Geology Division, SEPM (Society for Sedimentary Geology). Oct. 27 a.m.

T9. Processes of Supradetachment Basins. Oct. 27 p.m.

T10. Environmental Geology: The Voice of Warning. Geology and Public Policy Committee, Institute for Environmental Education. Oct. 27 a.m.

T11. Environmental Geology: The Voice of Reason. Geology and Public Policy Committee, Institute for Environmental Education. Oct. 27 a.m./p.m.

T12. Interpreting Stromatolites: Biological vs. Sedimentological Information. Oct. 27 a.m./p.m.

T13. Mineral Resources in Developing Nations: Economic Impact and Environmental Concerns. Institute for Environmental Education. (Canceled)

T14. Evolution and Global Consequences of the Himalayan Orogenic System. International Division. Oct. 25 p.m./Oct. 26 a.m.

T15. Evolution and Biogeography of Marine Microplankton During the Paleocene Epoch. Oct. 27 p.m.

T16. Health Implications of Metals in Soils. Engineering Geology Division, Institute for Environmental Education. Oct. 26 p.m.

T17. Constraints on the Evolution of the Early Earth. Oct. 25 a.m.

T18. Paleogeography of Silurian Taconica. Oct. 27 p.m.

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Boston Overview *continued*

T19. The Cretaceous-Tertiary Boundary Event: Biotic and Environmental Changes. Oct. 27 a.m./p.m.

T20. The New England-Acadian Shoreline Revisited. Oct. 25 p.m.

T21. Deep Seismic Imaging across Continental Margins: From the Ocean-Continent Boundary to the Beach and Beyond. Geophysics Division. Oct. 25 p.m. (posters).

T22. Fate and Transport of Contaminants in Boston Harbor and Massachusetts Bay. Sedimentary Geology Division, SEPM (Society for Sedimentary Geology). Oct. 25 p.m.

T23. Advances in Tectonic Models of Precambrian Orogens from Structural Geology and Geochronology. Oct. 26 p.m./Oct. 27 a.m.

T24. The Geology of Natural Gas Resources: Challenges and Opportunities. Oct. 27 a.m.

T25. Structure and Geophysics of the Appalachian Orogen. Geophysics Division. Oct. 26 a.m.

T26. High-Resolution Paleozoic Isochrons. Oct. 25 a.m.

T27. Paleoenvironments in Oxygen-deficient Basins: The Carbon-Sulfur-Iron System and Related Geochemical and Ecological Constraints. Society of Economic Geologists. Oct. 26 p.m.

T28. First Transition Series Metals and Health: Fact and Fiction. *(Canceled)*

T29. Applications of Modern Geodetic Techniques to the Solution of Geological Problems. National Research Council, Committee on Geodesy. Oct. 26 p.m.

T30. Isotope Paleobiology. Oct. 25 p.m.

T31. New Perspectives on the Evolution of Atlantic Continental Rises. Oct. 26 a.m.

T32. Geochemistry and Chronology of Appalachian Mylonites and Shear Zones. Oct. 28 a.m.

T33. Environmental Issues in Urban Settings. Quaternary Geology and Geomorphology Division, Institute for Environmental Education. Oct. 25 p.m.

T34. Metamorphism, Fluid Flow, and Ore Deposits. Society of Economic Geologists. Oct. 25 a.m.

T35. Flow and Transport in Variable-Density Ground Water. Hydrogeology Division. Oct. 26 a.m. (oral)/p.m. (posters).

T36. Geologic Disposal of Nuclear Waste and the Risks to Public Health and Safety. Institute for Environmental Education. Oct. 26 a.m.

T37. Advances in Dating Young Ground Water. Hydrogeology Division. Oct. 27 a.m./p.m.

T38. Thermobarometric Studies and P-T Path Determinations in Mountain Belts. Oct. 28 a.m.

T39. Paleoecology of Pre-Carboniferous Terrestrial Ecosystems. Oct. 25 a.m.

T40. Pluton Interiors: Structure and Dynamics. Oct. 27 a.m./p.m.

T41. New Developments in Quaternary Geology: Implications for Geoscience Education and Research. National Association of Geology Teachers, Quaternary Geology and Geomorphology Division. Oct. 27 a.m.

T42. Hydrogeology of Fractured Glacial Sediments and Fractured Crystalline Rock. Hydrogeology Division. Oct. 28 a.m./p.m.

Program Calendar

SUNDAY, OCTOBER 24 a.m.

Session 1, 8:00 a.m., HCC:304
GS—Organic Geochemistry Division Symposium (S12): Sedimentary Diagenesis of Nitrogen and Sulfur in Organic Matter (Part I)

Session 2, 8:00 a.m., HCC:210
SEG, International Geological Congress Symposium (S10): Organics and Ore Deposits (Part I)

SUNDAY, OCTOBER 24 p.m.

Session 3, 1:00 p.m., HCC:311
GS—Geochemical Society Symposium (S5): Fluids and Fluid Flow in the Crust

Session 4, 1:00 p.m., HCC:304
GS—Organic Geochemistry Division Symposium (S12): Sedimentary Diagenesis of Nitrogen and Sulfur in Organic Matter (Part II)

Session 5, 1:00 p.m., HCC:312
IEE Annual Environmental Forum (S24): A Crisis in Waste Management, Economic Vitality, and a Coastal Marine Environment: Boston Harbor and Massachusetts Bay

Session 6, 1:00 p.m., HCC:210
SEG, International Geological Congress Symposium (S10): Organics and Ore Deposits (Part II)

MONDAY, OCTOBER 25 a.m.

Session 7, 8:00 a.m., HCC:Ballroom A
Coal Geology Division Symposium (S7): Coalification: Metamorphic Parameters and Interpretation of Maturation Histories

Session 8, 8:00 a.m., HCC:208
Engineering Geology: Hazard Investigations and Corrective Actions

Session 9, 8:00 a.m., HCC:207
GS—Geochemistry I: Geochronology

Session 10, 8:00 a.m., HCC:Hall
History of Geology (Posters)

Session 11, 8:00 a.m., HCC:200
Hydrogeology Division Symposium (S3): Geologic Insight and Ground-water Modeling

Session 12, 8:00 a.m., HCC:309
International Division Symposium (S13): Evolution and Global Consequences of the Himalayan Orogenic System

Session 13, 8:00 a.m., HCC:Ballroom B
Keynote Symposium 1993, Annual Meeting Committee (S1): Geology and Health.

Session 14, 8:00 a.m., HCC:202
MSA—Igneous Petrology I: Granites and Rhyolites

Session 15, 8:00 a.m., HCC:Hall
NAGT—Geology Education (Posters)

Session 16, 8:00 a.m., HCC:313
Precambrian Geology I

Session 17, 8:00 a.m., HCC:Ballroom C
PS—Paleontology I: Patterns of Evolution

Session 18, 8:00 a.m., HCC:Hall
PS—Paleontology/Paleobotany (Posters)

Session 19, 8:00 a.m., HCC:312
Quaternary Geology/Geomorphology I: Quaternary Environments, Coastal Geology and Sea Level History

Session 20, 8:00 a.m., HCC:311
Sedimentology, Carbonate I: Depositional Systems

Session 21, 8:00 a.m., HCC:Hall
Sedimentology, Clastic (Posters)

Session 22, 8:00 a.m., HCC:306
Tectonics I

Session 23, 8:00 a.m., HCC:203
T17. Constraints in the Evolution of the Early Earth

Session 24, 8:00 a.m., HCC:304
T26. High-Resolution Paleozoic Isochrons

Session 25, 8:00 a.m., HCC:210
T34. SEG—Metamorphism, Fluid Flow, and Ore Deposits

Session 26, 8:00 a.m., HCC:302
T39. Paleoecology of Pre-Carboniferous Terrestrial Ecosystems

MONDAY, OCTOBER 25 p.m.

Session 27, 1:00 p.m., HCC:Hall
Archaeological Geology (Posters)

Session 28, 1:00 p.m., HCC:202
Geoscience Education Division Symposium (S20): Beyond Student Literacy: How to Create an Earth-Literate Public. *Dedicated to John Shelton.*

Session 29, 1:00 p.m., HCC:207
GS—Geochemistry II: Oceans, Porefluids, Weathering and the Atmosphere: Surface to the Sky

Session 30, 1:00 p.m., HCC:311
Hydrogeology I: Isotopic and Geochemical Hydrogeology

Session 31, 1:00 p.m., HCC:Ballroom A
MSA Symposium (S11): Geochemical Aspects of Minerals in Physiological Fluids

Session 32, 1:00 p.m., HCC:Hall
MSA—Experimental Petrology (Posters)

Session 33, 1:00 p.m., HCC:Hall
MSA—Igneous Petrology (Posters I)

Session 34, 1:00 p.m., HCC:200
MSA—Metamorphic Petrology I: Thermodynamic Properties, Mineralogy, and Regional Studies

Session 35, 1:00 p.m., HCC:Ballroom C
PS—Paleontology II: Invertebrate Paleontology

Session 36, 1:00 p.m., HCC:Hall
Remote Sensing (Posters)

Session 37, 1:00 p.m., HCC:304
Sedimentary Geology Division, SEPM (S8): Sedimentological and Stratigraphic Framework of Ground-water Resources

Session 38, 1:00 p.m., HCC:210
SEG Symposium (S23): Metamorphic and Metamorphosed Ore Deposits

Session 39, 1:00 p.m., HCC:Hall
Stratigraphy. General (Posters)

Session 40, 1:00 p.m., HCC:302
Structural Geology and Tectonics Division Symposium (S6): Inferring Paleo-earthquakes from Fault-Rock Fabrics: Experimental and Field Evidence

Session 41, 1:00 p.m., HCC:306
Tectonics II: Asia

Session 42, 3:00 p.m., HCC:208
T6. Geological Impacts of the Gulf War

Session 43, 1:00 p.m., HCC:309
T14. International Division: Evolution and Global Consequences of the Himalayan Orogenic System (Part I)

Session 44, 1:00 p.m., HCC:312
T20. The New England-Acadian Shoreline Revisited

Session 46, 1:00 p.m., HCC:203
T22. Sedimentary Geology Division, SEPM: Fate and Transport of Contaminants in Boston Harbor and Massachusetts Bay

Session 47, 1:00 p.m., HCC:313
T30. Isotope Paleobiology

Session 48, 1:00 p.m., HCC:208
T33. Quaternary Geology and Geomorphology Division, IEE: Environmental Issues in Urban Settings

TUESDAY, OCTOBER 26 a.m.

Session 49, 8:00 a.m., HCC:313
Archaeological Geology

Session 50, 8:00 a.m., HCC:207
CF Symposium (S15): Human Problems, Foraminiferal Solutions

Session 51, 8:00 a.m., HCC:208
Coal Geology

Session 52, 8:00 a.m., HCC:Hall
Geomorphology (Posters I)

Session 53, 8:00 a.m., HCC:Hall
Geophysics/Tectonophysics (Posters)

Session 54, 8:00 a.m., HCC:203
GIS Symposium (S22): Finding and Communicating Geoscience Information

Session 55, 8:00 a.m., HCC:Ballroom B
MSA—Mineralogy I

Session 56, 8:00 a.m., HCC:202
NAGT, National Science Foundation Symposium (S21): Successfully Funded Laboratory and Field Technique Programs in the Geosciences

Session 57, 10:00 a.m., HCC:208
Petroleum Geology

Session 58, 8:00 a.m., HCC:312
Planetary Geology Division Symposium (S16): The First Half-Billion Years in the Inner Solar System

Session 59, 8:00 a.m., HCC:Ballroom C
PS Symposium (S4): The Permian-Triassic Mass Extinction: Causes and Consequences

Session 60, 8:00 a.m., HCC:311
Quaternary Geology/Geomorphology II: Glacial Geology

Session 61, 8:00 a.m., HCC:Hall
Sedimentology, Carbonate (Posters)

Session 62, 8:00 a.m., HCC:210
SEG—Economic Geology I: Gold Deposits

Session 63, 8:00 a.m., HCC:Hall
Structural Geology (Posters)

Session 64, 8:00 a.m., HCC:306
Tectonics III: Cordillera A

Session 65, 8:00 a.m., HCC:309
T14. International Division: Evolution and Global Consequences of the Himalayan Orogenic System (Part II)

Session 66, 8:00 a.m., HCC:302
T25. Geophysics Division: Structure and Geophysics of the Appalachian Orogen

Session 67, 8:00 a.m., HCC:304
T31. New Perspectives on the Evolution of Atlantic Continental Rises

Session 68, 8:00 a.m., HCC:200
T35. Hydrogeology Division: Flow and Transport in Variable Density Ground Water

Session 69, 8:00 a.m., HCC:Ballroom A
T36. IEE: Geologic Disposal of Nuclear Waste and the Risks to Public Health and Safety

TUESDAY, OCTOBER 26 p.m.

Session 70, 1:30 p.m., HCC:313
Archaeological Geology Division Symposium (S19): Analytical Methods in Archaeological Geology

Session 71, 1:30 p.m., HCC:Hall
CF—Micropaleontology (Posters)

Session 72, 1:30 p.m., HCC:Hall
Coal Geology (Posters)

Session 73, 3:30 p.m., HCC:Ballroom A
Environmental Geology I: Environmental Pathways Case Studies

Session 74, 1:30 p.m., HCC:Hall
Geomorphology (Posters II)

Session 75, 1:30 p.m., HCC:Ballroom B
Geophysics/Tectonophysics

Session 76, 1:30 p.m., HCC:207
GS—Geochemistry III: Biogeochemistry

Session 77, 1:30 p.m., HCC:203
GS—Geochemistry IV: Fluid-Rock Interaction and Stable Isotopes

Session 78, 1:30 p.m., HCC:200
History of Geology Division Symposium (S18): Historical Research as a Function of Exploration Methodology

Session 79, 1:30 p.m., HCC:Hall
Hydrogeology: Quantitative Hydrogeology (Posters I)

Session 80, 1:30 p.m., HCC:208
MSA—Experimental Petrology

Session 81, 1:30 p.m., HCC:Hall
MSA—Mineralogy (Posters)

Session 82, 1:30 p.m., HCC:202
NAGT—Geology Education I

Session 83, 1:30 p.m., HCC:Hall
Petroleum Geology (Posters)

Session 84, 1:30 p.m., HCC:302
Planetary Geology

Session 85, 1:30 p.m., HCC:312
Quaternary Geology/Geomorphology III: Glacial History

Session 86, 1:30 p.m., HCC:311
Sedimentology, Carbonate II: Diagenesis

Program Calendar *continued on p. 238*

Program Calendar *continued from p. 237*

Session 87, 1:30 p.m., HCC:Hall
SGE Symposium (S25): Geological Concerns of the Future: Geology and its Effect on Society Today (Posters)

Session 88, 1:30 p.m., HCC:Ballroom C
Structural Geology I: Fluid Pressure, Fold and Thrust Belts

Session 89, 1:30 p.m., HCC:306
Tectonics IV: Gondwana

Session 90, 1:30 p.m., HCC:Ballroom A
T16. Engineering Geology Division, IEE: Health Implications of Metals in Soils

Session 91, 1:30 p.m., HCC:304
T23. Advances in Tectonic Models of Precambrian Orogens from Structural Geology and Geochronology (Part I)

Session 92, 1:30 p.m., HCC:210
T27. SEG: Paleoenvironments in Oxygen-Deficient Basins: The Carbon-Sulfur-Iron System and Related Geochemical and Ecological Constraints

Session 93, 1:30 p.m., HCC:309
T29. National Research Council, Committee on Geodesy: Applications of Modern Geodetic Techniques to the Solution of Geological Problems

Session 94, 1:30 p.m., HCC:Hall
T35. Hydrogeology Division: Flow and Transport in Variable Density Ground Water (Posters)

WEDNESDAY, OCTOBER 27 a.m.

Session 95, 10:00 a.m., HCC:202
Computers

Session 96, 8:00 a.m., HCC:Ballroom B
Engineering Geology Division Symposium (S2): Fractal Geometry and Chaos Theory, and Their Use in the Earth Sciences

Session 97, 8:00 a.m., HCC:202
GIS—Geoscience Information

Session 98, 8:00 a.m., HCC:203
GS—Geochemistry V: Geochemistry of Surface and Basin Fluids

Session 99, 8:00 a.m., HCC:200
History of Geology

Session 100, 8:00 a.m., HCC:313
Hydrogeology II: Quantitative Hydrogeology

Session 101, 8:00 a.m., HCC:Hall
MSA—Igneous Petrology (Posters II)

Session 102, 8:00 a.m., HCC:Hall
MSA—Metamorphic Petrology (Posters)

Session 103, 8:00 a.m., HCC:Hall
MSA—Volcanology (Posters)

Session 104, 8:00 a.m., HCC:210
PS—Paleontology III: A) Ichnology, B) Molecular Paleontology and Isotopes

Session 105, 8:00 a.m., HCC:311
Sedimentology, Clastic I

Session 106, 8:00 a.m., HCC:Hall
SEG—Economic Geology (Posters)

Session 107, 8:00 a.m., HCC:302
Structural Geology II: Brittle Deformation

Session 108, 8:00 a.m., HCC:306
Tectonics V: Cordillera B

Session 109, 8:00 a.m., HCC:Hall
T2. Tectono-metamorphic Evolution of North and Central America (Posters)

Session 110, 8:00 a.m., HCC:208
T8. Sedimentary Geology Division, SEPM: The Urban Ocean Environment: Geological Perspectives

Session 111, 8:00 a.m., HCC:Ballroom A
T10. GSA Geology and Public Policy Committee, IEE: Environmental Geology: The Voice of Warning

Session 112, 10:00 a.m., HCC:Ballroom A
T11. Geology and Public Policy Committee, IEE: Environmental Geology: The Voice of Reason (Part I)

Session 113, 10:00 a.m., HCC:304
T12. Interpreting Stromatolites: Biological vs. Sedimentological Information (Part I)

Session 114, 8:00 a.m., HCC:Ballroom C
T19. The Cretaceous-Tertiary Boundary Event: Biotic and Environmental Changes (Part I)

Session 115, 8:00 a.m., HCC:304
T23. Advances in Tectonic Models of Precambrian Orogens from Structural Geology and Geochronology (Part II)

Session 116, 8:00 a.m., HCC:207
T24. The Geology of Natural Gas Resources: Challenges and Opportunities

Session 117, 10:00 a.m., HCC:200
T37. Hydrogeology Division: Advances in Age-dating Young Ground Water (Part I)

Session 118, 8:00 a.m., HCC:309
T40. Pluton Interiors: Structure & Dynamics (Part I)

Session 119, 8:00 a.m., HCC:312
T41. NAGT, Quaternary Geology & Geomorphology Division: New Developments in Quaternary Geology: Implications for Geosciences Education and Research

WEDNESDAY, OCTOBER 27 p.m.

Session 120, 1:30 p.m., HCC:Hall
Computers (Posters)

Session 121, 1:30 p.m., HCC:208
Geophysics Division Symposium (S14): Deep Seismic Imaging across Continental Margins: From the Ocean-Continent Boundary to the Beach and Beyond

Session 122, 1:30 p.m., HCC:Hall
GIS—Geoscience Information (Posters)

Session 123, 1:30 p.m., HCC:Hall
GS—Geochemical Jumble (Posters)

Session 124, 1:30 p.m., HCC:207
MSA—Metamorphic Petrology II: Devolatization, Infiltration, and Diffusion

Session 125, 3:30 p.m., HCC:309
MSA—Volcanology

Session 126, 1:30 p.m., HCC:Hall
Paleoceanography/Paleoclimatology (Posters)

Session 127, 1:30 p.m., HCC:313
PS—Paleontology IV: A) Colonial Organisms and Growth Disruptions, B) Extinctions

Session 128, 1:30 p.m., HCC:312
Quaternary Geology and Geomorphology Division Symposium (S9): Neogene and Quaternary Sea Level Change and Coastal Plain Evolution: U.S. East Coast

Session 129, 1:30 p.m., HCC:302
Sedimentology, Clastic II: Clastic Diagenesis

Session 130, 1:30 p.m., HCC:304
Stratigraphy I: Proterozoic and Paleozoic Sequence Stratigraphy

Session 131, 1:30 p.m., HCC:306
Tectonics VI: Europe

Session 132, 1:30 p.m., HCC:Ballroom B
T1. Engineering Geology Division: Fractal Geometry, Self-Organized Criticality, Chaos Theory, and Their Application in the Earth Sciences (Part I)

Session 133, 1:30 p.m., HCC:202
T3. MSA: Teaching Mineralogy

Session 134, 1:30 p.m., HCC:203
T7. Hydrology Division, IEE: Hydrogeochemistry Related to Health and Disease

Session 135, 3:30 p.m., HCC:302
T9. Processes of Supradetachment Basins

Session 136, 1:30 p.m., HCC:Ballroom A
T11. Geology and Public Policy Committee, IEE: Environmental Geology: The Voice of Reason (Part II)

Session 137, 1:30 p.m., HCC:311
T12. Interpreting Stromatolites: Biological vs. Sedimentological Information (Part II)

Session 138, 3:30 p.m., HCC:Ballroom C
T15. Evolution and Biogeography of Marine Microplankton During the Paleocene Epoch

Session 139, 1:30 p.m., HCC:200
T18. Paleogeography of Silurian Taconica

Session 140, 1:30 p.m., HCC:Ballroom C
T19. The Cretaceous-Tertiary Boundary Event: Biotic and Environmental Changes (Part II)

Session 141, 1:30 p.m., HCC:210
T37. Hydrogeology Division: Advances in Dating Young Ground Water (Part II)

Session 142, 1:30 p.m., HCC:309
T40. Pluton Interiors: Structure & Dynamics (Part II)

THURSDAY, OCTOBER 28 a.m.

Session 143, 8:00 a.m., HCC:200
Environmental Geology II: Land Use Impacts and Case Studies

Session 144, 8:00 a.m., HCC:207
GS, MSA Symposium (S17): Chlorine and Fluorine as Monitors of Fluid-Rock Interaction: New Developments

Session 145, 8:00 a.m., HCC:Hall
Hydrogeology: Hydrogeochemistry (Posters II)

Session 146, 8:00 a.m., HCC:Hall
Marine Geology (Posters)

Session 147, 8:00 a.m., HCC:203
MSA—Mineralogy II

Session 148, 8:00 a.m., HCC:202
NAGT—Geology Education II

Session 149, 8:00 a.m., HCC:Ballroom A
Paleoceanography/Paleoclimatology I

Session 150, 8:00 a.m., HCC:Hall
Precambrian Geology (Posters)

Session 151, 8:00 a.m., HCC:Ballroom C
PS—Paleontology V: A) Chemosymbiosis, B) Paleobotany

Session 152, 8:00 a.m., HCC:Hall
Quaternary Geology (Posters)

Session 153, 8:00 a.m., HCC:312
Quaternary Geology/Geomorphology IV: Surficial Processes

Session 154, 8:00 a.m., HCC:311
Sedimentology, Carbonate III: Dolomite & Paleosols

Session 155, 8:00 a.m., HCC:210
SEG—Economic Geology II: Magmatic and Magmatic-Hydrothermal Deposits

Session 156, 8:00 a.m., HCC:304
Stratigraphy II: Mesozoic and Cenozoic Sequence Stratigraphy

Session 157, 8:00 a.m., HCC:302
Structural Geology III: Ductile Deformation

Session 158, 8:00 a.m., HCC:306
Tectonics VII: Extension

Session 159, 8:00 a.m., HCC:Ballroom B
T1. Engineering Geology Division: Fractal Geometry, Self-Organized Criticality, Chaos Theory, and Their Application in the Earth Sciences (Part II)

Session 160, 10:00 a.m., HCC:202
T5. Geochemistry of Large Rivers

Session 45, 1:00 p.m., HCC:Hall
T21. Geophysics Division: Deep Seismic Imaging Across Continental Margins: From the Ocean-Continent Boundary to the Beach and Beyond (Posters)

Session 161, 8:00 a.m., HCC:313
T32. Geochemistry and Chronology of Appalachian Mylonites and Shear Zones

Session 162, 8:00 a.m., HCC:309
T38. Thermobarometric Studies and P-T Path Determinations in Mountain Belts. *Dedicated to Jeffrey A. Grambling, 1953–1993.*

Session 163, 8:00 a.m., HCC:208
T42. Hydrogeology Division: Hydrogeology of Fractured Glacial Sediments and Fractured Crystalline Rock (Part I)

THURSDAY, OCTOBER 28 p.m.

Session 164, 1:00 p.m., HCC:207
CF—Micropaleontology

Session 165, 1:00 p.m., HCC:Hall
Engineering Geology: Tunnels, Techniques & Terraces (Posters)

Session 166, 1:00 p.m., HCC:Hall
Environmental Geology: Contamination Impacts in Soil and Ground Water (Posters)

Session 167, 1:00 p.m., HCC:Ballroom B
GS—Geochemistry VI: Thermodynamics and Kinetics of Water-Rock Interaction

Session 168, 1:00 p.m., HCC:200
Hydrogeology III: Geology and Hydrology

Session 169, 1:00 p.m., HCC:203
Marine Geology

Session 170, 1:00 p.m., HCC:Ballroom A
MSA—Igneous Petrology II: The Mantle, Basalts, and Anorthosites

Session 171, 1:00 p.m., HCC:313
MSA—Metamorphic Petrology III: Migmatites, Granulites, Blueschists, and Mafic Assemblages

Session 172, 1:00 p.m., HCC:202
NAGT—Geology Education III

Session 173, 1:00 p.m., HCC:Ballroom C
Paleoceanography/Paleoclimatology II

Session 174, 3:00 p.m., HCC:208
Precambrian Geology II

Session 175, 1:00 p.m., HCC:309
PS—Paleontology VI

Session 176, 1:00 p.m., HCC:312
Quaternary Geology/Geomorphology V: Tectonic Geomorphology and Quaternary Dating

Session 177, 1:00 p.m., HCC:311
Sedimentology, Clastic III: Clastic Depositional Systems

Session 178, 1:00 p.m., HCC:Hall
Sedimentology, Stratigraphy, and Hydrogeology of the Savannah River Site and Adjacent Atlantic Coastal Plain (Posters)

Session 179, 1:00 p.m., HCC:210
SEG—Economic Geology III: Magmatic-Hydrothermal to Sedimentary Deposits

Session 180, 1:00 p.m., HCC:304
Stratigraphy III: General

Session 181, 1:00 p.m., HCC:302
Structural Geology IV: Extension and Ductile Shear

Session 182, 1:00 p.m., HCC:Hall
Tectonics (Posters)

Session 183, 1:00 p.m., HCC:306
Tectonics VIII: Appalachians

Session 184, 1:00 p.m., HCC:208
T42. Hydrogeology Division: Hydrogeology of Fractured Glacial Sediments and Fractured Crystalline Rock (Part II)

SPECIAL SESSION AT THE BOSTON ANNUAL MEETING

The Great Flood of '93

organizers: Rhea L. Graham and Stephen G. Wells
cosponsored by these GSA Divisions: Archaeological, Engineering, Hydrogeology, Quaternary Geology & Geomorphology

5:45–7:30 p.m., Wednesday, October 27 ■ Hynes Convention Center

ARE YOU PLANNING ON GOING TO GRADUATE SCHOOL?

Shortcut your search for the right graduate school to suit your needs. Come to the GSA Annual Meeting in Boston and meet with representatives from universities across the nation without spending the travel time and money to go to each school for interviews. The schools participating (at press time) are listed below.

Individual appointments are not necessary, although students are welcome to contact the schools in advance to schedule a meeting time. If you would like to receive a complete list of schools with the contact persons and telephone numbers, please write, call, or fax Matt Ball, GSA Meetings Department, (303) 447-2020, ext. 141, or fax 303-447-0648.

Graduate School Information Forum Current Schedule
Hynes Convention Center, Exhibit Hall
9:30 a.m. to 5:30 p.m. Daily

Participating Schools	Table #	MON. Oct. 25	TUES. Oct. 26	WED. Oct. 27
Boston College	25	•	•	•
Bryn Mawr College	16		•	•
California Institute of Technology	17	•	•	
Cornell University	6	•	•	•
Duke University	16	•		
East Carolina University	18	•	•	
Florida International University	15	•		•
George Washington University	1			•
Georgia State University	4	•	•	•
Graduate School and Brooklyn College of the City Univeristy of New York	22	•	•	
Lehigh University	3		•	
New Mexico Institute of Mining and Technology	8		•	
Northern Arizona University	3			•
Notre Dame	11	•	•	•
Pennsylvania State University	14		•	
Southern Illinois University	9	•	•	
Temple University	15		•	
Texas Christian University	20	•	•	•
University of Alabama	19	•	•	
University of Alaska, Fairbanks	7		•	
University fo California, Los Angeles	5			•
University of California, Riverside	14	•		
University of Florida	7	•		•
University of Illinois at Urbana-Champaign	8	•		
University of Kentucky	8			•
University of Maryland at College Park	2	•	•	•
University of Massachusetts	24	•	•	
University of New Hampshire	13	•	•	
University of North Carolina at Chapel Hill	10		•	
University of North Dakota	5	•	•	
University of Pennsylvania	16		•	•
University of Tennessee	3	•		
University of Texas at Arlington	1	•	•	
Vanderbilt University	10	•		
Virginia Polytechnic Institute & State University	21	•	•	
Yale University	12	•	•	•

STUDENT TRAVEL GRANTS

The GSA Foundation will award matching grants up to a total of $3500 each to the six GSA Sections. The money, when combined with equal funds from the Sections, will be used to assist GSA Student Associates traveling to the 1993 GSA Annual Meeting in Boston in October and to the 1994 Section meetings. Contact your Section Secretary for application procedures.

Cordilleran	Bruce A. Blackerby	(209) 278-2955
Rocky Mountain	Kenneth E. Kolm	(303) 273-3932
North-Central	George R. Hallberg	(319) 335-1575
South-Central	Rena M. Bonem	(817) 755-2361
Northeastern	Kenneth N. Weaver	(410) 554-5534
Southeastern	Michael J. Neilson	(205) 934-5102

BOSTON Event Highlights

See on-site program for final times and locations of events
HCC=Hynes Convention Center
MAR=Marriott Copley Place Hotel
BPP=Boston Park Plaza Hotel

SATURDAY
Field Trips/Continuing Education Courses/Workshops
Boston Symphony Orchestra, Symphony Hall, 6:00–10:30 p.m.
Jazz Concert, BPP, 7:30–10:00 p.m.

SUNDAY
Field Trips/Continuing Education Courses/Workshops/Forums
Bradford Washburn Photo Display, HCC, 8:00 a.m.–5:00 p.m.
Guest Tours, MAR,
  Bird Watching, 6:45 a.m.–5:00 p.m.
  Boston Overview, 12:15–4:15 p.m.
Employment Opportunities-Roundtable Discussions, HCC, 12:00 noon–2:00 p.m.
IEE Annual Environmental Forum, HCC, 1:30–5:30 p.m.
Guest Hospitality Welcoming Reception, MAR, 4:15–5:00 p.m.
Deep Structure of the Himalayas: Project INDEPTH, HCC, 5:00–9:00 p.m.
Exhibits Opening and Welcoming Reception, HCC, 5:00–9:00 p.m.
Mt. Everest Relief Model, HCC, 5:00–9:00 p.m.
Science Classroom of the Future, HCC, 5:00–9:00 p.m.

MONDAY
Keynote Symposium: Health and Geology, HCC, 8:00 a.m.–12:00 noon.
Bradford Washburn Photo Display, HCC, 8:00 a.m.–5:00 p.m.
Deep Structure of the Himalayas: Project INDEPTH, HCC, 9:30 a.m.–5:30 p.m.
Exhibits, HCC, 9:30 a.m.–5:30 p.m.
Graduate School Information Forum, HCC, 9:30 a.m.–5:30 p.m.
Workshops/Forums
Guest Seminars, MAR,
  Welcome to Boston, 8:15–9:00 a.m.
  Thriving on Uncertainty and Change, 1:15–3:30 p.m.
Guest Tours, MAR,
  Historic Homes Walking Tour, 9:15 a.m.–12:15 p.m.
Mt. Everest Relief Model, HCC, 9:30 a.m.–5:30 p.m.
Science Classroom of the Future, HCC, 9:30 a.m.–5:30 p.m.
NAGT Lunch, MAR, 12:00 noon–2:00 p.m.
GS Lunch, MAR, 12:30–2:00 p.m.
GSA Presidential Address and Awards Ceremonies, HCC, 5:30–7:00 p.m.
GSA Awards Reception, HCC, 7:00–7:30 p.m.
Alumni Night, BPP, 7:00–9:30 p.m.

TUESDAY
Association for Women Geoscientists Breakfast, MAR, 6:45–9:00 a.m.
Bradford Washburn Photo Display, HCC, 8:00 a.m.–5:00 p.m.
Guest Seminar, MAR,
  History of Boston's Neighborhoods, 9:00–11:15 a.m.
Guest Tours, MAR,
  Newport, Rhode Island, 8:00 a.m–4:30 p.m.
  Walking Tour of Newbury Street, Copley Square, 9:00–11:15 a.m.
  Botanical and Gardner Museums, 12:30–4:30 p.m.
Deep Structure of the Himalayas: Project INDEPTH, HCC, 9:30 a.m.–5:30 p.m.
Exhibits, HCC, 9:30 a.m.–5:30 p.m.
Graduate School Information Forum, HCC, 9:30 a.m.–5:30 p.m.
Mt. Everest Relief Model, 9:30 a.m.–5:30 p.m.
Science Classroom of the Future, HCC, 9:30 a.m.–5:30 p.m.
Geoscience Education Division Luncheon, MAR, 11:45 a.m.–1:15 p.m.
PS Lunch, BPP, 11:30 a.m.–5:00 p.m.
SEG Lunch, BPP, 11:30 a.m.–2:00 p.m.
Geology and Public Policy Forum, HCC, 12:00 noon–1:30 p.m.
Hydrogeology Lunch, MAR, 12:00 noon–3:30 p.m.
GIS Lunch, MAR, 12:15–2:15 p.m.
MSA Lunch, MAR, 12:15–2:00 p.m.
Earth Scientists on Capitol Hill (meet GSA's Congressional Science Fellow), HCC, 1:30–2:30 p.m.
GSA President's Student Forum, HCC, 4:00–5:30 p.m.
Bravo Boston GSA Chorale, Jordan Hall, 7:00–10:00 p.m.

WEDNESDAY
Bradford Washburn Photo Display, HCC, 8:00 a.m.–5:00 p.m.
Guest Seminar, MAR,
  Peace Through Music, 9:00–10:30 a.m.
Guest Tours, MAR,
  Lexington and Concord, Historic Literary Trail, 8:30 a.m–4:00 p.m.
Old Salem and Marblehead, 12:15–4:15 p.m.
Deep Structure of the Himalayas: Project INDEPTH, HCC, 9:30 a.m.–3:00 p.m.
Exhibits, HCC, 9:30 a.m.–3:00 p.m. - Last Day!
Graduate School Information Forum, HCC, 9:30 a.m.–5:30 p.m.
Mt. Everest Relief Model, HCC, 9:30 a.m.–3:00 p.m.
Science Classroom of the Future, HCC, 9:30 a.m.–3:00 p.m.
Coal Geology Division Lunch, MAR, 12:00 noon–4:00 p.m.
Engineering Geology Division Lunch, MAR, 12:00 noon–2:00 p.m.
History Division Lunch, MAR, 12:00 noon–1:30 p.m.
The Great Flood of '93, HCC, 5:45–7:30 p.m.
Lobster Clambake Dinner Cruise, The Spirit of Boston, 6:00–10:00 p.m.

THURSDAY
Bradford Washburn Photo Display, HCC, 8:00 a.m.–5:00 p.m.
Field Trips (postmeeting)
T.A.C. (Thursday Afternoon Club), HCC, 3:30–5:00 p.m.

FRIDAY (postmeeting)
Field Trips/Continuing Education Course

Bravo Boston GSA Chorale

Tuesday, October 26, 8:00 p.m.
Jordan Hall at New England Conservatory of Music
Cost: Concert only $18; Concert with Reception $28.

This year one of the special events for the GSA Annual Meeting is indeed very special. Many of you may recall the performance by the 1988 GSA Centennial Orchestra of geologists in Denver, heard on National Public Radio. Once again musical geologists will have the opportunity to come together, this time in a dazzling choral performance in Boston, where the musical arts are a thriving part of the city's culture.

The performance will take place in the intimate and cherished Jordan Hall, treasured for its turn-of-the-century architecture, renowned for its excellent acoustics, and widely used by recording companies and famous artists. The hall is on the campus of the New England Conservatory of Music, an easy 10-minute walk from the Hynes Convention Center and the Marriott Hotel. The Bravo Boston GSA Chorale, with a professional orchestra and conductor, will perform the melodic and moving Mozart Requiem, popularized in the film *Amadeus*. In addition, the performance will feature two double concertos by Vivaldi, featuring your musical colleagues as soloists. This is an evening not to be missed!

For those wishing to sing with the Bravo Boston GSA Chorale, contact Holly Stein, U.S. Geological Survey, MS 981, National Center, 12201 Sunrise Valley Drive, Reston, VA 22092, (703) 648-5326. You must be an active, accomplished singer who reads music. ***Spouses and guests, particularly those with soprano and alto voices, are also welcome.***

For those wishing to attend this very special performance, ticket purchase in advance is highly recommended. Seating is limited, and given the sell-out performance by the GSA Centennial Orchestra, a ticket purchase with your meeting preregistration assures you a seat. You won't want to miss the excitement!

Transportation. Jordan Hall is within walking distance of the Marriott, Lenox, Copley Square, Hilton, and Colonnade hotels. Bus service will not be provided; however, taxi service will be available.

PRE-CONCERT WINE AND CHEESE AT THE COLONNADE

5:30 to 7:00 p.m.; Colonnade Hotel

As a special addition to this special evening, join us for wine, cheese, and other tasty hors d'oeuvres just before the concert. A glass of wine and hors d'oeuvres come with the fee. Additional drinks will be on a cash basis. The Colonnade Hotel is located conveniently between the Marriott and Jordan Hall.

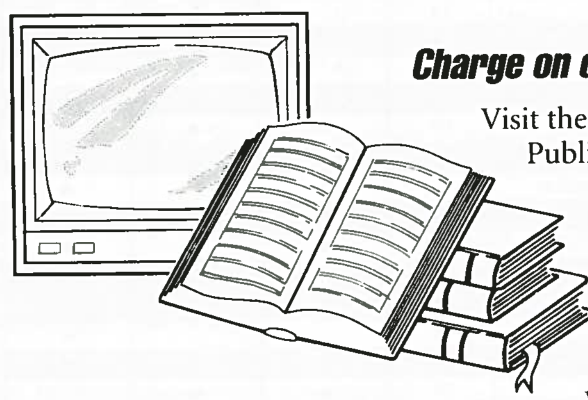
Was your abstract accepted for a Poster Session during the GSA Annual Meeting in Boston?

While putting your display together, consider this. The 1993 Annual Meeting Committee is sponsoring a Best Poster Award daily at the beginning of each session. Entries will be judged by the committee members. Decision will be based on scientific content, clarity, coherence, and graphics. Names of awardees will be posted daily in the poster area and will also appear in a future issue of *GSA Today.*

Would you like to be a Poster Awards Committee Judge?
Choose a morning or afternoon session on any day or multiple days. Contact our Poster Awards Chairman, J. Allan Cain, University of Rhode Island, (401) 792-2184 or (401) 792-2265, or call Kathy Lynch at GSA headquarters for details. Sign up as one of our judges today!

1993 Combined Publishers' Display

GSA ANNUAL MEETING
Boston, Massachusetts ▪ October 25–28



Charge on over...

Visit the GSA Combined Publishers' Display exhibit booth at the GSA Annual Meeting in Boston and get a first-hand look at an assortment of books and videos offered by a variety of publishers—all in one stop!

BOOTH #622

ICE HOCKEY

Tuesday, October 26, 8–10 p.m., Boston College Conte Forum

Pickup game of ice hockey, anyone? Any GSA hockey players wanting to join in this non-checking, no slapshot, informal pickup game are welcome. Players will need to provide their own standard hockey equipment such as helmets, pads, and sticks. For further information and sign-up, contact Grant Garven, Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, MD 21218, (410) 516-8689.

Any visit to Boston must include a dinner of lobster and a tour of the harbor area, so call your friends and make a night of it!

It had to happen!

Lobster Clambake Dinner Cruise

Don't you miss the boat!

Wednesday, October 27

6:00 to 7:00 p.m. board, 7:00 to 10:00 p.m. cruise

Narrated cruise of historic Boston Harbor aboard *The Spirit of Boston*

Buffet Dinner includes
New England Lobster ▪ Barbecued Chicken ▪ Steamed Shellfish
Corn on the Cob ▪ Roasted New Potatoes ▪ Cole Slaw
Choice of Scrumptious Desserts ▪ Coffee
Cash Bar

Salute to Broadway review performed following dinner by your waiters

Dance to a Live Band featuring top 40s and Oldies

Boarding begins at 6:00 p.m.—Boat departs at 7:00 p.m. **sharp**

Cost: $48 (includes transportation to and from boat, narrated cruise, dinner, entertainment, dancing).

SOUTH-CENTRAL SECTION, GSA 28th Annual Meeting

Little Rock, Arkansas
March 21–22, 1994

The Arkansas Geological Commission, the Department of Earth Science at the University of Arkansas, Little Rock, and the Geology Department at Arkansas Tech University will host the 1994 meeting of the South-Central Section of the Geological Society of America. In conjunction with the GSA South-Central Section, joint meetings of the Texas Section and the Midcontinent Section of the National Association of Geology Teachers (NAGT) and the South-Central Section of the Paleontological Society will be held. The meetings will be held at the Holiday Inn West in Little Rock.

CALL FOR PAPERS

Papers are invited for technical sessions, symposia, and poster sessions. The technical sessions will allow 20 minutes for presentation and discussion. Symposia conveners may allow more time to invited speakers. Papers of regional interest to geologists in the South-Central Section (Arkansas, Kansas, Oklahoma, and Texas) as well as papers of general interest will be considered for the program. Poster presentations are encouraged. All abstracts should be submitted directly to the Program Committee.

REGISTRATION

Preregistration deadline: February 18, 1994. To help keep registration fees down and to assist the local committee, in planning, please preregister. Preregistration will be handled by the local committee, and registration forms will appear in the December issue of *GSA Today*.

Preregistrants may pick up their registration materials at the registration desk in the lobby of the Holiday Inn West on Sunday, March 20, 1994, between 3:00 p.m. and 8:00 p.m. On-site registration will also be available a that time and will continue on Monday, March 21, 7:00 a.m. to 5:00 p.m., and on Tuesday, March 22, 7:00 a.m. to 11:00 a.m., at the registration desk.

HOUSING

Blocks of rooms have been reserved at Holiday Inn West in Little Rock. You must ask for the GSA rate when reserving a room. The rate is $60.00 per night for a single, double, triple, or quad occupancy for a king or double room. Reservations must be made by *February 26, 1994*.

Holiday Inn West (meeting site)
201 South Shackleford
Little Rock, AR 72211
(501) 223-3000

Other motels nearby are LaQuinta Inn, 200 Shackleford Road, Little Rock, AR 72211, (501) 224-0900; Motel 6, 10524 West Markham, Little Rock, AR 72211, (501) 225-7366; Budgetel, 1010 Breckenridge Drive, Little Rock, AR 72211, (501) 225-7007; Amerisuites, 10920 Financial Centre Parkway, Little Rock, AR 72211, (501) 225-1075; Courtyard by Marriott, 10900 Financial Centre Parkway, Little Rock, AR 72211, (501) 227-6000.

SYMPOSIA

The following symposia are planned for the meetings. Please note that abstracts for symposia should be submitted directly to William Bush, and a copy will be forwarded to the conveners. For information concerning a symposium, contact the conveners listed below.

1. **Ouachita Mountains of Arkansas and Oklahoma.** Charles G. Stone or Boyd R. Haley, Arkansas Geological Commission, 3815 West Roosevelt Road, Little Rock, AR 72204, (501) 324-9165.
2. **Industrial Minerals, with Emphasis on Diamonds.** Drew F. Holbrook, Twin City Bank Bldg., Suite 730-A, One Riverfront Place, North Little Rock, AR 72114, (501) 372-3362; Charles T. Steuart, Malvern Minerals Company, P.O. Box 1246, 220 Runyan Street, Hot Springs National Park, AR 71901, (501) 623-8893.
3. **New Madrid Seismic Zone.** John David McFarland III, Arkansas Geological Commission, 3815 West Roosevelt Road, Little Rock, AR 72204, (501) 324-9165; Roy VanArsdale, Department of Geology, Memphis State University, Memphis, TN 38152, (901) 678-2177.
4. **Hydrogeology and Environmental Geology.** Kenneth F. Steele, Arkansas Water Resources Center, University of Arkansas, 113 Ozark Hall, Fayetteville, AR 72701, (501) 575-3410; Dr. John Van Brahana, U.S. Geological Survey, WRD, University of Arkansas, 118 Ozark Hall, Fayetteville, AR 72701, (501) 575-2570.
5. **Planetary Geology in Geological Education (NAGT).** Donald Lokke, 7721 El Padra Lane, Dallas, TX 75248, (214) 239-7920.

ABSTRACTS

Abstracts are limited to 250 words and must be submitted camera-ready on the official 1994 GSA abstract form, which is available from Abstracts Coordinator, Geological Society of America, P.O. Box 9140, Boulder, CO 80301, (303) 447-8850. Send one original and five copies of abstracts to be considered for the general technical sessions, symposia, or poster sessions to:

GSA Program Committee
c/o William V. Bush
Arkansas Geological Commission
3815 West Roosevelt Road
Little Rock, AR 72204
(501) 324-9165.

ABSTRACT DEADLINE: NOVEMBER 30, 1993.

FIELD TRIPS

Both premeeting and postmeeting field trips will be offered. All field trips will begin and end at the Holiday Inn West in Little Rock. Contact a member of the Field Trip Committee listed below for details about particular field trips. Trips are still in the planning stages but will focus on the following areas.

1. Ouachita Mountains of central and western Arkansas.
2. New Madrid seismic zone, a tour in eastern Arkansas, the Crowley's Ridge area.
3. The new Crater of Diamonds State Park (diamond mine) and other industrial mineral sites in the state.
4. Geohydrology and environmental geology

Field Trip Committee

Victor Vere
Department of Physical Sciences—Geology
Arkansas Tech University
Russellville, AR 72801
(501) 968-0362

J. Michael Howard
Arkansas Geological Commission
3815 West Roosevelt Road
Little Rock, AR 72204
(501) 324-9165

Don Owens
Department of Earth Science
University of Arkansas
2801 South University
Little Rock, AR 72204
(501) 569-3545

PROJECTION EQUIPMENT

Projection equipment will be provided for 2" x 2" slides in standard 35-mm carousel trays. Please bring your own slide tray(s). Two slide projectors, two screens, and a single overhead projector will be provided for each room. A preview room will be available for the speakers.

DISPLAYS AND EXHIBITS

Commercial vendors, book sellers, educational institutions, and government agencies will present displays and exhibits at the meeting site. Contact the Exhibit Committee, Bill Prior or Doug Hanson, Arkansas Geological Commission, 3815 West Roosevelt Road, Little Rock, AR 72204, (501) 324-9165, for information on renting exhibit space. There is limited space available for exhibits, so reserve your space early.

STUDENT SUPPORT

The South-Central Section has funds available for grants to GSA Student Associates who are presenting papers at the meeting. Students are encouraged to apply for these grants. Send applications for assistance with your abstract to William V. Bush, Arkansas Geological Commission, 3815 West Roosevelt Road, Little Rock, AR 72204, (501) 324-9165.

Application letters must be sent by *November 30, 1993*. Letters should include certification that the student is a GSA Student Associate in the South-Central Section and is presenting a paper or poster session at the meeting in Little Rock.

SPECIAL EVENTS AND SOCIAL ACTIVITIES

A welcoming party for those who have preregistered will be held at the Holiday Inn West from 6:00 p.m. until 10:00 p.m., Sunday, March 20. The annual banquet will be held Monday evening, March 21, at 6:00 p.m. at the Holiday Inn banquet hall. The program for the banquet will be listed in the final meeting announcement in the December issue of *GSA Today*.

SPOUSE AND GUEST PROGRAM

Several activities have been planned for spouses and guests. Trips to the historical sites in the Little Rock area and local museums will be available. Van rides to local shopping malls will be available each day. More specific information will appear in the final meeting announcement in December.

DETAILED INFORMATION

Complete information concerning registration, accommodations, and activities will appear in the December issue of *GSA Today* and as part of the *Abstracts with Programs* for 1994. Requests for additional information or suggestions should be sent to either of the General Co-Chairs:

Philip L. Kehler
Department of Earth Science
University of Arkansas
2801 South University
Little Rock, AR 72204
(501) 569-3545
fax 501-569-8020

William V. Bush
Arkansas Geological Commission
3815 West Roosevelt Road
Vardelle Parham Geology Center
Little Rock, AR 72204
(501) 324-9165
fax 501-663-7360. ■

CORDILLERAN SECTION, GSA Annual Meeting

San Bernardino, California March 21–23, 1994

The Department of Geological Sciences, California State University, San Bernardino, will host the 1994 meeting of the Cordilleran Section of the Geological Society of America.

SETTING

The meeting will be held at the San Bernardino Hilton, which is within walking distance of numerous restaurants, several other lodging options, and the San Jacinto fault. The weather in late March is pleasant and/or interesting, with an average high of 66 °F and an average low of 54 °F. The area receives an average of 3.25 inches of rain. Access to the city is easy; Interstate 10 passes east-west through the city and Interstate 215 (a branch of I-15) passes north-south. The two intersect just west of the Hilton. For other modes of transportation, Ontario Airport is the closest airport, and San Bernardino has an Amtrak station.

CALL FOR PAPERS

Papers are invited for presentation in oral technical sessions, symposia, theme sessions, and poster sessions. Papers dealing with all aspects of the Cordilleran region, as well as those of general geological interest, will be considered for presentation and discussion. Technical sessions will allow 12 minutes for presentation and 3 minutes for discussion. Symposia may allow equivalent or longer times for presentation, at the option of the conveners and symposium coordinator.

REGISTRATION

Preregistration deadline: February 11, 1994.

For lower registration fees and to assist the local committee in planning, please preregister.

Preregistration will be handled by GSA headquarters. Registration forms will appear in the December issue of *GSA Today.*

FIELD TRIPS

For details of the premeeting and postmeeting field trips, contact the field trip leaders listed. General questions should be addressed to Sally F. McGill, Field Trip Coordinator, Dept. of Geological Sciences, California State University, San Bernardino, CA 92407-2397, (909) 880-5347, fax 909-880-7007, e-mail: smcgill@wiley.csusb.edu. Preregistration forms will be available in the Final Announcement in the December 1993 issue of *GSA Today.*

Premeeting

1. **Reconstruction of the Mojave Block.** March 17–20. Allen F. Glazner, Dept. of Geology, CB 3315, Mitchell Hall, University of North Carolina, Chapel Hill, NC 27599-3315, (919) 962-0689; and Elizabeth R. Schermer, J. Douglas Walker, and John M. Bartley.
2. **Black Mountains Crustal Section, Death Valley Extended Terrane, California.** March 17–20. Daniel K. Holm, Dept. of Geology, Kent State University, Kent, OH 44242, (216) 672-4094; and Terry L. Pavlis.
3. **Growth Fault Basin from the Mojave Mountains North to Lake Mead.** March 17–20. James E. Faulds, Dept. of Geology, University of Iowa, Iowa City, IA 52242, (319) 335-1097; and Phillip B. Gans, Jane Nielson, and Eugene I. Smith.
4. **New Approaches to Ichnofabric and Trace Fossil Analyses: Examples from the Mesozoic and Cenozoic of Southern California.** March 20. Mary L. Droser, Dept. of Earth Sciences, University of California, Riverside, CA 92521, (909) 787-3434; and David J. Bottjer.
5. **Structure and Stratigraphy of Pre-Tertiary Rocks at the Nevada Test Site.** March 17–20. Limited to U.S. citizens. Patricia H. Cashman and James H. Trexler, Jr., Dept. of Geological Sciences, University of Nevada, Reno, NV 89557, (702) 784-6050; and James C. Cole and Mark R. Hudson.
6. **Geology and Geophysics of the Sierra Madre–Cucamonga Fault Zones, San Gabriel Mountains, California.** March 20. Margaret Van Buskirk, Dept. of Earth Sciences, University of California, Riverside, CA 92521, (909) 787-3434; and Debra Brooks.
7. **Sedimentary and Structural Evolution of Miocene Synextensional Hanging Wall Basins, Colorado River Region, California and Arizona.** March 17–20. Julia M.G. Miller, Dept. of Geology, Vanderbilt University, Nashville, TN 37235, (615) 322-2144 or 2976; and Barbara E. John.
8. **Mid-Tertiary to Recent Extension Associated with the Development of the Sierra El Mayor Metamorphic Core Complex, Northern Baja California, Mexico.** March 17–20. Martin E. Siem, Woodward-Clyde Consultants, 2020 East 1st St., Suite 400, Santa Ana, CA 92705, (909) 835-6886, ext. 489; and R. Gordon Gastil.
9. **Quaternary Landscape Evolution across the California Shear Zone.** March 17–20. Stephen G. Wells, Dept. of Earth Sciences, University of California, Riverside, CA 92521, (909) 787-3434.
10. **Geology of San Gorgonio Pass and the San Bernardino Mountains.** March 19–20. John Matti, USGS, Western Regional Geology, Gould-Simpson Building, #77, University of Arizona, Tucson AZ 85721, (602) 670-5577.

Postmeeting

11. **Peninsular Ranges in the Riverside Area.** March 24. Douglas M. Morton, Dept. of Earth Sciences, University of California, Riverside, CA 92521, (909) 276-6397.
12. **Peninsular Ranges East from San Diego.** March 25. Victoria A. Todd, Dept. of Earth Sciences, University of California, Riverside, CA 92521, (909) 276-6397.
13. **Tectonics and Sedimentation, Southern Death Valley.** B. W. Troxel, 2961 Redwood Rd., Napa, CA 94558.
14. **Sedimentation Patterns Resulting from Detachment Faulting: Miocene Sedimentary Rocks in the Whipple Mountains, Southeastern California.** March 23–26. Kathi Beratan, Dept. of Geology and Planetary Science, University of Pittsburgh, Pittsburgh, PA 15260, (412) 624-1408.
15. **Landers: Earthquakes and Aftershocks.** March 24–25. Robert E. Reynolds, San Bernardino County Museum, 2024 Orange Tree Lane, Redlands, CA 92374, (909) 798-8570; and Michael J. Rymer.
16. **Mesozoic Structure of the Maria Belt, Southeastern California and Southwestern Arizona.** March 23–26. Stephen M. Richard, Arizona Geological Survey, 845 N. Park Ave., Tucson, AZ 85719, (602) 882-4795; and Stan N. Ballard, Stefan S. Boettcher, Warren B. Hamilton, Thomas D. Hoisch, and Richard M. Tosdal.
17. **Late Miocene Stratovolcano Complex on South Ranges, Naval Air Weapons Station.** March 23–26. Commanding Officer, Naval Air Weapons Station, Geothermal Program Office (C8306), China Lake, CA 93555-6001, Attn: Francis C. Monastero, (619) 939-4046.
18. **Stratigraphy and Gravity-Slide Elements of a Miocene Supradetachment Basin, Eastern Mojave Desert.** March 23–26. S. Julio Friedmann, Dept. of Geological Sciences, University of Southern California, Los Angeles, CA 90089-0740, (213) 740-6726.
19. **Hydrogeology in the Los Angeles Basin.** March 24. Prem K. Saint, Dept. of Geological Sciences, P.O. Box 34080, California State University, Fullerton, CA 92634-9480, (909) 773-2154.
20. **Neoproterozoic-Cambrian Boundary Interval in the Southern Great Basin: An Integrative Stratigraphic Approach.** March 23–26. Frank Corsetti, Dept. of Geological Sciences, University of California, Santa Barbara, CA 93106, (805) 893-3471; and Anthony R. Prave and John D. Cooper.
21. **Stratigraphy and Deformational History of the Mecca Hills, Southern California.** March 24–25. Ray J. Weldon, II, Dept. of Geological Sciences, University of Oregon, Eugene, OR 97403-1272, (503) 346-4584; and John P. Stimac, Judith M. Sheridan, Janet L. Boley, Gordon G. Seitz, and Michael J. Rymer.
22. **Neogene History of the Central Portion of the Garlock Fault.** March 24–25. Bruce A. Carter, Dept. of Physical Sciences, Pasadena City College, Pasadena, CA 91106, (818) 585-7140; and Sally F. McGill.

SYMPOSIA

The following symposia will include both invited papers and selected volunteered papers. Prospective authors are encouraged to contact the respective conveners. General questions should be addressed to Joan E. Fryxell, Meeting Chair, Dept. of Geological Sciences, California State University, San Bernardino, CA 92407-2397, (909) 880-5311, fax 909-880-7007, e-mail jfryxell@wiley.csusb.edu.

1. **Paleoseismology.** Sally F. McGill, Dept. of Geological Sciences, California State University, San Bernardino, CA 92407, (909) 880-5347; and Robert S. Yeats.
2. **Phanerozoic Cordilleran Metamorphism: Distribution and Tectonic Implications.** Phyllis A. Camilleri, Dept. of Geology and Geophysics, University of Wyoming, P.O. Box 3006, Laramie, WY 82071, (307) 766-2914; and David M. Miller.
3. **Neoproterozoic-Cambrian of the Great Basin: New Developments in Stratigraphy, Sedimentology, Paleontology, and Related Fields.** Frank Corsetti, Dept. of Geological Sciences, University of California, Santa Barbara, CA 93106, (805) 893-3471; and Anthony R. Prave and John D. Cooper.
4. **Tertiary Basins and Volcanism in the Death Valley Region: Their Tectonic Significance.** B. W. Troxel, 2961 Redwood Rd., Napa, CA 94558.
5. **Sequence Stratigraphy of the Great Basin: Facies Patterns and Sequence Boundaries.** Mark Harris, Dept. of Geosciences, University of Wisconsin—Milwaukee, P.O. Box 413, Milwaukee, WI 53201, (414) 229-5777; and Kathy Nichols.
6. **Poster Symposium: Recent Contributions to the Southern California Areal Mapping Project.** John Matti, USGS, Western Regional Geology, Gould-Simpson Building, #77, University of Arizona, Tucson, AZ 85721, (602) 670-5577.
7. **Hydrogeology of Southern California.** Prem K. Saint, Dept. of Geological Sciences, P.O. Box 34080, California State University, Fullerton, CA 92634-9480, (909) 773-2154.
8. **Tectonic Evolution of Baja California.** Rebecca J. Dorsey, Dept. of Geology, Box 6030, Northern Arizona University, Flagstaff, AZ 86011, (602) 523-4561; and Arturo Martin.
9. **Accommodation Zones and Transfer Zones: The Significance and Nature of the Large-scale Segmentation of the Basin and Range.** James Faulds, Dept. of Geology, University of Iowa, Iowa City, IA 52242, (319) 335-1097.
10. **Effects of the 1993 Storm Events on Southern California.** Robert A. Larson, 6416 Woodley Ave., #5, Van Nuys, CA 91406, (818) 458-4923.
11. **Episodic Mesozoic and Cenozoic Extension in the Basin and Range.** Wanda J. Taylor, Dept. of Geoscience, University of Nevada, Las Vegas, NV 89154, (702) 597-4615; and David M. Miller.
12. **The Uses of Vertebrate Fossils in Solving Biostratigraphic Problems.** Stuart Sumida, Dept. of Biology, California State University, San Bernardino, CA 92407-2397, (909) 880-5346.
13. **Mesozoic Deformation Southwest of the Colorado Plateau, the Cordilleran-Chihuahuan Linkage.** Stephen M. Richard, Arizona Geological Survey, 845 N. Park Ave., Tucson, AZ 85719, (602) 882-4795; and Richard M. Tosdal.

THEME SESSION

Geologic and Paleogeographic Influences on Mesozoic Vertebrate Community Dynamics. Anthony R. Fiorillo and Cathleen L. May, Museum of Paleontology, University of California, Berkeley, CA 94720, (415) 642-1821.

POSTER SESSIONS

Poster sessions will be located adjacent to the exhibit area. If you wish to take advantage of this highly effective means of communication, please indicate your preference for a poster session on the GSA abstract form.

Cordilleran *continued on p. 243*

Cordilleran *continued from p. 242*

ABSTRACTS

Abstracts are limited to about 250 words and must be submitted camera-ready on official 1994 GSA abstract forms, available from the Abstracts Coordinator, Geological Society of America, P.O. Box 9140, Boulder, CO 80301, (303) 447-8850.

ABSTRACTS DEADLINE: NOVEMBER 29, 1993

An original and five copies are required for each abstract. Authors of symposium papers and posters should send their abstracts directly to the appropriate convener (see lists above). Other abstracts should be sent directly to Joan E. Fryxell, Dept. of Geological Sciences, California State University, San Bernardino, CA 92407-2397, (909) 880-5311, fax 909-880-7007, E-mail jfryxell@wiley.csusb.edu.

Abstracts will be reviewed for information content and format, appropriate geographic coverage (Cordilleran region), and originality. Only one volunteered paper may be presented by each individual, although a person may also co-author papers presented by others and may present additional papers invited for symposia.

PROJECTION EQUIPMENT

All slides must be 2" x 2" and fit standard 35 mm carousel trays. Two projectors and two screens will be available for all oral sessions. Overhead projectors will not be available. Please bring loaded carousel trays, if possible.

EARTH SCIENCE EDUCATION PROGRAMS

Several special programs designed for teachers (K–12) and interested professionals will be scheduled during the meeting. Field trips specifically designed to be useful to teachers will be offered. For information on any of the earth science education programs, contact James M. Mehegan, Dept. of Geological Sciences, California State University, San Bernardino, CA 92407-2397, (909) 880-5337, fax 909-880-7007, e-mail jmehegan@wiley.csusb.edu.

EXHIBITS

Exhibits will be located adjacent to the poster sessions. The cost of exhibits will be $300 for commercial exhibitors and $150 for educational and nonprofit institutions. For further information and space reservations, please contact Timothy M. Ross, Exhibits Coordinator, Dept. of Geological Sciences, California State University, San Bernardino, CA 92407-2397, (909) 880-5311, fax 909-880-7005.

STUDENT SUPPORT

The GSA Cordilleran Section has funds available for grants to support GSA Student Associates of the section who are presenting papers at the meeting. Students are strongly encouraged to apply for these grants, and we anticipate that most students who qualify will be funded to some degree. Apply to Cordilleran Section Secretary Bruce A. Blackerby, Dept. of Geology, California State University, Fresno, CA 93740, (209) 278-2955 (direct) or 278-3086. Applications should include certification that the student is presenting a paper and is a GSA Student Associate of the Cordilleran Section. *All letters must be received by January 15, 1994.*

ACCOMMODATIONS

A block of rooms at the San Bernardino Hilton, the site of the meeting, has been reserved for attendees, at a special reduced rate of $65 for a single or a double. Additional housing is available within both walking and driving distance of the Hilton. Specific information will be provided in the December 1993 issue of *GSA Today*.

DETAILED INFORMATION

Information concerning registration, accommodations, and activities will appear in the December 1993 issue of *GSA Today* and as part of the Cordilleran Section *Abstracts with Programs* for 1994. Preliminary questions and suggestions should be addressed to the meeting chair, Joan E. Fryxell, Department of Geological Sciences, California State University, San Bernardino, CA 92407-2397, (909) 880-5311, fax 909-880-7007, e-mail jfryxell@wiley.csusb.edu. ■

Preliminary Announcement and Call for Papers

SOUTHEASTERN SECTION, GSA
43rd Annual Meeting

Blacksburg, Virginia
April 7–8, 1994

The Southeastern Section of the Geological Society of America will meet in the Donaldson Brown Center for Continuing Education, the adjacent Squires Student Center, and nearby Owens Hall on the campus of Virginia Polytechnic Institute and State University (Virginia Tech) in Blacksburg. The meeting will be hosted by the Department of Geological Sciences, Virginia Tech, in cooperation with the Department of Geology at Radford University.

SETTING

Blacksburg, the home of Virginia's largest university, is located in the Valley and Ridge at the junction of the central and southern Appalachians. The town is on a rolling upland at 2100 feet of elevation and a short drive from the state's highest natural lake, Mountain Lake and resort, at 3900 feet. In early April spring bulbs are in full bloom and dogwoods are just opening. In addition to major regional malls in the Blacksburg–New River Valley area, the Roanoke metropolitan area (population about 200,000) provides shopping, museums, airport access, and entry to the Blue Ridge Parkway in just 40 minutes by four-lane Interstate I-81 and US 460 from Blacksburg.

CALL FOR PAPERS

Abstracts are invited for oral presentations, poster sessions, theme sessions, and symposia. Papers dealing with all aspects of the southeastern region of the United States are especially encouraged. All oral presentations will be limited to 20 minutes, including five minutes for discussion. Poster sessions are scheduled for the first day and the second morning, and a special Poster Symposium is planned for Thursday afternoon. All poster sessions will be set up for four hours and authors will be available for two hours. Abstracts not accepted for symposia or theme sessions will be considered for regular technical sessions.

REGISTRATION

Preregistration deadline: March 4, 1994

For lower registration fees and to assist the local committee in planning, please preregister.

A reduced registration fee will be offered to precollege earth science teachers and students. One-day registration is available for those unable to attend the full meeting. Field trip and short course attendees (except pre-college earth science teachers) must register for the meeting.

Preregistration will be handled by GSA headquarters. Registration forms will appear in the January issue of *GSA Today.*

ABSTRACTS

Abstracts for all sessions must be submitted camera-ready on official 1994 GSA abstract forms. These forms are available from Abstracts Coordinator, Geological Society of America, P.O. Box 9140, Boulder, CO 80301, (303) 447-8850.

An original and five copies of all abstracts (volunteered and invited) should be sent to Krishna Sinha (Dept. of Geological Sciences, VPI&SU, Blacksburg, VA 24061). We encourage participants in theme sessions and symposia to send an *extra* copy to the convener of the session. GSA rules prohibit any individual from presenting more than one volunteered abstract, although they can be co-authors on additional volunteered abstracts. Abstracts submitted for symposia do not come within this limitation.

ABSTRACT DEADLINE: DECEMBER 1, 1993

FIELD TRIPS

Both premeeting and postmeeting trips will be offered. For details about particular field trips, contact the field trip leaders listed.

PREMEETING

1. **Late Precambrian Rift and Drift Sequences and Structure Across the Blue Ridge–James River Gorge to Lynchburg, Virginia.** Two days. Lynn Glover, III, Dept. of Geological Sciences, VPI&SU, Blacksburg, VA 24061, (703) 231-6213; and Edgar Spencer, Dept. of Geology, Washington and Lee University, Lexington, VA 24450, (703) 463-8800.
2. **Structural and Stratigraphic Relations Across the Mountain Run Fault Zone, Albemarle and Fluvanna Counties, Virginia.** Two days. Nick Evans, Virginia Division of Mineral Resources, Box 3667, Charlottesville, VA 22903, (804) 293-5121; and Robert Milici, USGS, Denver, Colorado.
3. **K-Bentonites, Conglomerates, and Unconformities in the Ordovician of Southwestern Virginia.** Two days. John Haynes, Halliburton NUS Corp., 910 Clopper Rd., Gaithersburg, MD 20878-1399, (301) 258-6000.

POSTMEETING

4. **Geology of the Mount Rogers Area, Virginia.** Two days. Douglas Rankin, U.S. Geological Survey, 926 National Center, Reston, VA 22092, (703) 648-6903; Julia Miller, Department of Geology, Vanderbilt University; and Edward Simpson, Department of Physical Sciences, Kutztown University .
5. **Geologic and Structural Transect of the New River Valley: Valley and Ridge and Blue Ridge Province, Southwest Virginia.** Two days. Jerry Bartholomew, Earth Science and Resource Institute, University of South Carolina, Columbia, SC 29208, (803) 777-5908; Sharon Lewis, Westinghouse Savannah River Company, Aiken, SC; and William Henika, Virginia Division of Mineral Resources, Blacksburg.
6. **Engineering Geology of Southwest Virginia.** Chester Watts and Robert Whisonant, Dept. of Geology, Radford University, Radford, VA 24142, (703) 831-5224.
7. **Devonian Strata of Catawba Syncline Near Salem, Virginia.** Thomas Rossbach and John Dennison, Dept. of Geology, University of North Carolina, Chapel Hill, NC 27599-3315, (919) 966-4516.
8. **Sedimentology and Paleoecology in Carboniferous Cycles, Kentucky.** Two days. Fred Read and Richard Bambach, Dept. of Geological Sciences, VPI&SU, Blacksburg, VA 24061, (703) 231-6521.
9. **Geology of the New River Valley: A Field Trip for Earth Science Educators.** Saturday, April 9, 8:30 a.m. to 12:30 p.m. This field trip includes stops where evidence of sedimentation, uplift, and folding can be observed and at an abandoned coal mine. Emphasis will be on teacher-guided exploration of geologic processes through discovery by modeling inquiry-based instruction. For more information, contact Susan C. Eriksson, Virginia Tech Museum of Natural History, 428 North Main St., Blacksburg, VA 24061-0542, (703) 231-5360.

SYMPOSIA

Five symposia are already planned for the meeting, and individuals are encouraged to contact Krishna Sinha (Dept. of Geological Sciences, VPI&SU, Blacksburg, VA 24061, (703) 231-5580, E-mail searches@vtvm1.cc.vt.edu) for suggestions regarding additional symposia for possible consideration. Please contact respective conveners for information about symposia listed below.

1. **Provenance Characterization of Appalachian Clastic Wedges: Implications for Terrane Assembly.** Ken Eriksson, Dept. of Geological Sciences, VPI&SU, Blacksburg, VA 24061, (703) 231-4680. Cosponsored by SEPM Southeastern Section.
2. **Timing, Location, and Nature of Cambrian (Penobscot?) and Middle Ordovician (Taconic) Collisions in the Central and Southern Appalachians.** Lynn Glover, III,

Southeastern *continued on p. 244*

GSA Congressional Science Fellow Named for 1993–1994

Murray W. Hitzman has been selected as the eighth GSA Congressional Science Fellow. He will work as a special legislative assistant on the staff of a committee or member of the U.S. Congress from September 1993 through August 1994.

As a Congressional Science Fellow, Hitzman hopes to work on issues spanning environment, natural resources law, education, scientific research, and the economic impact of these intertwining areas. Viewing the environment as a broad issue that touches most current legislation, Hitzman expects to apply his international scientific and business experience to "the complicated social issues of science and technology that confront our citizens and government."

Hitzman received his Ph.D. in geology in 1983 from Stanford University. His principal research interests and training are in the fields of structural geology, carbonate sedimentology, economic geology, and geochemistry. For the past ten years Hitzman has worked for Chevron companies worldwide. Recently, he was largely responsible for the discovery of the Lisheen deposit in 1990, one of the largest zinc deposits in Europe, and as general manager of Chevron Mineral Corporation of Ireland, he served as corporate and community liaison involving feasibility and environmental impact studies, emphasizing engineering, economics, and environmental excellence. Hitzman received a B.A. in anthropology and a B.A. in geology from Dartmouth College in 1976, and a masters in geology in 1978 from the University of Washington.

The Fellowship

The Congressional Science Fellowship gives a geoscientist first-hand experience with the legislative process and the opportunity to view science policy issues from the lawmaker's perspective. At the same time, the Fellow assists in the analysis of public policy issues by providing scientific and technical expertise.

Murray Hitzman

Funded by GSA and by a grant from the U.S. Geological Survey, the fellowship demonstrates the value of science-government interaction, and relates the need for informed involvement to the earth science community. The program places highly qualified, accomplished scientists with the offices of individual members of Congress or committees for a one-year assignment. Fellows perform in much the same way as regular staff members; they have the opportunity to be involved in varied legislative, oversight, and investigative activities. They offer their special knowledge, skills, and competence for the opportunity to acquire experience and the chance to contribute to the formulation of national policy. The Fellow reports periodically to the GSA membership and to the USGS during the one-year period.

Requirements for the fellowship include exceptional competence in some area of the earth sciences, cognizance of a broad range of matters outside the fellow's particular area, and a strong interest in working on a range of public policy problems. Fellows attend a two-week orientation conducted by the American Association for the Advancement of Science.

Southeastern *continued from p. 243*

Dept. of Geological Sciences, VPI&SU, Blacksburg, VA 24061, (703) 231-6213; and Alexander Gates, Dept. of Geology, Rutgers University, Newark, NJ 07102, (201) 648-5034.

3. **Evolution of the Southeast Piedmont: Island Arc to Continental Collision.** *In honor of J. Robert Butler.* Steven Goldberg, Dept. of Geology, University of North Carolina, Chapel Hill, NC 28804, (919) 966-4519; and W. Ranson, Furman University, Greenville, SC.
4. **SPECIAL POSTER SYMPOSIUM SESSION—NEW.** Plans have been made for a special poster session, "Geologic and Geophysical Maps: Recent Advances." J. Wright Horton, Jr., MS 928, U.S. Geological Survey, Reston, VA 22092, (703) 648-6933.
5. **Special Symposium on Earth Science Education.** This symposium will explore the current national models of education in promoting earth science literacy through more effective teaching and learning of earth science process skills. It is designed to appeal to earth science educators in K–12 schools as well as freshman and sophomore college levels. We seek broad-based, dynamic presentations of tested programs or educational models that fulfill the goals of AAAS's Project 2061 and AGI's Earth Science Education for the 21st Century: A Planning Guide. For information, contact Susan C. Eriksson, Virginia Tech Museum of Natural History, 428 North Main St., Blacksburg, VA 24061-0542, (703) 231-5360.

THEME SESSIONS

Individuals interested in convening a theme session (all papers are volunteered) should contact Krishna Sinha (Dept. of Geological Sciences, VPI&SU, Blacksburg, VA 24061, (703) 231-5580, E-mail searches@vtvm1.cc.vt.edu). The following is already planned.

1. **Investigative Activities in Earth Science Education.** This theme session for earth science educators K–12 and freshman and sophomore college levels will be organized into 50-minute workshops on earth science activities that follow national guidelines for teaching excellence in science. Mini-field trips, hands-on classroom and laboratory activities, building partnerships, and applications of computers in the classroom will make up these workshops. For more information, contact Susan C. Eriksson, Virginia Tech Museum of Natural History, 428 North Main St., Blacksburg, VA 24061-0542, (703) 231-5360.

POSTER SESSIONS

Three half-day poster sessions will be organized, and we encourage poster contributions because they permit extended discussions. Space for 20 poster boards (8′ x 4′) will be available for each of the three sessions. Please indicate your preference for a poster session on the GSA abstract form.

SPECIAL SYMPOSIUM AND THEME SESSION ON GEOSCIENCE EDUCATION

A one-day program on earth science education has been planned for Friday, April 8, for teachers of K–12 and freshman and sophomore courses. The morning symposium and afternoon theme session will focus on *Earth Science Education for the 21st Century: A Planning Guide*, produced by AGI. For more information, contact Susan Eriksson, Dept. of Geological Sciences, VPI&SU, Blacksburg, VA 24061, (703) 231-5360.

SHORT COURSES AND WORKSHOPS

PREMEETING

Two half-day workshops on Wednesday afternoon, April 6, are planned. For suggestions of other possible short courses and workshops, please contact Krishna Sinha (Dept. of Geological Sciences, VPI&SU, Blacksburg, VA 24061).

1. **Getting Maximum Information from Highly Deformed Rocks.** Carol Simpson, Johns Hopkins University, Baltimore, MD 21218, (410) 516-7135, and Declan G. De Paor, George Washington University, Washington, D.C. This hands-on course is designed for professionals and graduate students.
2. **Don't Crush That Sample—Hand Me the Pliers! The Care of Rock and Mineral Collections.** Llyn Sharp, Virginia Tech Museum of Natural History, 428 N. Main St., Blacksburg, VA 24061, (703) 231-4080. A workshop for curators of all kinds of geologic collections, including departmental teaching collections, private mineral collections, display collections, research project collections, voucher collections, and fossil collections.

PROJECTION EQUIPMENT

All slides must be 2″ x 2″ and fit a standard 35-mm carousel tray. Please bring your own loaded carousel trays. Two 35-mm slide projectors and screens will be available for each oral technical session.

EXHIBITS

Exhibit booths for business, educational, and governmental institutions will be available in the Owens Banquet Hall, sharing this location with poster sessions and coffee breaks. The exhibit area will be open all day Thursday and Friday. For further information and space reservation, contact Susan C. Eriksson, Virginia Tech Museum of Natural History, 428 North Main St., Blacksburg, VA 24061-0542, (703) 231-5360.

GUEST ACTIVITIES (Preliminary)

1. Tour and luncheon at the world-famous Greenbrier Hotel at White Sulphur Springs, West Virginia.
2. Visit to 18th Century Smithfield Plantation and regional art galleries.
3. A day of antique shops.

STUDENT ASSISTANCE

A limited amount of support for travel expenses of students presenting papers at the meeting is available from the Southeastern Section. For information, contact Michael J. Neilson, Dept. of Geology, University of Alabama, Birmingham, AL 35294, (205) 934-5102.

TRAVEL TO BLACKSBURG

Blacksburg is located on U.S. Route 460 nine miles west of Interstate 81 in southwestern Virginia. It is serviced by Roanoke Regional Airport located just off Interstate 81 about 40 miles to the east of Blacksburg. Access is by USAir, United, American, Delta, and Northwest airlines. Blacksburg Limousine Service, (703) 951-3973, furnishes transportation between the airport and Blacksburg.

SPECIAL PROGRAM FOR SCIENCE EDUCATION TEACHERS

A special program is being organized for science education teachers, and it will include a half-day field trip in the New River Valley (see Field Trips), a Special Symposium on Earth Science Education (see Symposia), and a Theme Session, "Investigative Activities in Earth Science Education (see Theme Sessions). A reduced registration fee will be available for those unable to attend the rest of the meeting.

HOUSING

Rooms have been reserved for participants in Blacksburg motels within 1.5 miles of the meeting site. Bus transportation will be available for attendees. Do not plan to park at the conference site.

OTHER INFORMATION

More detailed information concerning fees and registration, motel accommodations, field trips, and other activities will appear in the January 1994 issue of *GSA Today*, and as part of the GSA Southeastern Section *Abstracts with Programs* for 1994. For detailed information regarding technical programs, contact Krishna Sinha (Dept. of Geological Sciences, VPI&SU, Blacksburg, VA 24061, (703) 231-5580, E-mail searches@vtvm1.cc.vt.edu). For all other information contact Lynn Glover, Dept. of Geological Sciences, VPI&SU, Blacksburg, VA 24061, (703) 231-6213; or Bob Tracy, Dept. of Geological Sciences, VPI&SU, Blacksburg, VA 24061, (703) 231-5980, co-chairs of the local organizing committee. ■

GSA Committee Awards Research Grants

June Forstrom, Research Grants Administrator

The GSA Committee on Research Grants met in Boulder, Colorado, on April 5–6, 1993, and awarded $257,882 to 178 student applicants. Two postdoctoral applicants for the Gladys W. Cole and W. Storrs Cole Awards received $14,000. Committee members for 1993 are Howard W. Day (Chairman), Raymond V. Ingersoll, Molly Fritz Miller, Peter C. Patton, Darryll T. Pederson, Ben A. van der Pluijm, and Thomas O. Wright (National Science Foundation conferee).

Of the 178 grant recipients, 64 were master's candidates and 114 were doctoral candidates. The size of the average award increased from $1273 in 1992 to $1449 this year. Proposal requests totaled $970,348, from 575 student applicants.

The committee's budget included $152,000 from the Penrose Endowment, $75,000 from the National Science Foundation, $3000 income from the Harold T. Stearns Fund, and $4300 for awards from five GSA Divisions: Engineering Geology, Geophysics, Hydrogeology, Sedimentary Geology, and Structural Geology and Tectonics. It also included $23,700 from the GSA Foundation. The Gladys W. Cole and W. Storrs Cole Awards were funded by $14,000 income from the two Cole Award Funds from the GSA Foundation.

Cole Awards for Postdoctoral Research

The Gladys W. Cole Memorial Research Award for 1993 went to Nicholas Lancaster of the Desert Research Institute, Reno, Nevada, to support of his project titled "Studies of Desert Dune Initiation." This award, established in 1980, is restricted to support of research for the investigation of the geomorphology of semi-arid and arid terrains in the United States and Mexico.

The W. Storrs Cole Memorial Research Award for research in invertebrate micropaleontology was established in 1989. It was presented this year to Jere H. Lipps of the University of California, Berkeley, for his project titled "Molecular Phylogeny of Foraminifera."

Eligibility for both Cole awards is restricted to GSA Members and Fellows between 30 and 65 years of age.

Student Awards

Gretchen L. Blechschmidt Research Award. The family and friends of Gretchen Louise Blechschmidt established a fund in her memory in 1990 to support research for women in the geological sciences. The award was presented this year to Aradhna Srivastav of the University of Nebraska, Lincoln, for her project titled "Neogene Antarctic Glacial History: Development of Diatoms as Biostratigraphic, Paleoenvironmental, and Paleoceanographic Tools for Antarctica and Southern Ocean."

John T. Dillon Alaska Research Award. John Dillon was particularly noted for his radiometric dating work in the Brooks Range, the results of which have had a major impact on understanding the geologic characteristics of this mountain range. The 1993 recipient is John S. Davis of the University of California, Davis, for "Do Strained Conglomerate Clasts in the Chugach Terrane Indicate Oblique Convergence During Accretion to Western North America?"

Robert K. Fahnestock Award. Ken Fahnestock was a member of the Committee on Research Grants. This award is given to the applicant with the best proposal in sediment transport or related aspects of fluvial geomorphology. The 1993 recipients are Diane E. Anderson, University of California, Riverside, for "Fluvial Geomorphology and Late Quaternary Paleohydrology of the Amargosa River: Reconstruction of Paleofloods and Lake-Building Events at the Great Basin/Mojave Desert Boundary," and, Kevin Cornwell, University of Nebraska, Lincoln, for "Catastrophic Breakout Floods in the Western Himalaya, Pakistan."

Harold T. Stearns Fellowship Award. The three recipients of this award, for research on aspects of the geology of the Pacific Islands and the circum-Pacific region, are Cheryl A. Gansecki, Stanford University, for "The Origin of Extraneous Argon in Silicic Volcanic Rocks: $^{40}Ar/^{39}Ar$ Studies of Rhyolites from the Sierra La Primavera, Mexico"; Michal Kowalewski, University of Arizona, for "Taphonomy and Ecology of a Living Fossil: The Lingulid Brachiopod *Glottidia palmeri* on Tidal Flats of the Colorado Delta, NE Baja California"; and Glenn David Thackray, University of Washington, Seattle, for "Chronology of Alpine Glaciation on the Western Slope of the Olympic Mountains, Washington."

Industrial Donations and Awards. Mobil Oil Corporation donated $2000 in support of the research grants program for this year. This is the 24th year of support, totaling $42,000 from Mobil Oil for the grants program. The 1993 recipients are Rolf S. Arvidson, University of Hawaii, for "Kinetics of Low-Temperature Dolomitization"; Brian K. Horton, Montana State University, for "Relations Among Transverse Structures, Depositional Environments, and Sedimentation Patterns of a Neogene Extensional Basin, East-Central Nevada"; and Kathryn A. Schubel, Johns Hopkins University, for "Dolomite Microstructures and Reaction Mechanisms of Dolomitization: An Integrated TEM, Petrographic, Geochemical and Field Study of Selected Dolomite Bodies."

Outstanding Mention. The committee on Research Grants specially recognized 39 of the proposals as being of exceptionally high merit in conception and presentation: Susan J. Altman, Pennsylvania State University, for "Transport of Nutrients in Groundwater Flowing Through Porous Media and Shallow Bedrock Beneath Farmland and Removal of Nutrients in the Riparian Zone"; Rolf S. Arvidson, University of Hawaii, for "Kinetics of Low-Temperature Dolomitization"; Sandeep Burman, University of Minnesota, for "Mathematical and Physical Scale Modelling for Determination of Ground-Water Sensitivity to Surface-Generated Contaminants"; Karen Chin, University of California, Santa Barbara, for "Biogeochemical and Petrographic Analysis of Presumed Dinosaurian Coprolites"; Philippe Claeys, University of California, Davis, for "Evidences for an Extraterrestrial Impact at the Frasnian-Famennian Boundary: Did it Trigger Mass Extinctions?"; David G. Coler, Syracuse University, for "An Isotopic Study of the Raleigh Belt and the Goochland Terrane: Implications for the Extent of Grenville Basement in the North Carolina and Virginia Piedmont"; Kevin Cornwell, University of Nebraska, Lincoln, for "Catastrophic Breakout Floods in the Western Himalaya, Pakistan"; Angela Coulton, SUNY, Albany, for "Timing of Serpentinization in the Josephine Ophiolite, NW California: A Field, Petrographic and Isotopic Study"; Eleanor Tamiko Dixon, University of Michigan, for "A Test of Hornblende Barometry"; Jaelyn J. Eberle, University of Wyoming, for "The Mammalian Transition Across the Lancian-Puercan Boundary in the Hanna Basin, South-Central Wyoming"; Michael Edwards, SUNY, Albany, for "Investigation of Normal Fault Development Patterns on the Outer Wall of the Trench and Their Effect on the Mechanical Behavior of the Subducting Lithosphere"; Steven B. Feldman, Virginia Polytechnic Institute & State University, for "Paleopedological Reconstruction and Quaternary Geochronology Along a Piedmont Soil Climosequence, Eastern U.S.A."; Cheryl A. Gansecki, Stanford University, for "The Origin of Extraneous Argon in Silicic Volcanic Rocks: $^{40}Ar/^{39}Ar$ Studies of Rhyolites from the Sierra La Primavera, Mexico"; John A. Groff, New Mexico Institute of Mining & Technology, for "The Characterization of Auriferous Fluids and Timing of Gold Mineralization for Deposits along the Getchell Trend, Humboldt County, Nevada"; Marc J. Hinton, University of Waterloo, for "The Role of Groundwater Flow on Stream Discharge and Chemistry in Glacial Till Watersheds"; Nei-Che Ho, University of Michigan, for "Textural Analysis of Diagenetic to Low-grade Pelites"; Edward R.C. Hornibrook, University of Western Ontario, for "'Greenhouse' Gas Generation, Consumption and Transport within Wetland Ecosystems: An Evaluation Using Naturally Occurring Stable Isotopes"; Brian K. Horton, Montana State University, for "Relations Among Transverse Structures, Depositional Environments, and Sedimentation Patterns of a Neogene Extensional Basin, East-Central Nevada"; Michael L. Hulver, University of Chicago, for "Post-Permian Paleogeographic Evolution of Eastern North America"; Michal Kowalewski, University of Arizona, for "Taphonomy and Ecology of a Living Fossil: The Lingulid Brachiopod *Glottidia palmeri* on Tidal Flats of the Colorado Delta, Northeastern Baja California"; John Leland, University of California, Los Angeles, for "Calibration of ^{36}Cl In Situ Production Rate and Its Applications to Determining Differential Rates of Uplift in the NW Himalaya"; David Tondl Lescinsky, Arizona State University, for "Explosive Volcanism at Glaciated Volcanoes: An Examination of 'Wet' Pyroclastic Flows"; Barbara J. Mahler, University of Texas, Austin, for "Sediment-Contaminant Transport in Karst Terrains"; Patricia Marshik, University of California, Los Angeles, for "Confidence Intervals on Stratigraphic Ranges for Taxa with Non-Random Distributions of Fossil Horizons"; Jed Leigh Mosenfelder, Stanford University, for "Emplacement History of the Oman Ophiolite"; Cheryl Petrina, Duke University, for "Propagation and Interaction of Border Faults in the Turkana Rift, Kenya"; John N. Plant, University of Hawaii at Manoa, for "The Proposed Use of Compound Specific Isotopic Analysis as a Tracer for Terrestrial Organic Matter in Marine Sediments"; Michael C. Pope, Virginia Polytechnic Institute & State University, for "Cyclic Sedimentary and Diagenetic Record During Ordovician 'Greenhouse' to 'Icehouse' Transition"; Todd Randall, McMaster University, for "Subglacial or Glaciolacustrine?—Re-evaluation of the Sunnybrook Drift, Scarborough Bluffs, Canada"; Peter E. Sauer, University of Colorado, for "Investigation of the Meteoric Water Isotope Signal in Submergent Aquatic Plant Macrofossils: A New Technique in Paleoclimatology"; Stephen A. Schellenberg, University of South Florida, for "Sub-millennial Scale Climate Variability in the Middle Pliocene of the

Grant Awards *continued on p. 246*

GSA SECTION MEETINGS

South-Central Section

University of Arkansas, Little Rock, Arkansas, March 21–22, 1994. Philip L. Kehler, Department of Earth Sciences, University of Arkansas—Little Rock, 2801 S. University Ave., Little Rock, AR 72204, (501) 569-3546, fax 501-569-8020. *Abstract Deadline: November 30, 1993.*

Cordilleran Section

California State University, San Bernardino, California, March 21–23, 1994. Joan E. Fryxell, Department of Geological Sciences, California State University, 5500 University Parkway, San Bernardino, CA 92407-2397, (909) 880-5311. *Abstract Deadline: November 29, 1993.*

Northeastern Section

SUNY at Binghamton, Binghamton, New York, March 28–30, 1994. H. Richard Naslund, Department of Geological Sciences, SUNY, Binghamton, NY 13902-6000, (607) 777-4313. *Abstract Deadline: December 2, 1993.*

Southeastern Section

Virginia Polytechnic Institute and State University, Blacksburg, Virginia, April 7–8, 1994. Lynn Glover, III, and Robert J. Tracy, Department of Geological Sciences, Virginia Tech, Blacksburg, VA 24061-0420, Glover's direct (703) 231-6213, Tracy's direct (703) 231-5980, fax 703-231-3886. *Abstract Deadline: December 1, 1993.*

North-Central Section

Western Michigan University, Kalamazoo, Michigan, April 28–29, 1994. Alan Kehew, Department of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5495, fax 616-387-5513. *Abstract Deadline: January 6, 1994.*

Rocky Mountain Section

Fort Lewis College, Durango, Colorado, May 4–6, 1994. Douglas Brew, Geology Department, Fort Lewis College, Durango, CO 81301, (303) 247-7254, fax 303-247-7310. *Abstract Deadline: January 13, 1994*

Grant Awards *continued from p. 245*

Western Caribbean: Inferences from Coralline Chemistry"; Kenneth M. Schopf, Harvard University, for "Ecosystem Dynamics and Evolution in the Upper Cretaceous (Montana Group, U.S. Western Interior)"; Meg E. Schramm, University of Nevada, Las Vegas, for "Structural Analysis of the Hurricane Fault in the Transition Zone Between the Basin and Range Province and the Colorado Plateau"; Kathryn A. Schubel, Johns Hopkins University, for "Dolomite Microstructures and Reaction Mechanisms of Dolomitization: An Integrated TEM, Petrographic, Geochemical and Field Study of Selected Dolomite Bodies"; Kirk Stephens, Western Washington University, for "Mesozoic Tectonic History of the Tiefort Mountains, Northeastern Mojave Desert, California"; Eric A. Tenthorey, University of South Florida, for "The Effect of Ductile Deformation on the Kinetics and Mechanism of the Kyanite/Sillimanite Phase Transformation"; Glenn David Thrackray, University of Washington, for "Chronology of Alpine Glaciation on the Western Slope of the Olympic Mountains, Washington"; Xiaosong Wang, Case Western Reserve University, for "Mass Transport and Bioturbation in the Great Lake Sediments"; and Mei-fu Zhou, Dalhousie University, for "The Origin of Diamonds and Their Host Peridotites and Chromitites in Tibetan Ophiolites: A Mineralogical and Geochemical Study."

Other Successful Applicants. Other applicants recommended for funding are the following: Benjamin N.F. Adams, L. Barry Albright, John Alroy, Nuni-Lyn E.S. Anders, Brian G. Anderson, Andrew J. Bach, Eric M. Baer, Walter Barnhardt, Peter M. Blisniuk, Stefan S. Boettcher, Nevine Boghossian, Cheryl L. Brown, Madeline Jinx Bryant, Brenda J. Buck, Bradford R. Burton, Jay P. Busch, David C. Campbell, Lisa Marianne Campbell, Ben Castellana, Timothy L. Clarey, Frederick R. Coll, Erich Saxon Cowgill, Juliet G. Crider, Mary Katherine Crombie, James Selwyn Cureton, Brian S. Currie, Pauline Deutz, Donald Thomas Donley, Debra F. Dooley, Peter A. Drzewiecki, Jeffrey D. Edson, Scott A. Engel, Stephen Forrest, Richard Keith Fowlow, Bjarni Gautason, Martha L. Gerdes, Lisa M. Gerloff, Bosiljka Glumac, Matthew Lee Gorring, Richard F. Graham, Joe D. Gregson, D. Allen Gresham, Charles P. Hart, Steinunn Hauksdottir, David D. Hauth, Steven N. Hayden, Bradley Paul Hellickson, Jennifer Higgins, R. Forrest Hopson, Joseph Davis Hughes, Jonathan Icenhower, Bradley R. Ilg, Linda C. Ivany, Peter J. Jaumann, Mingming Jia, Kenneth Johnson, Linda Christine Kah, Alysa M. Keller, John F. King, Eric Kirby, Nami Elisabeth Kitchen, Andrew George Klein, Melissa (Lisa) Lamb, Rebecca Anne Lang, Elizabeth Large, Robert S. Leighty, Halard Lescinsky, Claudia J. Lewis, Hongqi Li, Ning Li, Xu Li, Joseph M. Licciardi, Jun Liu, Katherine Becker Long, J. Brian Mahoney, David Henry Malone, Natalia Malyk-Selivanova, Paul J. Markwick, L. Lynn Marquez, Jose Luis Masaferro, Joseph A. Mason, Jane Masterson, David Mayo, Kelli A. McCormick, Katie Joe McDonough, Steven B. McKnight, Michael Measures, William Meurer, Sarah Mock, Ann Molineux, Sven Soren Morgan, Malay Mukul, Thomas A. Okey, Kyeong Park, James C. Pickens, Donna Ann Porter, Cathy Ratcliff, Trent Alan Rehill, Susan S. Richards, Ruth A.J. Robinson, James W. Roche, Gregory T. Roselle, Julie A. Roska, Bruce F. Rueger, Janet L. Saltzman, Ken Saunders, Beverly Z. Saylor, Stephanic Jutta Schwabe, Parvinder Singh Sethi, Brian T. Sheldon, Robyn Kaye Skelton, Valerie F. Sloan, Alexei Smirnov, Langhorne B. Smith, Jr., Piyush Srivastav, Ann B. Stefani, Marc T. Syracuse, Jennifer R. Tegan, Friedrich Teichmann, Frank J. Tepley III, Caleb H. Thompson, Karen Thorbjornsen, Basil Tikoff, Alan Lee Titus, Sean M. Todaro, Frank J. Tokar, Jr., Paul B. Tomascak, Ashraf Uddin, David F. Ufnar, Dixon T. Van Hofwegen, Robert Joseph Viens, Timothy Andrew Warman, Darryl Keith Willis, Haiqing Wu, Xudong Ying, Xiaoming Zhai. ■

GSA ANNUAL MEETINGS

■ 1994

Seattle, at the leading edge

Seattle, Washington
Washington State
Convention and Trade Center
Seattle Sheraton Hotel
October 24–27

General Chairman: Darrel S. Cowan

Technical Program Chairman: Mark S. Ghiorso
Symposia and theme proposals due: January 3, 1994

Field Trip Chairman: Donald A. Swanson
Field trip proposal deadline was May 15, 1993; however, a few trips may still be accepted. Call today if you are interested in leading a trip. First draft of guidebook copy will be due January 1, 1994.

These chairmen are located at the Dept. of Geosciences, University of Washington, Seattle, WA 98195, (206) 243-1190, fax 206-543-3836. Proposals go directly to them.

For information call the GSA Meetings Department, 1-800-472-1988 or (303) 447-2020.

At the Leading Edge: 1994 Technical Program Theme

Geology *At the Leading Edge* will be the scientific theme of the 1994 GSA Annual Meeting in Seattle. The theme will draw emphasis both to the geographical position of Seattle, situated on the leading edge of a convergent plate margin, and to the application of "leading edge" theoretical approaches to and technological advances in the elucidation of geological problems. Theme sessions and symposium proposals are sought in all aspects of Pacific Rim and convergent margin geology, with particular emphasis on the utilization of new technology. The Seattle Program Committee will sponsor a GSA symposium titled "The Birth and Death of a Plate," which will include invited talks on topics such as arc volcanism, kinematics of plate motion, accretionary wedges, and evolution of ocean-ridge spreading centers. Speakers will illuminate these issues with results from remote sensing, geodesy, seismic imaging, experimental studies of geologic materials, and computational advances in modeling geologic systems. Theme sessions will have the option of being organized with more flexibility. One proposal is to lead off a theme session with an invited speaker who will review the subject of the theme and set the tone and organization of the abstracts in the remainder of the session. The Seattle Program Committee also proposes to have several less formal evening sessions aimed at bringing attendees up to date on new techniques such as GIS (Geographical Information Systems), GPS (Global Positioning System), and major nationally funded research projects such as the RIDGE initiative and the Continental Drilling Program. The 1994 GSA Annual Meeting in Seattle promises an exciting opportunity to discuss important geological questions in a nontraditional way. Plan to join us *At the Leading Edge.*

NEW NEW NEW

Call for Continuing Education Course Proposals

PROPOSALS DUE BY OCTOBER 1

The GSA Committee on Continuing Education (*formerly the Short Course Committee*) invites those interested in proposing a GSA-sponsored or cosponsored course or workshop to contact GSA headquarters for proposal guidelines.

Continuing Education courses may be conducted in conjunction with all GSA annual or section meetings. We are particularly interested in receiving proposals for the 1994 Seattle Annual Meeting OR 1995 New Orleans Annual Meeting.

NEW DEADLINE—Proposals must be received by **October 1, 1993.** Selection of courses for 1994 will be made by February 1, 1994. For those planning ahead, we will also consider courses for 1995 at that time.

For proposal guidelines or information contact:
Edna A. Collis, Continuing Education Coordinator,
GSA headquarters, 1-800-472-1988.

■ FUTURE

Boston	October 25–28	1993
Seattle	October 24–27	1994
New Orleans	November 6–9	1995
Denver	October 28–31	1996
Salt Lake City	October 20–23	1997

For general information on technical program participation (1993 or beyond) contact Sue Beggs, Meetings Manager, GSA headquarters.

Robert L. Fuchs

Heroy Fund To Benefit GSA Research Grants

William and Dorothy Heroy have established the Heroy Research Fund to support student research grants. Their gift of $50,000 was made to the Foundation's Pooled Income Fund. Under the terms of the PIF, the Heroys will receive income for their lives, following which the remainder interest will become part of the Foundation's endowment. Income from the gift will then be used annually for research grants.

Bill Heroy is a Trustee of the Foundation and has a long history of service to the Society. He served as GSA Treasurer from 1977 to 1982 and was a Councilor from 1968 to 1970. In addition, he has been a member of numerous GSA committees including Investment (20 years), Executive, Budget, Committees, and Audit. He was an Associate Editor for the GSA *Bulletin* for 11 years and also has undertaken numerous special tasks and assignments for the Society. He received the GSA Distinguished Service Award in 1990.

Other professional societies have benefited from Bill Heroy's advice, support, and leadership, including AAPG (treasurer) and AGI (treasurer, vice president, and president). He has been a member of SEG, SExG, AGU, and AIPG. In 1986 AGI awarded him the Ian Campbell Award.

After graduating from Dartmouth and receiving a Ph.D. in geology from Princeton, Bill Heroy went to work for Texaco as a geologist in 1941. He was subsequently employed by Geotech, becoming president of that company in 1961, and continuing in that role after Geotech was acquired by Teledyne. Heroy joined the faculty of Southern Methodist University in 1979, ultimately becoming vice president and treasurer of the university. He retains the title of Professor Emeritus.

In 1992 the Heroys moved to a retirement community in Durham, North Carolina, after many years in the Dallas, Texas, area. They thoroughly endorse their new life-style and recommend it to other senior GSA members. Commenting on their gift, Heroy said, "The GSA student research grants program has been a superb benefit for young geoscientists for over 60 years. We feel very fortunate to be able to provide future financial support to this program. The Foundation's Pooled Income Fund enabled us to do this without disrupting our retirement income."

Eaton Terrace Under Construction

Gordon P. Eaton and his wife Virginia have made a generous gift and pledge to the construction of the addition to GSA's Boulder headquarters. In recognition of this contribution, a terrace being constructed on the south side of the expanded building, with access from the new wing, will be named the Eaton Terrace. When completed this winter, the terrace will afford a dramatic view of the Rocky Mountains and the Flatirons, which rise abruptly on the west side of the city of Boulder.

Eaton is currently a GSA Councilor and is a Fellow of the Society. A nearly 40-year member, he has served on various GSA committees, was chairman of the Geophysics Division in 1979, and has been a publications and DNAG writer and editor. A graduate of Wesleyan University in 1951, Gordon Eaton received Master of Science and Ph.D. degrees in geology and geophysics from Cal Tech. From graduate school he returned to Wesleyan as an assistant professor and then held a position as associate professor at the University of California at Riverside. For 16 years he worked for the USGS in geophysics and geochemistry, including positions as scientist-in-charge at the Hawaiian Volcano Observatory and associate chief geologist in Reston, Virginia.

In 1981 Eaton returned to academia as dean of Texas A&M's College of Geosciences, later to become provost and vice president of the university. In 1986 he was chosen president of Iowa State University, a position he held until 1990, when he joined Lamont-Doherty Geological Observatory as Director.

When asked about their gift, the Eatons commented, "GSA is very fortunate to have built an architecturally fine and well sited structure in Colorado that has served as an effective headquarters for more than 20 years. The Society has nearly doubled in size during this period, and more space is acutely needed in the conduct of its business. We are very pleased to be involved with the capital project of an organization and a body of members with whom we have had a great many rewarding associations and experiences over a span of nearly four decades. We are especially pleased to have a close tie to the new wing, looking out as it does on mountains that we have loved for years and where, not far to the southwest, we have a seasonal home." ■

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Hydrogeology Lectures Gain in Popularity

Sandra Rush, GSA Public Information Consultant

Hydrogeologists in North America have an opportunity to benefit from the Birdsall Distinguished Lecture Series, established by GSA's Hydrogeology Division in November 1976. Each year an outstanding hydrogeologist is chosen to present research results as a Birdsall Distinguished Lecturer. Income from a bequest from John M. Birdsall, a ground-water geologist with the U.S. Geological Survey, along with other Hydrogeology Division income and contributions, covers the recipient's travel expenses to participating universities.

The term of the lectureship usually coincides with the academic year. The objective is to promote timely discussion of hydrogeologic topics as well as to provide the opportunity for university students to interact with well-known scientists. The initial intent was to visit a few universities a year, but the lectureship has received such acclaim that as many as 30 or 40 schools may request visits, according to Frank W. Schwartz, present chairman of the Hydrogeology Division and a 1984 Birdsall Lecturer.

Increased interest in environmental problems and awareness of the role hydrogeology plays in the resolution of these problems contribute to the popularity of the Birdsall Distinguished Lecture tour. In fact, the demand for such lectures is so great that other professional organizations are instituting series identical to those of the Birdsall Lecture Series.

In addition to the formal lectures, the Birdsall Lecturer also participates in informal discussions with students and faculty at the universities included in the lecture tour. "The diffusion of knowledge and understanding through these lectures has motivated scientists and stimulated students to advance the basic principles and application of the science of hydrogeology," says William Back, one of the first hydrogeologists honored as a Birdsall Lecturer, in 1979.

Each year, a three-member committee (the current and two previous lecturers) nominates the distinguished lecturer for the following year. The nomination is transmitted to the chair of the Hydrogeology Division for approval, and the award is conferred at the Hydrogeology Division awards ceremony during the GSA Annual Meeting. Traditionally, the Birdsall Lecturer of the preceding academic year presents a talk at the Annual Meeting.

The Birdsall Distinguished Lecturer for 1994 will be Fred M. Phillips of New Mexico Institute of Mining and Technology. For 1993 the lecturer was Donald I. Siegel, professor of geology at Syracuse University, who visited 27 institutions during the year. His most popular lecture was "Hydrogeology of Wetlands: Paradigm Lost." He comments that his audiences are sometimes surprised at the multidisciplinary bent of his lectures, which cover ecology, paleohydrology, ground-water studies, chemistry, and, of course, humor. He has been told by general geology students, "I never knew hydrogeologists did this kind of thing." Siegel feels that one of the contributions of his lectures is showing how "applied" and "pure" hydrogeology are actually the same thing on different scales, both involving critical thinking.

Shirley Dreiss, University of California at Santa Cruz, received the award in 1992, and she discovered that "the Birdsall Lectureship carries with it several benefits. One of these is the opportunity to get a snapshot view of hydrogeology programs across the continent. I was struck by the variety and vitality of the programs that I visited." In 1991, Robert Farvolden of the University of Waterloo in Ontario made four lecture trips during which he visited 23 cities and presented 27 lectures.

Each year, announcement of the award winner for that academic year is published in *The Hydrogeologist*, the newsletter of the Hydrogeology Division of GSA, along with topics to be part of the lecture series for that year. Institutions wishing to become part of the lecture tour should contact the lecturer directly and are expected to cover the local expenses incurred.

> ***"The Birdsall Lectureship carries with it several benefits. One of these is the opportunity to get a snapshot view of hydrogeology programs across the continent."***

John Manning Birdsall was a Fellow of the Geological Society of America and a retired geologist with the Water Resources Division of the U.S. Geological Survey at the time of his death in 1975. He was the donor of the Birdsall Bowl, which has been awarded each year since 1967 with GSA's O.E. Meinzer Award. Birdsall's will bequeathed $10,000 to the Hydrogeology Division, income from which is used to fund the Birdsall Distinguished Lecture Series. According to Back, Birdsall's friend and colleague, "I know that John would find it personally gratifying that he has continued to contribute to the fundamental development and understanding of ground-water principles after his death, as he did in life." ■

Fred Phillips To Be 1994 Birdsall Lecturer

Fred Phillips, Department of Geoscience, New Mexico Institute of Mining and Technology, Socorro, N.M., has been selected as the 16th Birdsall Distinguished Lecturer. Topics that Fred will include in his lecture series are: "Chlorine-36 in Fossil Rat Urine: A Key to the Chronology of Ground Water," "A Geological Approach to Characterizing Aquifer Heterogeneity," and "Ice-age Lakes and Glaciers: A History of the Hydrological Cycle." Abstracts will be given in the fall issue of *The Hydrogeologist*.

Contact Fred Phillips at (505) 835-5540, fax 505-835-6436, to schedule a visit during his tour, which begins in January 1994.

September *BULLETIN* and *GEOLOGY* Contents

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done by Kahle et al. (1967). However, in doing so, mathematical difficulties are encountered, as first elucidated by Roberts and Scott (1965) and Backus (1968). Under certain conditions, these difficulties may be at least partially circumvented (Voorhies and Backus, 1985; Backus and LeMouël, 1986; Lloyd and Gubbins, 1990; Jackson and Bloxham, 1991).

We seek the steady flow that best explains the secular variation. The rationale behind this is similar to that invoked earlier: the resolution of the core flow is uncertain, so a conservative approach is to seek first the steady part, because this should be the part that is best resolved. Figure 7 shows the steady flow for the period 1840–1990. This flow accounts for more than 98% of the variance of the secular variation. Note that westward flow is largely restricted to a region beneath the equatorial Atlantic Ocean, and there is no clear indication of westward drift elsewhere. The typical flow speed is about 15 km/yr or 0.5 mm/s. The flow is characterized by two large counter-rotating gyres, centered at mid-latitude in each hemisphere and at around 0° longitude. In Figure 7, the southern of the two gyres is more prominent. Beneath the Pacific, where secular variation is weak, the flow is also weak.

The flow is dominated by modes that are symmetric about the equator, the same flow symmetry mentioned above as necessary to preserve the symmetry of the steady part of the field. This is encouraging because not only does it simplify the development of dynamo models, but it also suggests that the deduced flow may indeed be indicative of the dynamo process in the core, rather than being merely some surface flow that bears little resemblance to the flow at depth in the core. An analogous problem exists in studying mantle convection: to what extent are surface plate motions indicative of the form of mantle convection? The motions at Earth's surface are obviously strongly influenced by rheological variations at the surface; similarly, core surface motions are influenced by conditions at the core surface. Among the many influences on core surface flow, lateral temperature variations in the mantle, which are most likely at least 10^4 times larger than those in the core (Stevenson, 1987), may be the most important. The effect of these mantle lateral temperature variations is to drive a thermal wind in the core (Bloxham and Gubbins, 1987; Bloxham and Jackson, 1990; Kohler and Stevenson, 1990). Although some evidence of this effect has been observed in the magnetic field (Bloxham and Gubbins, 1987), a challenge, in which some recent progress has been made by Zhang and Gubbins (1992), is to develop a more complete understanding of the interaction between this thermal wind and the underlying core convection.

Nonsteady Secular Variation

Because the steady part of the field accounts for over 80% of the variance of the field and steady flow accounts for over 95% of the remainder of the variance, only a very small proportion of the field model remains unexplained. Several arguments (Bloxham, 1992) suggest that this remaining signal is not entirely dominated by noise. This is remarkable because it suggests that the signal/noise ratio of the field maps is very much higher than might initially have been expected.

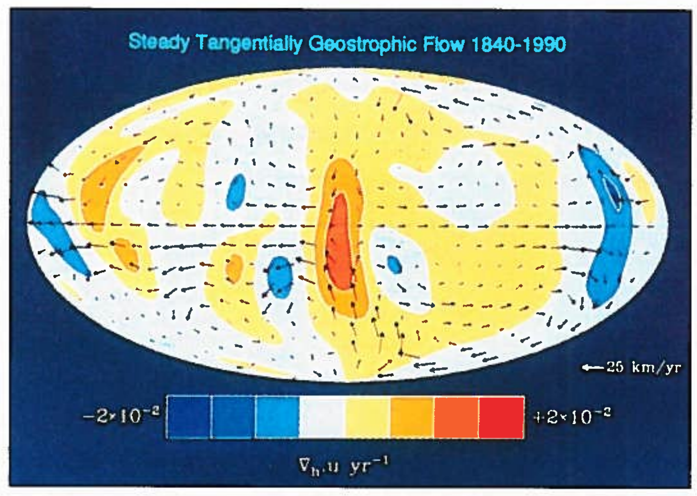
The strongest argument that the remaining signal is not entirely noise comes from the budget of angular momentum in the coupled core-mantle system. It has long been believed that, on the decadal time scale, variations in length of day (LOD) involve the exchange of angular momentum between the core and the mantle. The changes in angular momentum of the mantle are easily calculated from the LOD; the changes in angular momentum of the core require that we know, throughout the core, the time variations of those parts of the core flow that contribute to the axial angular momentum. Jault et al. (1988) have shown how these parts of the flow within the core can be estimated from the flow at the core surface. Although the assumptions that must be made about the core flow are quite strong (but not unrelated to the underlying dynamics) they found an encouraging agreement between the mantle and core changes in angular momentum over the period 1969–1985. Recently this has been corroborated over the longer time interval of 1840–1990 by Jackson et al. (1993) (see Fig. 8). This is an exciting result because it not only confirms the origin of decadal variations in the LOD, but it also provides an independent verification of the magnetic field and core surface flow models, because this agreement depends entirely upon this very small signal remaining after extracting the steady field and the steady secular variation.

Several interesting problems emerge from this study. First, magnetic signals from Earth's core are delayed on their passage through the mantle because of the electrical conductivity of the mantle. Some studies have suggested that this delay is as much as 13 years (Backus, 1983) or 18 years (Paulus and Stix, 1989). If this were the case, then we should see a lag, with the observed LOD leading the predictions based on the core flow; the lack of a discernible lag of this form in Figure 8 provides an upper bound on the electrical conductance of the mantle. In fact, before 1900 a lag of the opposite sign is discernible; the origin of this lag, which is noncausal, is being investigated. A second problem is to understand the mechanism of this angular momentum exchange. The necessary core-mantle coupling is not only of interest in explaining the LOD but is also of great importance in dynamo theory. A third problem is to examine whether this agreement in the LOD can be extended to shorter periods—say, a few years. At these periods changes in the LOD also arise from the exchange of angular momentum between the mantle and the atmosphere and oceans, raising the possibility of studying the response of the core to very long period coupled ocean-atmosphere oscillations.

Comments

The period for which it is possible to map the magnetic field at the core-mantle boundary is comparable in length to the advective time scale in the core. Although we can draw inferences about the operation of the dynamo, such as the role of core-mantle interactions and field symmetries, our conclusions must necessarily be guarded. The dynamo almost certainly evolves on a much slower diffusive time scale (perhaps as long as 15 ka), rather than on this fast advective time scale. To study the field on the diffusive time scale, we must resort to paleomagnetic observations. Such observations are too sparsely distributed to permit

Figure 7. Map of the steady part of the fluid flow at the core surface from Bloxham (1992). The flow is constrained to be tangentially geostrophic (LeMouël, 1984). The vectors show the speed and direction of the flow at the core surface, and the scale shows the intensity of horizontal divergence (upwelling and downwelling) of the flow.



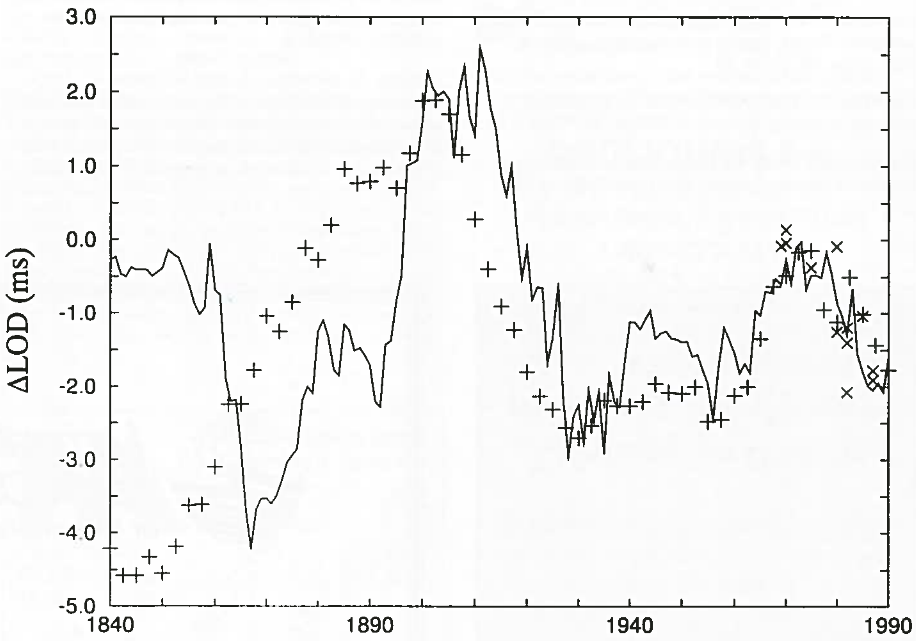


Figure 8. Comparison between the observed length of day (LOD; solid line) and the predictions based on models of the time-dependent part of the flow in the core. Plus-sign data are from Jackson et al. (1993); X-symbol data are from Jault et al. (1988).

field mapping of the sort described here, but they do provide a means of testing, over longer time scales, many of the suggestions I have described here.

Some significant progress has been made in this direction: Gubbins (1988) examined paleomagnetic data from the past 5 m.y. and found evidence of systematic departures from the axial dipole field consistent with the steady field configuration in Figure 3; Merrill and McFadden (1990) found evidence of the field symmetry property described above in the paleomagnetic secular variation; and, most recently, studies of geomagnetic reversals have indicated a tendency for the field during a reversal to exhibit aspects of the present-day field, notably a tendency for reversal paths to follow the longitude bands corresponding to the high-latitude flux concentrations identified in the recent core field (Clement, 1991; Laj et al., 1991; Constable, 1992). These are exciting results, which suggest that the historical field does provide an insight into the operation of the dynamo; furthermore, they suggest that aspects of the field morphology persist over time scales of millions of years, almost certainly the result of the influence of the mantle on convection in the core.

The highest priority in geomagnetism, though, is to ensure that this remarkable record of magnetic field observations is continued, preferably by further satellite missions. With continuous satellite monitoring, our ability to resolve both spatial and temporal detail in the field will improve dramatically, leading to greatly increased resolution of the time-dependent part of the flow and a more complete understanding of core-mantle interactions. Then we might at last be able to develop a working understanding of the dynamo. It is highly unfortunate that in the decade since Magsat our monitoring of the magnetic field has declined toward a level comparable to that of a century ago, and that the opportunity to build on the success of Magsat is slipping away.

ACKNOWLEDGMENTS

This work has been supported by the David and Lucille Packard Foundation, the National Science Foundation and the National Aeronautics and Space Administration (NASA).

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Field Mapper wanted for 3 to 6 months of full-time employment mapping at 1:24,000 scale in structurally complex areas of western Arizona that consist largely of Cenozoic volcanic rocks. Duties include preparation of maps and associated reports. Start in November or December, 1993. Send resume, references, and samples of past geologic maps to Personnel Division, Arizona Geological Survey #100, 845 N. Park Ave., Tucson, AZ 85719.

GEOLOGICAL ENGINEER

40 hr/wk. 7 a.m. to 3:30 p.m., $34,000/yr. Individual to evaluate & examine various rock excavations, do geological mapping of tunnels & shaft barrels. Provide preliminary recommendations on long-term stability measures, supervise the installation of rock reinforcement, evaluate groundwater inflow & make recommendations for grouting to control infiltration & assist in directing cement grouting work. Will assist in record keeping & report preparation, coordinate communcations among field personnel, render remedial geotechnical engineering to determine rock reinforcement. Supervise performance of contractors, monitor geotechnical engineering rendered by other contractors as field representative of employer.4 yrs college with a Bachelors Degree in Geological Engineering req. & 4 yrs exp. in job offered req. or 4 yrs. exp. as Geological or Geotechnical Engineer. Must have proof of legal authority to work permanently in the United States. Chicago, IL. No calls. Send resumes to: Illinois Department of Employment Security, 401 S. State Street-3 South, Chicago, IL 60605, Attn: Jean Woodson; Ref. # V-IL 6530-W, an employer paid ad.

U.S. REPRESENTATIVE TO JOIDES OFFICE

The JOI/U.S. Science Support Program is seeking applications for a 2-year position as the U.S. representative in the JOIDES scientific planning office, beginning October 1, 1994. The JOIDES office will be located at the University of Wales, Cardiff, in the U.K. The applicant will act as the executive assistant to the Chair of the JOIDES Planning Committee. The JOIDES executive assistant provides insight to the PCOM chair on how the drilling community outside the host country perceives and would respond to ODP related issues. Duties may include managing drilling proposals submitted to JOIDES, liaison to the Site Survey Panel, and assisting the PCOM chair in preparation of meeting agendas and agenda books.

A Ph.D. in earth sciences or related fields and previous involvement with the Ocean Drilling Program are desirable. Salary and benefits will be negotiated. Application letters must include vita and three references and should be sent to Dr. Ellen Kappel, Program Director, JOI/U.S. Science Support Program, JOI, 1755 Massachusetts Avenue, NW, Suite 800, Washington, DC 20036-2102. The application deadline is October 15, 1993. JOI is an equal opportunity employer.

GEOPHYSICIST

Applications are invited for a tenure-track assistant professor. Preference will be given to individuals with a strong background and interest in seismology, especially shallow seismic methods. A Ph.D. is required. The successful candidate will be expected to teach undergraduate and graduate courses and to develop a strong research program which involves both undergraduate and graduate students. Applicants should send résume, statements of teaching and research philosophy and interests, transcripts, and the names of three references to Nicholas H. Tibbs, Chairperson, Department of Geosciences, Southeast Missouri State University, Cape Girardeau, MO 63701. Screening of applications will begin October 1, 1993, and will continue until the position is filled. The position can be filled as early as January 1994, but candidates who prefer to begin in August 1994 will be given full consideration.

An equal opportunity/affirmative-action employer. Women and minorities are strongly encouraged to apply.

ASSISTANT PROFESSOR—SOIL PHYSICS

Emphasis on experimental field research including soil-water processes at ecosystem scales, field-scale investigation of water, solute, or energy fluxes, near-surface or vadose-zone studies of the physics of water, solute or energy cycling. This is a nine-month tenure-track position with opportunity for summer appointment. Salary and step within rank dependent on experience and qualifications. Teaching experience desirable; duties will include a lecture/laboratory course in soil physics and development of a graduate course in an area consistent with research interests. Shared responsibility for an undergraduate course in Environmental Physics is anticipated. Strong background in modern field research techniques and data analysis procedures for spatially-variable soil physical properties is required. Doctoral degree should be in a field appropriate for the research area. Position will be available July 1, 1994. Application dossier should consist of a curriculum vita, statements of research and teaching interests that are related to the program and teaching needs listed, copies of transcripts, and names and addresses of three references. Address applications to: Garrison Sposito, Chair Search Committee, Department of Environmental Science, Policy and Management, 108 Hilgard Hall, University of California, Berkeley, CA 94720. Review of applications will begin on October 1, 1993. The University of California is an Equal Opportunity Affirmative Action Employer.

Services & Supplies

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Out of Print Books and Periodicals on General Geology, Paleontology, Petroleum, Mining, Oceanography, Hydrology, Astronomy, Archaeology and related subjects. Catalog available upon request. The Hannum Company, Box 1505, Ardmore, OK 73402.

Fossil Books. We carry fossil collecting guidebooks for states of Ohio, Utah, Texas, Florida, Montana, etc. In fact, we now offer over 115 popular and professional books on paleontology. Catalog: $2.00 US/$3 Canada. No credit cards. Paleo Books & Prep. Supplies, P.O. Box 542-GS, Hot Springs, SD 57747. Tel. (605) 745-5446. Retail only!

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USGS Topo Maps Shipped Daily. Phone Or Fax SPEEDY TOPO SERVICE at (303) 499-0569, or write to 1705 14th St., #309, Boulder, CO80302.

Field Supplies: Binoculars, Scopes, Compasses, Transits. 1-800-545-4205. MONRADS, Box 576292, Modesto, CA 95357.

Opportunities for Students

Student Travel Grants. The GSA Foundation will award matching grants to each of the six GSA Sections to assist students wishing to travel to GSA Section and Annual meetings. For applications contact individual Section secretaries. For Section information, contact GSA (1-800-472-1988).

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

Consultants

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1993 GSA ANNUAL MEETING

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CHARGING INTO THE FUTURE

October 25–28, 1993
Boston, Massachusetts

Early morning at Jenny Farm, Reading, Vermont. Photo by Paul Corkum.

For Technical Program Information
see page 235 in this issue

For Registration and Housing Information
see the June issue of GSA Today

Preregistration Deadline: September 24

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