Vol. 10, No. 7 July 2000

GSA TODAY

A Publication of the Geological Society of America

INSIDE

Hydrothermal Systems: Doorways to Early Biosphere Evolution

Jack D. Farmer, *Department of Geology, Arizona State University, P.O. Box 871404, Tempe, AZ 85287, USA, jfarmer@asu.edu.*

ABSTRACT

Hydrothermal systems may have provided favorable environments for the prebiotic synthesis of organic compounds necessary for life and may also have been a site for life's origin. They could also have provided a refuge for thermophilic (heat-loving) microorganisms during late, giant-impact events. Phylogenetic information encoded in the genomes of extant thermophiles provides important clues about this early period of biosphere development that are broadly consistent with geological evidence for Archean environments. Hydrothermal environments often exhibit high rates of mineralization, which favors microbial fossilization. Thus, hydrothermal deposits are often rich storehouses of paleobiologic information. This is illustrated by studies of the microbial biosedimentology of hot springs in Yellowstone National Park that provide important constraints for interpreting the fossil record of thermophilic ecosystems. Hydrothermal processes appear to be inextricably linked to planetary formation and evolution and are likely to have existed on other bodies in the solar system. Such environments may have sustained an independent, extraterrestrial origin of life. Thus, hydrothermal systems and their deposits are considered primary targets in the search for fossil evidence of life elsewhere in the solar system.

Figure 1. Travertine thermal spring system at Angel Terrace, Mammoth Hot Springs, Yellowstone National Park, Wyoming.

INTRODUCTION

Hydrothermal systems develop anywhere in the crust where water coexists with a heat source. Hydrothermal systems were important in the differentiation and early evolution of Earth because they linked the global lithospheric, hydrologic, and atmospheric cycles of the elements (Des Marais, 1996). Over geologic time, volatile chemicals released by hydrothermal systems have contributed significantly to the evolution of the oceans and the atmosphere.

Most terrestrial hydrothermal systems are sustained by magmatic heat sources. Variations in the temperature (and density) of fluids drive convective circulation in the crust, producing large-scale transfers of energy and materials. As hot fluids move through the crust, they interact chemically with their host rocks, leaving behind distinctive geochemical, mineralogical, and biological signatures. The chemical precipitates of hydrothermal systems, called sinters, typically consist of simple mineral assemblages dominated by silica, carbonate, metallic sulfides and oxides, and clays. The mineralogy of hydrothermal deposits depends both on host rock composition and on the temperature, pH, and Eh of hydrothermal fluids.

This paper covers: (1) the importance of hydrothermal systems in the history of the biosphere, (2) the nature of biogeological information contained in hydrothermal deposits (e.g., travertine spring systems at Mammoth Hot Springs, Yellowstone National Park, Wyoming [Fig. 1]), and (3) hydrothermal systems as potential environments for prebiotic synthesis and biological evolution on other bodies in our solar system.

HYDROTHERMAL SYSTEMS AND EARLY BIOSPHERE EVOLUTION

Molecular phylogenies derived from comparisons of genetic sequences of living species have radically altered our view of the biosphere and of the contribution of microbial life to planetary

Hydrothermal Systems *continued on p. 2*

GSA TODAY July 2000
Vol. 10, No. 7

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

SUBSCRIPTIONS for 2000 calendar year: Society Members: *GSA Today* is provided as part of membership dues. Contact Membership Services at (888) 443-4472, (303) 447-2020 or member@geosociety.org for membership information. Nonmembers & Institutions: Free with paid subscription to both *GSA Bulletin* and *Geology,* otherwise $50 for U.S., Canada, and Mexico; $60 elsewhere. Contact Subscription Services. Single copies may be requested from Publication Sales. Also available on an annual CD-ROM, (together with *GSA Bulletin, Geology,* GSA Data Repository, and an Electronic Retrospective Index to journal articles from 1972); $89 to GSA Members, others call GSA Subscription Services for prices and details. Claims: For nonreceipt or for damaged copies, members contact Membership Services; all others contact Subscription Services. Claims are honored for one year; please allow sufficient delivery time for overseas copies, up to six months.

STAFF:
Chief Executive Officer: ***Sara S. Foland***
Science Editors: ***Karl E. Karlstrom,*** *Department of Earth and Planetary Science, University of New Mexico, Albuquerque, NM 87131-1116, kekl@unm.edu;* ***Molly F. Miller,*** *Department of Geology, Box 117-B, Vanderbilt University, Nashville, TN 37235, Molly.F.Miller@vanderbilt.edu*
Director of Publications: ***Peggy S. Lehr***
Managing Editor: ***Jeanette Hammann***
Editorial Assistant: ***Anika Burkard***
Production Manager: ***Diane C. Lorenz***
Production Coordinator: ***Gaynor Ann Bloom***
Graphics Production: ***Gaynor Ann Bloom***
Contact one of the Science Editors listed above before submitting a science paper.

ADVERTISING: Classifieds and display: contact Ann Crawford, (303) 447-2020; fax 303-447-1133; acrawford@geosociety.org.

Issues of this publication are available as electronic Acrobat files for free download from GSA's Web Site, http://www.geosociety.org. They can be viewed and printed on various personal computer operating systems: MSDOS, MSWindows, Macintosh, and Unix, using the appropriate Acrobat reader. Readers are available, free, from Adobe Corporation: http://www.adobe.com/acrobat/readstep.html.

GSA ONLINE: www.geosociety.org

This publication is included on GSA's annual CD-ROM, *GSA Journals on Compact Disc.* Call GSA Publication Sales for details.

Printed in U.S.A. using pure soy inks.

50% Total Recoverd Fiber
10% Postconsumer

IN THIS ISSUE

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

In Memoriam

Leroy E. Becker
Princeton, Illinois
July 15, 1999

Carlos Walter M. Campos
Rio de Janeiro, Brazil
February 18, 2000

Rollin Eckis
La Jolla, California
November 1999

John A. Forman
Goleta, California

Bernold M. Hanson
Midland, Texas
April 13, 2000

Harold L. James
Bellingham, Washington
April 2, 2000

William J. Morris
Battle Ground, Washington
January 2000

Kim R. Robeson
Logan, Utah

I. Gregory Sohn
Washington, D.C.

Rolfe S. Stanley
Fairfield, Virginia
February 15, 2000

Charles J. Vitaliano
Bloomington, Indiana
April 6, 2000

Robert A. Zimmermann
Englewood, Colorado
March 2000

Please contact the GSA Foundation for information on contributing to the Memorial Fund.

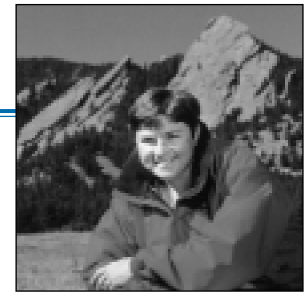
Hydrothermal Systems
continued from p. 1

biodiversity. By comparing genetic sequences in highly conserved molecules like ribosomal RNA, living species have been shown to cluster into three domains—the Archaea, the Bacteria, and the Eukarya (Fig. 2). When we look at the distribution of organisms within this "universal tree," exciting patterns emerge. The deepest branches (those nearest the common ancestor of all life) and the shortest branches (i.e., the most slowly evolving) of the domains Bacteria and Archaea are all populated by heat-loving species (hyperthermophiles) that only grow at temperatures >80 °C (Figure 2, red branches; see Woese, 1987; Stetter, 1996). The distribution of thermophiles suggests that hydrothermal systems may have been a "cradle" for early biosphere evolution. The most deeply branching thermophiles (i.e., most primitive) are all chemosynthetic organisms that use hydrogen and sulfur in their metabolism. Thus, both chemotrophy and thermophily are generally regarded as the most likely characteristics of the common ancestor of all life on our planet.

To date, only a small fraction (perhaps 1%–2%) of the total biodiversity on Earth has been sampled (Pace, 1997). However, the sampling of environments covered by the RNA tree is very broad and the three-domain structure of the RNA tree has only been strengthened with the addition of new taxa. The thermophilic

Dialogue

Sara Foland, CEO



© Paul Abdoo

> "A sound economy is a sound understanding brought into action: it is calculation realized; it is the doctrine of proportion reduced to practice; it is foreseeing consequences, and guarding against them; it is expecting contingencies and being prepared for them."
>
> *—Hannah More*

Stewardship of GSA Resources

Over the past several months, we've been examining GSA's core value of stewardship. So far we've looked at three different facets: GSA's stewardship of earth science information; the role of geoscientists as stewards of Earth itself; and stewardship as practiced by applied geologists. I'd like to wrap up by sharing with you a few thoughts on my role as steward of GSA's resources.

So Is This What the "CEO" Title Is All About?

When I arrived at GSA in May 1999, considerable buzz took place regarding my title. I think some feared GSA would turn into a corporate bureaucracy, insensitive to the needs and desires of its members and inappropriately obsessed with the bottom line. In fact, the title change from "Executive Director" to "Chief Executive Officer" was about taking more responsibility and maintaining a proactive relationship with GSA's Council. As GSA Treasurer David Dunn once noted, "I look forward to the day when Council can spend most of its time on policy issues, knowing that staff is, and will remain, fiscally prudent."

So as CEO, I was given full responsibility for operations, freeing the Council to spend more time on strategic thinking and planning for the organization. It's also my role to make sure that resources are available to implement the plans Council funds on members' behalf.

Balancing the Budget

My first, most urgent task was to pull GSA out of a deficit spending pattern that had existed since the early 1980s. Annual deficits ran, on average, from $500,000 to $600,000. This was due largely to a proliferation of programs in an environment with no strategic planning framework, no regular assessment of member needs and priorities, and no comprehensive budgeting process.

When I arrived at GSA, its projected year-end deficit was $1.5 million. At the end of the year, our actual deficit was $62,000 when adjusted for one-time inventory valuation and reorganization expenses. As of the end of first quarter 2000, GSA is operating in the black.

Stewardship of GSA's Endowment

An equally high priority was (and still is) ensuring the protection and growth of GSA's endowment, currently valued at $39.6 million. Under the leadership of Carel Ott and George Davis, GSA's Investment Committee made significant changes to our investment management practices. These improvements, coupled with a strong market, resulted in a 21.7 percent return on combined GSA and GSA Foundation assets. In fact, by year-end 1999, we had outperformed the Custom Index of not-for-profit organizations by 5.5 percent.

A Model That's Working

The next step was to balance portfolio growth with investment in GSA's core competencies, such as publications and meetings, and to ensure availability of funds for new programs. Now, we reinvest in the portfolio before any funds are spent, and we have three budgets that work together to ensure our resource needs are met and appropriately managed:

Operating. Within the authority of the CEO, with oversight by the Budget Committee, this encompasses all projects that are part of GSA's core business.

Capital. Within the authority of the CEO, with oversight by the Budget Committee, this encompasses non-routine maintenance, facility improvements, and new equipment for GSA's headquarters building in Boulder.

Strategic. Within the authority of the Programmatic Overview Committee and Council, this encompasses new projects funded from return on investments or from revenues from the GSA Foundation.

Nine outstanding business plans are currently under consideration for the 2001 Strategic Budget. Included among them are new Science, Education, and Outreach initiatives, online publications, electronic and online business capabilities, and globalization of GSA.

I'm confident these changes will prove to be beneficial for GSA over the long haul. That's what stewardship is all about. ■

---

character of the deep branches has also been widely embraced, although it has become clear that precise branching orders have been complicated by the transfer of genetic information between domains (Doolittle, 1998). Therefore, the properties of the common ancestor may undergo some revision as additional sequences are obtained from a broader range of environments.

Despite the uncertainties, the high-temperature nature and other properties of the common ancestor implied by the RNA tree are consistent with a wide variety of independent geological evidence, which indicates that hydrothermal, reducing environments were widespread on early Archean Earth. Theoretical calculations (Turcotte, 1980) indicate that crustal heat flows were much higher during the Archean and volcanism was more widespread. The restriction of komatiitic lavas (surface eruptions of high-temperature peridotite magmas) to primarily Archean terranes indicates that average crustal temperatures must have been much higher at that time. This view is also supported by trends in oxygen isotope abundances for well-preserved siliceous sediments (cherts) that suggest a steady decline in average surface (climatic) temperature from early Archean highs of 50–70 °C, to present values (Knauth and Lowe, 1978).

On early Earth, hydrothermal systems could also have been created by large asteroid or comet impacts. The lunar cratering record suggests that following an initial period of heavy bombardment, which lasted from ~4.6 to 3.8 Ga, both impactor size and flux declined dramatically (Maher and Stevenson, 1988). Theoretical considerations suggest that the stable atmosphere and oceans necessary for life's origin would have been possible only after ~4.4 Ga and that life could have been established on Earth by ~4.2 Ga (Chang, 1994; Zahnle et al., 1988).

Hydrothermal systems may also have been a primary site for life's origin. Thermodynamic calculations for hydrothermal environments suggest that a variety of complex organic compounds (potential precursor molecules for living systems) are synthesized at high temperatures (Shulte

Hydrothermal Systems *continued on p. 4*

Hydrothermal Systems
continued from p. 3

and Shock, 1995). Recent experimental work (Voglesonger et al., 1999) has demonstrated the synthesis of alcohols under simulated black smoker conditions, lending support to thermodynamic arguments for the role of hydrothermal systems in prebiotic organic synthesis.

As mentioned above, the origin of life appears to have overlapped with the end of heavy bombardment. Early biosphere development could have been frustrated by one or more late, giant impacts which would have disrupted early habitats, possibly extinguishing all surface life. For example, models indicate that a giant impact of ~500 km diameter would create a transient atmosphere of molten rock vapor that would evaporate the oceans over a period of months (see Chang, 1994). This would produce a steam atmosphere that would rain out over a period of a few thousand years, eventually restoring the oceans (Zahnle et al., 1988). Such high-temperature events could eliminate most, if not all, surface life, allowing only hyperthermophilic (primarily subsurface chemotrophic) species to persist.

If this scenario is true, then the thermophilic nature implied for the common ancestor of life could be simply a legacy of one or more late giant impacts that occurred during late bombardment (Gogarten-Boekel et al., 1995). Impact flux models suggest the last such events could have occurred as late as ~3.9 Ga, the age of the Imbrium Basin on the Moon and the approximate age of the oldest preserved metasedimentary sequences on Earth (Isua Supergroup, Akilia Island, Greenland), dated at >3.85 Ga (Nutman et al., 1997). These same sequences are purported to contain the oldest fossil biosignatures on Earth, chemofossils characterized by light (biologically fractionated?) carbon isotope signatures preserved in iron-rich metasedimentary rocks (Mojzsis et al., 1996; Mojzsis and Harrison, 2000). The geological events outlined above are broadly consistent with basic branching patterns observed in the RNA tree.

The root of the RNA tree is generally placed at the midpoint of the long branch that separates the Bacteria from the Archaea (Fig. 2). As noted previously, the deep basal branches are occupied by hyperthermophilic species that exhibit chemotrophic strategies based on hydrogen and sulfur. In contrast, photosynthesis, the surface metabolic strategy that supports most of the productivity on Earth today, apparently originated within the sulfur bacteria (anoxygenic photoautotrophs; Fig. 2). Oxygenic photosynthesis, an event of singular importance in the history of the biosphere, first appeared in the cyanobacteria and was later transferred to plants (domain Eukarya) through the development of endosymbiotic associations with that group (Fig. 2; Margulis and Chapman, 1998). Deposition of the banded iron formations, a proxy for the buildup of oxygen in the oceans, peaked around 2.5 Ga, at which time Earth's surface environment began to undergo a dramatic changeover to the highly oxidizing conditions that prevail today (Des Marais, 1997).

PALEOBIOLOGY OF THERMAL SPRINGS

Studies of ancient hydrothermal systems can provide important constraints for reconstructing the evolutionary history of thermophilic ecosystems on Earth (Walter, 1996). Comparative studies of the geochemistry, microbial biosedimentology, and fossilization processes in modern thermal spring systems (see Cady and Farmer, 1996) have provided a basis for constructing facies frameworks (e.g., Farmer and Des Marais, 1992), which have utility for interpreting the paleobiology of ancient deposits (e.g., Walter et al., 1996, 1998). Such studies also hold importance for refining our strategies to explore for signatures of life or prebiotic chemistry on other bodies in the solar system, as well as providing more robust criteria for recognizing biogenic features in ancient terrestrial and extraterrestrial materials (Farmer, 1995).

We have studied active travertine (carbonate-precipitating) thermal springs located at Angel Terrace, Mammoth Hot Springs, Yellowstone National Park, Wyoming (Bargar and Muffler, 1975; Farmer and Des Marais, 1994; Fouke et al., 2000). The following highlights three microfacies within this system that represent major differences in mineralogy, in community composition and style of microbial mat development, in stromatolite morphogenesis, and in sedimentary fabrics. Trends in the composition of microbiotas along thermal gradients (from high to low temperature), broadly mirror the inferred sequence of evolutionary events implied by the RNA tree for the global biosphere (cf. Figs. 2 and 4).

VENT MICROFACIES

Angel Terrace is a sulfide spring system (Castenholz, 1977) with vent temperatures and pH values of ~74 °C and ~6.7, respectively (Farmer and Des Marais, 1994). On Angel Terrace, vents exhibit both a high rate of discharge (~75–100 cm/s) and a rapid rate of carbonate (aragonite) precipitation (~35 cm/yr; Farmer and Des Marais, 1994). Vents and proximal channels (Figs. 3A and 3B) are dominated by filamentous sulfide and hydrogen-oxidizing species (Fig. 3B) that comprise the group Aquificales (Anna Louise Reysenbach, 1999, personal commun.). The Aquificales group (represented by *Aquifex* in Fig. 2) presently represents the deepest branch in the RNA tree. In shallow channels where flow rates are high, *Aquifex* mats form bacterial "streamers" (Fig. 3B) that become encrusted, forming characteristic sinter fabrics that preserve original

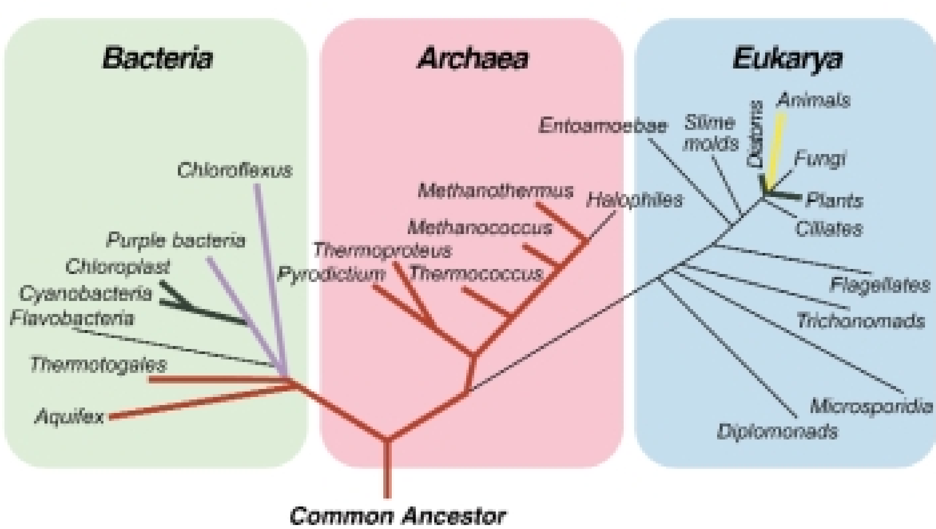


Figure 2. Universal phylogenetic tree based on comparative sequence data from 16S or 18S ribosomal RNA (modified from Madigan et al., 1997). Colors highlight three domains of life (Archaea, Bacteria, and Eukarya). Evolutionary distances between groups are proportional to branch length (from tip to branch node). Hyperthermophilic species (those that only grow at >80 °C) are represented by red. Anoxygenic photosynthetic species are lavender. Oxygenic photosynthetic species are green. Note that chloroplasts group with cyanobacteria, indicating that genes for oxygenic photosynthesis were transferred to Eukarya through development of endosymbioses with cyanobacteria.

flow orientations. These fabrics are retained during the recystallization of aragonite to calcite. Remarkably similar bacterial streamers have been described from ancient siliceous thermal spring sinters in the Carboniferous Drummond Basin of northeast Queensland, Australia (Walter et al., 1996, 1998).

MID-TEMPERATURE POOLS

The floors of mid-temperature (45–60 °C) ponds on Angel Terrace (Fig. 3C), are covered by centimeter-thick photosynthetic mats (Fig. 3D). These mats are dominated by a number of cyanobacterial form taxa (Farmer and Des Marais, 1994), including species of *Spirulina, Oscillatoria, Synechococcus,* and the green sulfur bacterium *Chloroflexus,* an anoxygenic photoautotroph (see Fig. 2). In this part of the system, flow rates are much lower (~10 cm/s), as are rates of aragonite precipitation (~5 cm/yr). Light-induced gliding of the filamentous cyanobacteria produces a variety of tufted (coniform) and ridged mat structures (Fig. 3D). Collectively, mat species produce a dense, gelatinous slime (exopolymer) matrix that entraps bubbles of photosynthetic oxygen and other gases, forming "lift-off" structures (Fig. 3D). These features eventually become mineralized to form distinctive associations of fabrics and microtextures that survive recrystallization to calcite. Much of the aragonite precipitation at mid-temperatures occurs just beneath the mat surface where pH is elevated during photosynthesis, favoring carbonate precipitation (Farmer and Des Marais, 1994).

DISTAL SLOPE ENVIRONMENTS

On the distal slopes of Angel Terrace (Fig. 3E), lying below the mid-terrace ponds discussed above are shallow (centimeter deep) terracette ponds (Fig. 3F) that are characterized by slow flow rates (<50 cm/s) and low rates of carbonate precipitation (<2 cm/yr). Temperatures are also low, falling in the range, ~40–15 °C. The microbial communities of these distal slope environments comprise a diverse association of microorganisms, including many species of diatoms and other representatives of the Eukarya, as well as grazing insects and protozoans. At the lowest temperatures, small enclaves of higher plants also survive on distal slopes (Fig. 3E). The filamentous cyanobacteria present include species of *Spirulina* and *Calothrix,* the latter characterized by heavy exopolymer sheaths that are relatively resistant to degradation. The primary precipitate in this part of the system is calcite, which tends to nucleate on organic surfaces, eventually forming small spherulites of calcite that accrete as they are rolled downslope along the floors of shallow channels (Fig. 3F). As the spherulites grow, they entomb cyanobacterial sheaths, epiphytic diatoms, and other attached organisms, which are often seen in thin sections of spherulites.

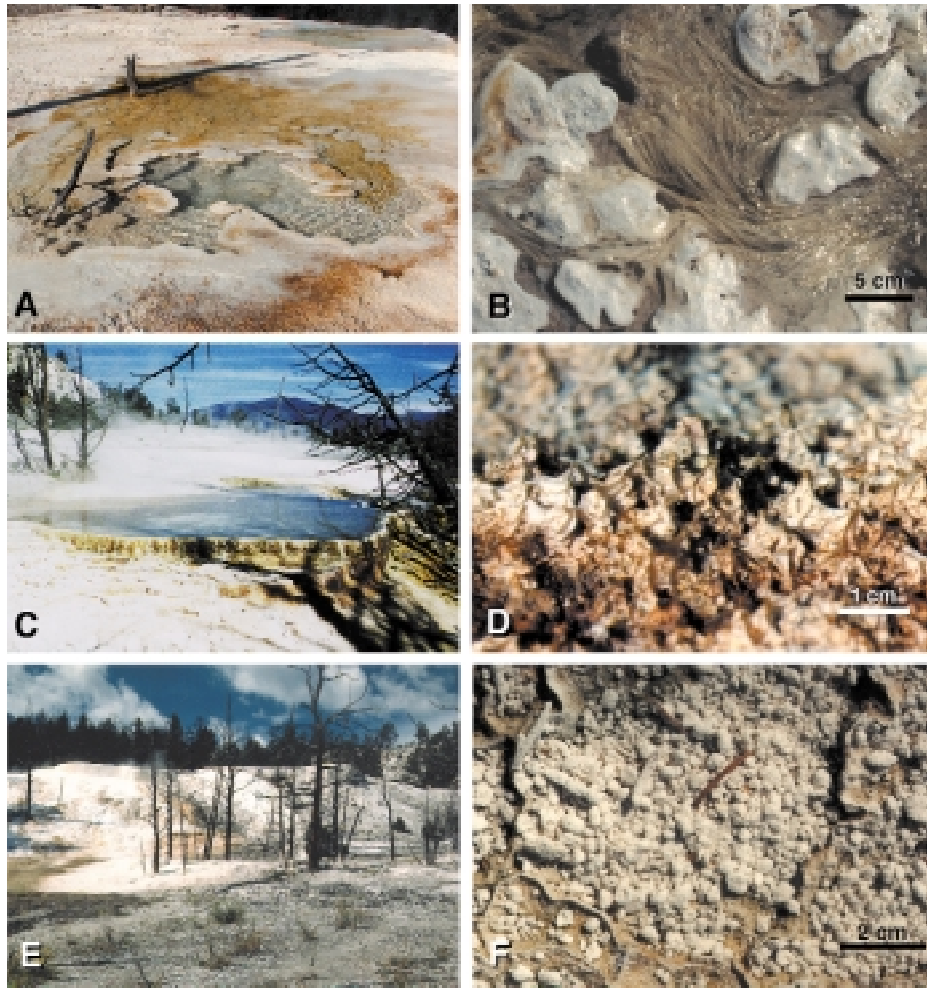


Figure 3. Microbial mats and microenvironments found at Angel Terrace. A. Sulfide vent that formed on south end of Angel Terrace in 1993. Vent temperature was ~73 °C and pH ~6.4. Orange colors along edges of vent are cyanobacterial communities living on and within drying sinter. B. Dominant mat-forming microorganism covering vent walls and channel floors is filamentous form that is genetically related to *Aquifex* (Anna Louise Reysenbach, 1999, personal commun.). *Aquifex* forms streamers in channels that become oriented by the flow. Bacterial streamers are eventually encrusted by aragonite, preserving original flow directions in sinter fabric. C. Large mid-temperature pond formed on Angel Terrace in 1996. Near upstream end of pond, temperature was ~65 °C (pH ~7). Floor of pool was covered by cm-scale aragonite shrubs (not shown). At temperatures up to and including 73 °C, thin biofilms of unicellular cyanobacteria *(Synechococcus)* covered surfaces of shrubs, tinting them yellow-orange. At downstream edge of pond, pool temperature was ~45 °C (pH ~8) and floor was covered by centimeter-thick coniform cyanobacterial mats (Fig. 3D). D. Coniform photosynthetic mats dominated by cyanobacterial taxa, including *Spirulina, Phormidium, Synechococcus,* and several unidentified oscillatoriceans. Also present is *Chloroflexus,* an anoxygenic photosynthesizer. Basic mat structure consists of cone-shaped peaks and networks of ridges formed by phototactic (light-induced) gliding of cyanobacteria. Some cones have bulbous enlargements at their tops where mat had entrapped gases (primarily photosynthetic oxygen). Tufted mat structure is faithfully replicated in microtexture of associated sinters. E. Distal slope environment at base of Angel Terrace, Mammoth Hot Springs, Yellowstone National Park, Wyoming (view looking west) (Fouke et al, 2000). Persistent thermal activity had killed most of the trees in this area. F. View of floor of shallow (<cm deep) terracette pond covered by spherulites of calcite. Spherulites typically form by nucleation of carbonate on organic material and continue to accrete as they are transported (rolled) downslope.

FACIES MODEL FOR TRAVERTINE THERMAL SPRINGS

Observations of modern springs at Angel Terrace were used to construct the integrated biofacies and lithofacies model shown in Figure 4. The model is organized around systematic variations in temperature, pH, and flow rates typically observed along spring outflows in the Mammoth Hot Springs area. Such facies frameworks are useful tools for reconstructing the paleobiology of ancient sinter deposits. We have recently extended this model to include important aspects of aqueous and

Hydrothermal Systems *continued on p. 6*

Hydrothermal Systems
continued from p. 5

solid-phase geochemistry, documenting systematic trends in oxygen and carbon isotopes, and elemental abundances along spring outflows (Fouke et al., 2000). Systematic variations in carbon and oxygen isotope abundances with declining temperature were entirely accounted for by CO_2 outgassing and evaporation, with no evidence of significant biological fractionation, even where mats were well developed (Fouke et al., 2000). This result emphasizes the importance of textural information in reconstructing the paleobiology of ancient subaerial sinters.

HYDROTHERMAL PROSPECTING ELSEWHERE IN THE SOLAR SYSTEM

Because subsurface fluids and crustal heat sources could have also coexisted on other planetary bodies in the solar system, hydrothermal deposits are also important targets for planetary exploration and the search for extraterrestrial life. Potential targets for hydrothermal systems include active vents on the floor of a putative subsurface ocean on Europa (Reynolds et al., 1983) and possibly other icy satellites in the outer solar system (Pendleton and Farmer, 1997). Results from the Galileo mission have significantly advanced our understanding of Europa, providing support for a substantial subcrustal ocean maintained by tidal frictional heating of the Moon's interior. Given the potential for abundant water, a sustained heat source, and reduced compounds, hydrothermal systems on Europa could provide long-term habitats for chemotrophic microbial ecosystems similar to those found in deep-sea vent environments on Earth (Pappalardo et al., 1999).

Hydrothermal systems may also have been important during the early history of the dark asteroids (Cronin et al., 1988), which are considered the most likely parent bodies for carbonaceous (C-1) chondrites. These meteorites show evidence of extensive aqueous alteration of minerals over a temperature range of 50–100 °C. The Murchison meteorite, perhaps our best studied carbonaceous meteorite, contains a diverse assemblage of biologically important amino acids (Cronin, 1989) that were apparently synthesized on the meteorite parent body during an early, transient hydrothermal phase (Oro and Mills, 1989). Along with comets, carbonaceous meteorites are believed to have contributed significantly to the early inventory of prebiotic organic compounds needed for the origin of life (Chyba and Sagan, 1992).

Hydrothermal environments also appear to have been widespread on Mars early in the planet's history (Farmer, 1996, 1998). Siliceous thermal spring deposits have been cited as important targets in the search for evidence of an ancient biosphere on Mars (Walter and Des Marais, 1993; Cady and Farmer, 1996). Based on our studies of terrestrial analogs, the discovery of ancient hydrothermal systems on Mars would provide access to: (1) localized environments capable of sustaining high rates of microbial productivity, and (2) high rates of mineralization (chemical precipitation), favorable for capturing and preserving microbial biosignatures. Thus, hydrothermal deposits are considered high-priority targets in the exploration for a Martian fossil record (Farmer and Des Marais, 1999).

Although active surface hydrological systems appear to have largely disappeared on Mars after ~3.5 Ga, models suggest that a global groundwater system could still be present on Mars today (Clifford, 1993; Carr, 1996). This view is supported by the

Engaging "My Neighbor" in the Issue of Sustainability Part VII: Spaceship Earth: There Is No Place Else to Go

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

Space travel has stirred our imaginations for more than a century and inspired not only writers of science fiction and "trekkies," but also the scientists and engineers of space agencies worldwide. At frequent intervals, presentations in various media speculate about human travel far beyond the international space station to other planets in our solar system in the not-too-distant future. To some people, this could solve Earth's population problem because they believe we will be able to emigrate to other worlds when push comes to shove. Space travel may be the special privilege of a few adventurous astronauts, but as a solution to our earthly problems, there is need for a reality check.

Let's start with a trip to the Moon and a look back to our blue planet—a spectacular view now common on many advertising pages. But look elsewhere in the universe. Nothing else that we see looks any bigger than it did from Earth. Planets are still points of light, as are the stars and galaxies. We are a long way from even our nearest planetary neighbor!

And then there's simple math. Earth's current population (about six billion) is increasing by about 1% annually. The U.S. Census Bureau projects that by 2050 there will be a somewhat smaller rate of increase of 0.46%, and a probable median population of nearly nine billion people. The ANNUAL population increase in 2050 (9 billion × .0046) will be an estimated 41.5 million persons, down from the present annual increase of about 60 million. On a DAILY basis (41.5 million ÷ 365), population increase in 2050 will be about 115,000 persons, down from the present DAILY increase of about 170,000 persons. Daily permanent emigration of that many people, even given possible technological advances in space vehicles and propulsion by 2050, might be a bit optimistic.

For all practical purposes, we must internalize and make plans for "Spaceship Earth" as the only realistic habitation for humans. Bringing human occupancy of this planet into balance with available ecological areas and terrestrial and oceanic resources must be one of our highest priorities if we wish a sustainable future for our descendants.

Note: This series of essays, with some enhancements for teachers, is now available through a link on GSA's Web site, www.geosociety.org. From either Public Interest or the "Related Links" area of Geoscience Initiatives, click "Sustainability" then "Toward a Stewardship of the Global Commons." ■

---

presence of large outflow channels in some younger Martian terranes formed during catastrophic releases of groundwater (Baker, 1982). Many Martian outflow channels originate within chaos terranes, collapse features thought to have formed by melting of the shallow cryosphere. Some chaos features show clear associations with potential magmatic heat sources (e.g., chaos at the base of Apollonaris Patera in Figure 5) that could have sustained hydrothermal systems for prolonged periods (Farmer, 1996).

The thermal emission spectrometer is a mid-infrared mapping spectrometer presently in orbit around Mars. The spectrometer recently detected a large deposit of coarse-grained (specular) hematite at Sinus Meridiani (Christensen et al., 2000). On Earth such deposits normally form by aqueous precipitation at elevated temperatures. This discovery lends credibility to the idea that hydrothermal systems were once active in shallow crustal environments on Mars.

CONCLUSIONS

Hydrothermal systems appear to have played a fundamental role in the early evolution of Earth and in the endogenous synthesis of prebiotic organic compounds that were the basic building blocks for life. The phylogenetic information encoded in the genomes of extant thermophilic species appears to provide important clues about early biosphere evolution and the processes that shaped its history. In addition to providing a potential site for life's origin, hydrothermal environments may also have been a refuge for thermophilic organisms during the late, giant-impact events that overlapped with early biosphere evolution. Hydrothermal environments typically sustain high rates of inorganic mineral precipitation favorable for capturing and preserving a microbial fossil record and integrated studies of the microbial biosedimentology, paleontology, and geochemistry of modern and ancient hydrothermal deposits provide important constraints for interpreting the fossils of thermophilic ecosystems. Hydrothermal systems are considered primary targets in the exploration for prebiotic chemistry and life on other bodies in the solar system (e.g., Mars, Europa, and dark asteroids) and could have provided cradles for the emergence of life in other planetary systems within our galaxy, and beyond.

ACKNOWLEDGMENTS

Work on hydrothermal systems was supported by grants from the NASA Astrobiology Institute and the NASA Exobiology Program. I thank Dave Des Marais (NASA Ames), Malcolm Walter (Macquarie University, Sydney), Bruce Fouke (University of Illinois), Laurie Leshin (Arizona State University), and Norman Pace (University of Colorado) for informative discussions, and Steve Mojzsis (University of California, Los Angeles) and Horton Newsome (University of New Mexico) for valuable reviews of the manuscript. I also thank Sue Selkirk and Maria Farmer (both from Arizona State University) for technical assistance in preparing the figures.

REFERENCES CITED

Baker, V.R., 1982, The channels of Mars: Austin, Texas, University of Texas Press, 198 p.

Bargar, K.E., and Muffler, L.P.J., 1975, Geologic map of the travertine deposits, Mammoth Hot Springs, Yellowstone National Park, Wyoming: U.S. Geological Survey, Miscellaneous Field Studies Map MF-659, 1:62,500 and 1:4,800 scales (sheet 1), 1:2,400 scale (sheet 2).

Cady, S.L., and Farmer, J.D., 1996, Fossilization processes in siliceous thermal springs: Trends in preservation along thermal gradients, *in* Bock, G., and Goode,

Hydrothermal Systems *continued on p. 8*

Hydrothermal Systems
continued from p. 7

J., eds., Evolution of hydrothermal ecosystems on Earth (and Mars?): New York, John Wiley & Sons, p. 150–173.

Carr, M.H., 1996, Water on Mars: London, Oxford University Press.

Castenholz, R.W., 1977, The effect of sulfide on blue-green algae of hot-springs II: Yellowstone National Park: Microbial Ecology, v. 3, p. 79–105.

Chang, S., 1994, The planetary setting of prebiotic evolution, *in* Bengston, S., ed., Early life on Earth, Nobel Symposium No. 84: New York, Columbia University Press, p. 10–23.

Christensen, P.R., Clark, R.L., Kieffer, H.H., Malin, M.C., Pearl, J.C., Banfield, J.L., Edgett, K.S., Hamilton, V.E., Hoefen, T., Lane, M.D., Morris, R.V., Pearson, R., Rousch, T., Ruff, S.W., and Smith, M.D., 2000, Detection of crystalline hematite mineralization on Mars by the thermal emission spectrometer: Evidence for near-surface water: Journal of Geophysical Research, v. 105, p. 9623–9642.

Chyba, C.F., and Sagan, C., 1992, Endogenous production, exogenous delivery and impact-shock synthesis of organic molecules: An inventory for the origins of life: Nature, v. 355, p. 125–131.

Clifford, S.M., 1993, A model for the hydrologic and climatic behavior of water on Mars: Journal of Geophysical Research, v. 88, p. 2456–2474.

Cronin, J.R., 1989, Origin of organic compounds in carbonaceous chondrites: Advances in Space Research, v. 9, p. 54–64.

Cronin, J.R., Pizzarello, S., and Cruikshank, D.P., 1988, Organic matter in carbonaceous chondrites, planetary satellites, asteroids and comets, *in* Kerridge, J.F., and Matthews, M.S., eds., Meteorites and the early solar system: Tucson, University of Arizona Press, p. 819–857.

Des Marais, D.J., 1997, Long-term evolution of the biogeochemical carbon cycle, *in* Bandfield, J.F., and Nealson, K.H., eds., Geomicrobiology: Interactions between microbes and minerals: Reviews in Minerology, v. 35, p. 429–448.

Des Marais, D.J., 1996, Stable light isotope biogeochemistry of hydrothermal systems, *in* Bock, G., and Goode, J., eds., Evolution of hydrothermal ecosystems on Earth (and Mars?): New York, John Wiley & Sons, p. 83–93, 273–299.

Doolittle, R.F., 1998, Microbial genomes opened up: Nature, v. 392, p. 339–342.

Farmer, J.D., 1998, Thermophiles, early biosphere evolution and the origin of life on Earth: Implications for the exobiological exploration of Mars: Journal of Geophysical Research, v. 103, p. 28,457–28,461.

Farmer, J.D., 1996, Hydrothermal processes on Mars: An assessment of present evidence, *in* Bock, G., and Goode, J., eds., Evolution of hydrothermal ecosystems on Earth (and Mars?): New York, John Wiley & Sons, p. 273–299.

Farmer, J.D., 1995, Mars exopaleontology: Palaios, v. 10, p. 197–198.

Farmer, J.D., and Des Marais, D.J., 1999, Exploring for a record of ancient Martian life: Journal of Geophysical Research, v. 104, p. 26,977–26,995.

Farmer, J.D., and Des Marais, D.J., 1994, Biological versus inorganic processes in stromatolite morphogenesis: Observations from mineralizing systems, *in* Stal, L.J., and Caumette, P., eds., Microbial mats: Structure, development and environmental significance: Berlin, Springer-Verlag, p. 61–68.

Farmer, J.D., and Des Marais, D.J., 1992, Comparative biosedimentology of some terraced travertine deposits: Geological Society of America Abstracts with Programs, v. 24, no. 7, p. 53–54.

Fouke, B.W., Farmer, J.D., Des Marais, D.J., Pratt, L., Sturcio, N.C., Burns, P.C., and Discipulo, M.K., 2000, Depositional facies and aqueous-solid geochemistry of travertine-depositing hot-springs (Angel Terrace, Mammoth Hot Springs, Yellowstone National Park, U.S.A.): Journal of Sedimentary Research, v. 70, p. 565–585.

Gogarten-Boekel, M., Hilario, H., and Gogarten, J.P., 1995, The effects of heavy meteorite bombardment on early evolution—The emergence of the three domains of life: Origins of Life and Evolution of the Biosphere, v. 25, p. 251–264.

Knauth, L.P., and Lowe, D.R., 1978, Oxygen isotope geochemistry of cherts from the Onverwacht Group (3.4 billion years), Transvaal, South Africa with implications for secular variations in the isotopic compositions of cherts: Earth and Planetary Science Letters, v. 41, p. 209–222.

Madigan, M.T., Martinko, J.M., and Parker, J., 1997, Brock biology of microorganisms, 8th edition: New Jersey, Prentice-Hall.

Maher, K.A., and Stevenson, D.J., 1988, Impact frustration of the origin of life: Nature, v. 331, p. 612–614.

Margulis, L., and Chapman, M.J., 1998, Endosymbioses: Cyclical and permanent in evolution: Trends in Microbiology, v. 6, p. 342–345.

Mojzsis, S.J., and Harrison, T.M., 2000, Vestiges of a beginning: Clues to the emergent biosphere recorded in the oldest known sedimentary rocks: GSA Today, v. 10, no. 4, p. 1–6.

Mojzsis, S.J., Arrhenius, G., McKeegan, K.D., Harrison, T.M., Nutman, A.P., and Friend, C.R.L., 1996, Evidence for life on Earth before 3,800 million years ago: Nature, v. 384, p. 55–59.

Nutman, A.P., Mojzsis, S.J., and Friend, C.R.L., 1997, Recognition of >3,850 Ma water-lain sediments and their significance for the early Archean Earth: Geochimica et Cosmochimica Acta, v. 61, p. 2475–2484.

Oro, J., and Mills, T.V., 1989, Chemical evolution of primitive solar system bodies: Advances in Space Research, v. 9, p. 105–120.

Pace, N.R., 1997, A molecular view of microbial diversity and the biosphere: Science, v. 276, p. 734–740.

Pappalardo, R.T., Head, J.W., and Greeley, R., 1999, The hidden ocean of Europa: Scientific American, v. 281, no. 10, p. 34–43.

Pendleton, Y., and Farmer, J.D., 1997, Life: A cosmic imperative?: Sky and Telescope, v. 94, p. 42–47.

Reynolds, R.T., Squyres, S.W., Colburn, D.S., and McKay, C.P., 1983, On the habitability of Europa: Icarus, v. 56, p. 246–254.

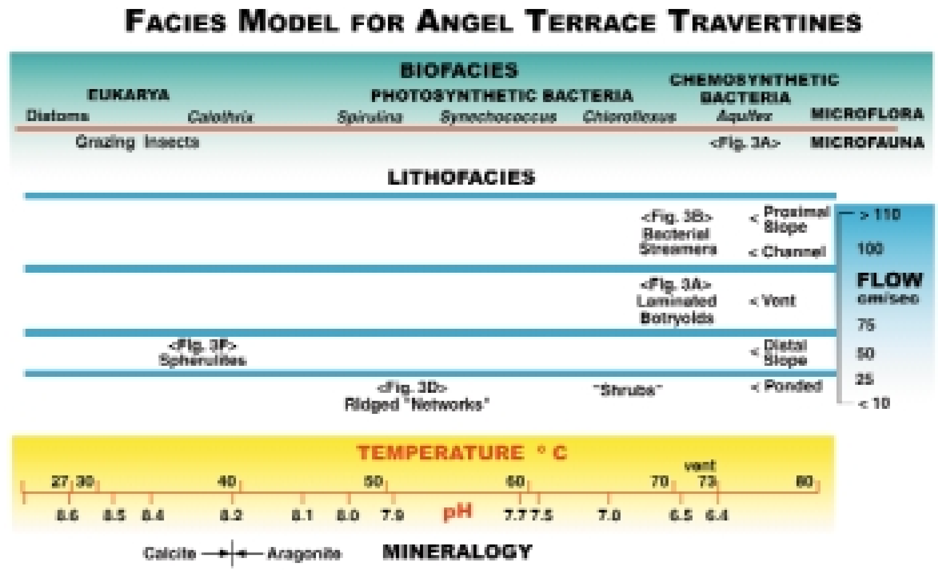


Figure 4. Simplified facies model for travertine thermal springs based on comparative study of springs in Mammoth Hot Springs system. Model integrates biological and lithological observations relative to changes in temperature and pH measured along outflows. In diagram, dominant groups of microorganisms and grazing metazoans are positioned relative to their average temperature and/or pH distribution and associated sinter microstructures.

Figure 5. Mars Orbiter Camera image (false color) of Apollonaris Patera, an ancient Martian caldera (~70 km diameter) located in Elysium Basin–Terra Cimmeria region of Mars. Note chaos features and associated outflow channels especially abundant near base of volcano (lower left), which could have formed by melting of subsurface cryosphere. Proximity of chaos to volcano suggests possibility of prolonged hydrothermal activity (courtesy of NASA).

Hydrothermal Systems
continued on p. 9

Call for Geological Papers for 2001 GSA Section Meetings

NORTHEASTERN SECTION

March 12–14, 2001
Sheraton Burlington Hotel
Burlington, Vermont

Abstract Deadline:
December 5, 2000

For meeting information:
Tracy Rushmer
Dept. of Geology
University of Vermont
Perkins Hall
Burlington, VT 05405-0122
(802) 656-8136
trushmer@zoo.uvm.edu

SOUTHEASTERN SECTION

April 5–6, 2001
Sheraton Capital Center
Raleigh, North Carolina

Abstract Deadline:
January 2, 2001

For meeting information:
Edward Stoddard
Dept. of Marine, Earth & Atmospheric Sciences
North Carolina State University
Raleigh, NC 27695-8208
(919) 515-7939
skip_stoddard@ncsu.edu

CORDILLERAN SECTION

April 9–11, 2001
Sheraton Universal Hotel
Universal City, California

Abstract Deadline:
December 20, 2000

For meeting information:
Peter W. Weigand
Dept. of Geological Sciences
California State University–Northridge
18111 Nordhoff Street
Northridge, CA 91330-8266
(818) 677-2564
peter.weigand@csun.edu

NORTH–CENTRAL SECTION

April 23–24, 2001
Bone Student Center
Normal, Illinois

Abstract Deadline:
January 17, 2001

For meeting information:
Robert S. Nelson
Illinois State University
Dept. of Geography–Geology
Campus Box 4400
Normal, IL 61790-4400
(309) 438-7808

ROCKY MOUNTAIN AND SOUTH-CENTRAL SECTIONS

April 30–May 2, 2001
University of New Mexico
Albuquerque, New Mexico

Abstract Deadline:
January 24, 2001

For meeting information:
John Geissman
University of New Mexico
Dept. of Earth & Planetary Sciences
203 Northrop Hall
Albuquerque, NM 87131-1116
(505) 277-3433
jgeiss@unm.edu

Hydrothermal Systems
continued from p. 8

Schulte, M.D., and Shock, E.L., 1995, Thermodynamics of Strecker synthesis in hydrothermal systems: Origins of Life and Evolution of the Biosphere, v. 25, p. 161–173.

Stetter, K.O., 1996, Hyperthermophiles in the history of life, *in* Bock, G., and Goode, J., eds., Evolution of hydrothermal ecosystems on Earth (and Mars?): New York, John Wiley & Sons, p. 1–18.

Turcotte, D.L., 1980, On the thermal evolution of the Earth: Earth and Planetary Science Letters, v. 48, p. 53–58.

Voglesonger, K.M., O'Day, P.A., Dunn, E.E., Dalla-Betta, P.J., Korkina, N.A., and Holloway, J.R., 1999, Experimental synthesis of primary alcohols under seafloor hydrothermal conditions from hydrogen, carbon dioxide, and water: Geological Society of America Abstracts with Programs, v. 31, no. 7, p. A-488.

Walter, M.R., 1996, Ancient hydrothermal ecosystems on Earth: A new palaeobiological frontier, *in* Bock, G., and Goode, J., eds., Evolution of hydrothermal ecosystems on Earth (and Mars?): New York, John Wiley & Sons, p. 112–127.

Walter, M.R., and Des Marais, D.J., 1993, Preservation of biological information in thermal spring deposits: Developing a strategy for the search for a fossil record on Mars: Icarus, v. 101, p. 129–143.

Walter, M.R., Des Marais, D.J., Farmer, J.D., and Hinman, N.W., 1996, Paleobiology of mid-Paleozoic thermal spring deposits in the Drummond Basin, Queensland, Australia: Palaios, v. 11, p. 497–518.

Walter, M.R., McLoughlin, S., Drinnan, A.N., and Farmer, J.D., 1998, Palaeontology of Devonian thermal spring deposits, Drummond Basin, Australia: Alcheringa, v. 22, p. 285–314.

Woese, C.R., 1987, Bacterial evolution: Microbiological Reviews, v. 51, p. 221–271.

Zahnle, K.J., Kasting, J.F., and Pollack, J.B., 1988, Evolution of a steam atmosphere during Earth's accretion: Icarus, v. 74, p. 62–97.

Manuscript received April 21, 2000; accepted May 10, 2000. ■

GSA ON THE WEB

Visit the GSA Web site at www.geosociety.org. *From our home page you can link to many information resources.*

Reminder: The Abstracts Deadline for Summit 2000 is July 25 for paper submissions and August 1 for online submissions. You can also check the latest information and register online for the meeting. Look for the Summit 2000 buttons on the Home page.

Check for the latest information on the 2001 joint GSA-GSL International Conference in Edinburgh, Scotland. You can locate this in the Meetings section of the Web site.

Browse the GSA Bookstore and purchase GSA publications online.

The Marine Eocene-Oligocene Transition

Conveners: ***Donald Prothero,*** *Department of Geology, Occidental College, prothero@oxy.edu*
Linda Ivany, *Museum of Paleontology, University of Michigan, ivany@umich.edu*
Elizabeth Nesbitt, *Burke Memorial Museum, University of Washington, lnesbitt@u.washington.edu*

The Eocene-Oligocene transition was a critical period in Earth history, when the “greenhouse” climates of the Eocene were replaced by the “icehouse” conditions that persist today. In the past few years, new information has accumulated on this important interval of time, but understanding and synthesis have been hampered by lack of communication among various specialists. For this reason, we organized a Penrose Conference, “The Marine Eocene-Oligocene Transition,” which was held August 17–22, 1999, at Evergreen State College in Olympia, Washington. Forty-seven scientists from the United States, Canada, Cuba, China, Japan, New Zealand, Germany, Belgium, and Hungary participated; among them were ten graduate students and four undergraduate students. Together we hoped to broaden our understanding of the changes associated with the transition from Eocene warmth to Oligocene glaciers from oceanographic, climatic, and paleontological perspectives. We addressed such questions as: What is the nature of change during the transition? Was it synchronous or diachronous? Were there discrete events or was the change protracted and cumulative? What was the nature of the extinctions at the end of the middle Eocene, and during the early Oligocene? Is there selectivity dependent upon latitude or ecology? How can we correlate and compare records?

Oceanic Record

The first day of the conference surveyed the Eocene-Oligocene marine record on a global basis, focusing on the pelagic and Antarctic record in particular. These are the best-studied records, and the growth of Antarctic glaciers is a critical factor in climatic change. Jim Kennett provided the keynote talk, reviewing our current understanding of Eocene-Oligocene climatic change. He pointed out that the Eocene-Oligocene cooling event was almost the mirror image of the Paleocene-Eocene warming event, with both long-term (millions of years) effects, due to plate tectonics (e.g., separation of Australia from Antarctica and development of the Circum-Antarctic current), and short-term events (rapid ice growth in the early Oligocene on a time scale of tens to thousands of years). Kennett suggested that clathrates (gas hydrates) might be a critical factor in short-term changes of the carbon reservoir and greenhouse gases, although the group felt that clathrates were probably more significant in the Paleocene-Eocene transition than during the Eocene-Oligocene transition.

The next few speakers examined the pelagic biotic record in detail. Paul Pearson and Hiroshi Nishi discussed the planktonic foraminifera; this group showed significant extinction at the end of the middle Eocene, and lesser extinction in the early Oligocene. However, revisions to foraminiferal taxonomy makes their extinction peaks less severe than specialists thought only ten years ago, because many pseudoextinctions have been eliminated. Etienne Steuerbaut gave an overview of the changes in the calcareous nannoplankton, which also showed significant extinctions at the end of the middle Eocene and in the early Oligocene, although many nannofossil datums are temperature-controlled and time-transgressive. Steve Schellenberg discussed the deep-sea ostracodes, which undergo a significant drop in diversity and decrease in biogeographic heterogeneity in the early Oligocene; they also suggest significant cooling at the end of the middle Eocene. According to Ewan Fordyce, the radiation of toothed and baleen whales must have occurred very rapidly in the early Oligocene, possibly in response to increased pelagic food resources with changes in oceanic circulation.

The Southern Ocean benthic record also indicates dramatic changes. Nancy Buening discussed the isotopic record of brachiopods from New Zealand, which experienced a dramatic temperature drop of 8–13 °C in the early Oligocene. Ellen Thomas and Liselotte Diester-Haass discussed the record of benthic foraminifers, focusing on the influence of trophic resources. In particular, the Oligocene shows increased productivity and benthic foraminiferal accumulation rates, possibly due to more vigorous circulation and increased nutrients compared to the sluggish, warm Eocene oceans. Steve Pekar examined the record of sea-level change, arguing that the evidence no longer supports the huge 130 m mid-Oligocene sea-level drop shown on the Exxon-Vail onlap-offlap curve, but that the early Oligocene ice-volume increase produced a 50 m eustatic sea-level fall, bigger than predicted in other sea-level curves. Finally, Paul Gammon described an incredible deposit of siliceous sponges along 2000 km of shoreline in southern Australia. It may indicate increased upwelling between Antarctica and Australia in the early Oligocene, or may also be due to increased silica delivery from continental weathering during early Oligocene cooler and wetter climates.

Pacific Rim

On the second day, the focus shifted to the record of the Pacific Rim, especially the northern Pacific basins now uplifted as coastal outcrops from California to Alaska and Kamchatka. This record has been underexploited in the past, because its correlation to the global time scale was so poorly known. Don Prothero reviewed the latest magnetostratigraphic studies of most of the key units in California, Oregon, and Washington. Enough sections have now been dated that their fossils can be compared to the global record on a finely resolved basis. Karen Wetmore did a comparison with the benthic foraminifers and found that they showed an overall decrease in diversity from the middle Eocene to early Oligocene. The next five speakers examined the excellent molluscan record recovered from Pacific Coast Eocene-Oligocene strata. Richard Squires presented a summary of his taxonomic review of gastropods, and found an overall decline in diversity from the late early Eocene maximum, with the biggest turnover in the early Oligocene, when Tethyan taxa were replaced by taxa from the north Pacific. Carole Hickman and Liz Nesbitt looked at the molluscan record of Oregon and Washington, respectively, and disagreed on when the maximal faunal turnover occurred. This may be an artifact of comparison between shallow- and deep-water faunas, which should be resolved soon now that correlation has improved. Louie Marincovich and Anton Oleinik discussed the molluscan record of Alaska and Kamchatka, respectively. Although detailed analysis and chronostratigraphy have not yet been done in these regions, they see a major increase in cool-water taxa in the early Oligocene, in agreement with the influx of similar taxa reported in California, Oregon, and Washington. Dave Scholl concluded the day by describing a remarkable 2-km-thick body known as the Meiji sediment drift, deep in the ocean between the Emperor and Aleutian seamount chains. It implies the formation of cold, deep water out of the Bering Sea in the early Oligocene, suggesting that the Circum-Antarctic current and the North Atlantic Deep Water were not the only sources of cold bottom waters at that time.

Field Trip

As a mid-meeting break from the conference, we took a day trip on August 19 to two important Eocene-Oligocene localities in western Washington. In the morning, we visited the classic Eocene-Oligocene exposures of the Lincoln Creek Formation at Porter Bluffs, near the towns of Porter and Malone. The entire group walked along the roadcuts collecting fossils, and got a good chance to see the kinds of exposures and fossils that typify the marine Eocene-Oligocene of the Pacific Northwest. After a leisurely lunch stop at the mysterious Mima Mounds, we drove down to Longview, Washington, and visited the famous exposures of the middle Eocene Cowlitz Formation at Coal Creek. The creek level was very low, so the entire group had excellent collecting at several levels in the formation, including a dense oyster bed more than 1 m thick that crosses the creek.

Atlantic, Gulf, and Tethyan Record

During the final two days, attendees reviewed the evidence from the Atlantic margin, including the Gulf, Caribbean, North Sea, Tethys, and Paratethys. Ernie Mancini opened the Gulf Coast discussion with a review of the stratigraphy. Linda Ivany then described isotopic studies of the otoliths of conger eels, which preserve a detailed record of bottom-water conditions. She found little evidence of long-term temperature change from the middle Eocene to the Oligocene, suggesting that ice volume may be more important to the global isotopic shift, but there was evidence of greater seasonality in the Oligocene. Tom Yancey and Francisca Oboh-Ikuenobe looked at Gulf Coast pollen, finding significant evidence of long-term cooling and drying. Rick Fluegeman summarized the Gulf Coast benthic foraminifera, and noted that the major diversity change occurs in the early Oligocene. Burt Carter discussed the echinoid record, which is highly controlled by facies patterns so overall trends are difficult to discern; nevertheless, there is a big drop in diversity across all habitats in the early Oligocene. David Dockery, and Dave and Matt Campbell reviewed the molluscan record in the Gulf and Atlantic regions. Like other workers, they found the highest diversity in the middle Eocene, and major extinctions at the end of the middle Eocene, and especially in the early Oligocene. Rowan Lockwood looked at the venerid clams in greater detail; she found that the survivors of these extinctions had shapes adapted for more rapid burrowing ability. According to Earl Manning, the Gulf Coast vertebrate record shows relatively few changes in the diversity of sharks and other marine vertebrates (except for the extinction of archaeocete whales and giant sea snakes). Manuel Iturralde-Vinent provided a provocative synthesis of the Cenozoic paleogeography of the Caribbean, suggesting that the restricted subtropical flow in the Eocene was replaced by more open circumtropical current in the Oligocene.

The final day began with a review of climatic modeling of the Eocene by Karen Bice. She touched on a number of the points raised by earlier presenters, and suggested how they were or were not compatible with the current generation of climatic models. Noel Vandenberghe then reviewed the record of the North Sea, and Miklos Kazmer the Paratethys, regions that were very sensitive to changes in the faunal composition and temperature of the tropical Tethyan seaway to the south. The final three talks (Wylie Poag, Yin Yanhong, and Jim Whitehead) focused on the well-documented impacts that occurred in the middle late Eocene (35.5–36.0 Ma), primarily at the Popigai crater in Siberia, and the crater beneath Chesapeake Bay. Although these impacts were almost as large as that of the K-T, it is now well documented that they caused no extinctions of significance, a point driven home by many of the speakers. This casts serious doubt on the suggestion that all major impacts cause extinctions. However, Wylie Poag suggested that the latest Eocene reversals in the cooling trend might be a long-term effect of the impacts.

The meeting concluded with a free-form discussion about a variety of topics by all the participants. In our final afternoon, the group reached the following conclusions: (1) the earliest Oligocene isotopic event is real and globally synchronous, and mostly caused by ice volume (some regions show limited cooling); (2) the opening and closing of gateways to oceanic circulation played a key role in climatic change; (3) major faunal turnover is associated with both the end of the middle Eocene (37 Ma) cooling, and the early Oligocene glaciation (33 Ma); (4) extinctions were earlier and more severe at higher latitudes; and (5) the extraterrestrial impacts in the middle late Eocene had no obvious effect on life.

By the end of the meeting, it was very clear that the interest level, excitement, and morale of the participants were very high, and we were all eager to learn more and make further connections. This momentum is now maintained by a Web site (www.washington.edu/burkemuseum/paleo.html, click on Geology and look in the Invertebrate Fossils section). Many participants started new collaborations that should lead to important new discoveries and interdisciplinary projects.

Acknowledgments

We thank the staff at Evergreen State College for providing a splendid venue for our conference, and Lois Elms of Western Experience for handling the logistics of the meeting. We thank the Penrose Conference Fund of the Geological Society of America for help funding student participants. ■

CONFERENCE PARTICIPANTS

Warren Allmon	Ewan Fordyce	Louie Marincovich	Richard Squires
John Armentrout	Paul Gammon	Elizabeth Nesbitt	Etienne Steuerbaut
Karen Bice	Karina Hankins	Hiroshi Nishi	Ashley Streig
Clio Bitboul	Carole Hickman	Francisca Oboh-Ikuenobe	Carol Tang
Nancy Buening	John Hurley	Anton Oleinik	Nick Tew
Dave Campbell	Manuel Iturralde-Vinent	Paul Pearson	Ellen Thomas
Matt Campbell	Linda Ivany	Steve Pekar	Noel Vandenberghe
Burt Carter	Miklos Kazmer	Wylie Poag	Karen Wetmore
Liselotte Diester-Haass	James Kennett	Don Prothero	James Whitehead
David Dockery	Rowan Lockwood	Elizabeth Sanger	Tom Yancey
Linda Donohoo	Ernest Mancini	Steve Schellenberg	Yin Yanhong
Rick Fluegeman	Earl Manning	David Scholl	

Sedimentary Systems in Space and Time—High Priority National Science Foundation Research Initiatives in Sedimentary Geology

Report of NSF-sponsored workshop, March 29–31, 1999, Boulder, Colorado

Introduction

At the urging of NSF and with the coordination of SEPM and GSA, a group of ten geologists[1] met at GSA Headquarters in Boulder, Colorado, March 27–29, 1999, to identify one or more high-priority research opportunities in sedimentary geology. This report summarizes the major results. The identified priorities are meant to provide a focus, without being exclusionary, and they are meant to stimulate greater discussion within the sedimentary geological community.

Those of us who attended the Boulder workshop feel strongly that we would like to encourage a change in the culture of sedimentary geology away from individualistic to community-based, from individually acquired data to the sharing of larger community, industrial, and governmental databases. The rapid advances in numerical modeling and the success with which these have been applied in the atmospheric and oceanographic sciences tell us that dramatic advances can also be expected in sedimentary geology by choosing similar approaches.

The publication of the highly influential SEPM Special Publication No. 12[2] in 1965 may be considered the start of process sedimentology. Some 35 years later, process sedimentology, depositional systems analysis, and predictive (sequence) stratigraphy have become fairly mature sciences. Facies models and diagenetic reactions, extraterrestrial impacts, the sedimentary record of evolutionary steps and climatic extremes, boundary layer dynamics, and maturation of organics deep in sedimentary basins are the major physical and chemical components of Earth's sedimentary record that now are beginning to be understood. What is still in its infancy, in contrast, is an integrated understanding of sedimentary systems—both in space and time—and the role of life, microbial or otherwise, in the control of these systems. We propose that the start of a new century is an audacious time to initiate a systems analysis approach to sedimentary geology. This would entail first characterizing and modeling each component, then characterizing and modeling the interaction between those components, on a continuously ascending scale.

Systems analysis is a valid and valuable approach to the study of sedimentary deposits both in space and time. The study of sedimentary systems in space (initiative 1, Predictive Sedimentary Basin Dynamics) would be based on a forward modeling of sedimentary responses to external factors of change. The key infrastructure part of the program is the establishment of a community sedimentary database and community basin model, to which all investigators contribute data, numerical models and other software, and from which all investigators access any or all elements needed for the analysis of their particular part of the system. The study of sedimentary systems in time (initiative 2, Sedimentary Systems Through Time) would be based on inverse modeling aimed at extracting first-order factors that controlled critical events, thresholds, and secular trends in Earth history.

[1]Dag Nummedal, convener, Rudy Slingerland, Donald Lowe, Peter Flemings, Donald Swift, Paul Heller, James Syvitski, Toni Simo, Chris Paola, Gail Ashley, and Isabel Montañez (correspondent).

[2]G.V. Middleton, ed., 1965, Primary Sedimentary Structures and their Hydrodynamic Interpretation: SEPM Special Publication no. 12, Tulsa, Oklahoma, 265 p.

INITIATIVE 1: PREDICTIVE SEDIMENTARY BASIN DYNAMICS

A Community Initiative in Depositional System Processes and Earth History

Opportunity

Large volumes of high-resolution 3-dimensional seismic and other geophysical data already collected by industry comprise a significant but underused data set for understanding the dynamics and evolution of Earth's sedimentary basins. At the same time, advances in mathematical and physical models of basin processes, increased computing power, and a growing paleoclimate database provide a powerful systems methodology through which these data can be analyzed and understood.

Objective

We propose an integrated, multidisciplinary study of an active sedimentary basin that for the first time will analyze a whole basin as a system. Key elements include:

- Establishing a community sedimentary database of high-resolution 3-dimensional seismic, wireline, and Seabeam/GLORIA data through a partnership among academia, government, and industry.
- Establishing a modular, Web-based community sedimentary model akin to the community climate model (CCM).
- Establishing an integrated monitoring network of contemporary sediment fluxes and processes.
- Developing new technologies such as SAR and GLORIA interferometry which will exploit EOS data to remotely monitor sediment fluxes and processes.

Potential Benefits

It is critical to understand the origin and internal dynamics of sedimentary basins because the bulk of Earth's energy and mineral wealth is created and stored in them and the record of global change is written there. Furthermore, basins act as large chemical reactors in the biogeochemical cycle and may participate strongly in the global cycling of elements. A focused initiative in predictive basin dynamics would help us:

- improve predictive capability at all scales of stratal architecture, and consequently improve our ability to explore and exploit energy and mineral source rocks and reservoirs;
- understand the role of basin-water storage and chemical processing in the hydrologic cycle;
- understand the role of sedimentary basins as incubators of the deep biosphere;
- understand the manner in which sedimentary basins control carbon and other elemental cycles; and
- better interpret the record of global and regional climate change.

Key Infrastructure: Building a Community Database and Model

We propose that the earth science community create a professionally managed digital database that archives an evolving community sedimentary database (CSD) and community basin model (CBM). We consider this an important new infrastructure for EAR because we are emphasizing changing the sedimentary geological community's behavior to be more communal, analogous to the oceanographic community.

Community Sedimentary Database

The CSD will be a repository for key data used in sedimentary research initiatives. Possible data types include 3-dimensional seismic data, log, core, grain size, bathymetry, rock descriptions, geochemical analysis, paleontology, images, and tomographic data. All data should be online.

Community Sedimentary Model

Two great achievements in earth science modeling have been the Princeton Ocean Model (POM) and the Community Climate Model (CCM). Both are based on the following guiding principles: (1) University researchers working in a competitive yet cooperative environment can produce a more reliable and more flexible simulation model than a federal line agency (as is the case in other countries, e.g., Canada). (2) The code is free, eliminating the endless rewriting of the same initial algorithms allowing more time to be spent on new advances. This also creates honesty in what modelers claim and allows faster verification and comparison of different approaches on new data sets. (3) Communication is greatly increased among users and coders; a community is built. (4) Teams of experts can focus on portions of code without needing to learn the details of the entire code, thus focusing their efforts by ability. (5) If a new component of the model is developed, and the identified community agrees on the substantive improvement, then the new component replaces the old component and a new version of the model is released.

Where POM and CCM differ is in the logistical base for supporting the two efforts. POM is a virtual model (available on the Web), whereas CCM is available but administrated through a central facility (National Center for Atmospheric Research). Both have advantages and disadvantages.

If stratigraphic modeling is to reach the same level of accuracy and acceptance as weather modeling, three things must occur: (1) a coherent, cooperative effort by stratigraphic modelers needs to determine the optimum algorithms, input parameters, and observations at the relevant scales, much like what happened in constructing CCM and POM; (2) stratigraphic modeling needs to be used consistently (i.e., applied to research problems) in order to acquire the feedback for improved accuracy; and (3) the level of funding for stratigraphic modeling must increase significantly and centers facilitated to produce rapid growth.

We propose that the sediment dynamics community pool their efforts to develop a community sediment model (CSM). CSM would allow us to (1) better predict sedimentary processes; (2) better predict the distribution of lithostratigraphic properties away from points of control; and (3) provide better understanding of Earth's system when it was abiotic, hotter or colder, when there was no flocculation, when the Moon was closer, or the oceans were more saline. The model would be valuable to those working on modern environmental applications, future global warming scenarios, natural disaster mitigation efforts, natural hazards efforts, reservoir characterization, oil exploration, and national security. In fact, it could be argued that the new EOS global databases and the large-scale 3-dimensional geophysical data sets can only realize their full potential in collaboration with a community sediment model. CSM would be based on algorithms which conceptually or dynamically simulated real-world processes and conditions, incorporating into the program all the important input and boundary conditions and processes that define a sedimentary system. The effort would be coordinated and funded by NSF, other government agencies, and industry.

The U.S. Office of Naval Research sponsored program called STRATAFORM (STRATA FORmation on Margins) is an example of a large project with many investigators working together to develop predictive models. It provides a blueprint for a larger national and international effort. One goal of STRATAFORM is to have individual models adequately communicate with each other, transferring the necessary boundary conditions and data input for the next model to run. The STRATAFORM family of models must be able to simulate the delivery of sediment and their accumulation on continental margins over time scales of tens to thousands of years. Our NSF effort would extend the number of processes and environments being modeled. CSM predictions would include the effects of sea-level fluctuations, river floods, ocean storms, and other relevant environmental factors (climate trends, random catastrophic events), and work at a variety of time steps to be sensitive to short-term variations of Earth's surface.

CSM is anticipated to have a unifying architecture, but beyond that, NSF-funded researchers would be expected to develop competing subroutines and approaches. Occasionally, the community would elevate one approach over another to aid in the advancement of other linkages. However, the CSM would be flexible enough to allow divergence models to be spun off for specialized purposes.

For the effort to be successful, several key questions must be resolved:

- What hierarchy of data and processes should be used?
- Which scales are important in reaching the objectives of a simulation?
- What are the scales of observations, both spatial and temporal, and how do they compare to the scales of model outputs?
- Which groups of parameters will most economically define large- and small-scale systems?
- What are the critical values of input, such as topography, bathymetry, climate, discharge, sediment volume, grain size, vegetation, wave and current regimes that constrain the output?
- To what extent does the use of process models depend on the knowledge of initial conditions?

Sedimentary Systems *continued on p. 14*

Geological Society of America and Geological Society of London

present

Earth System Processes

a global meeting in **Edinburgh, Scotland**

June 24–28, 2001
Edinburgh International Conference Center

Earth System Processes will focus on two themes critical to the understanding of how our planet works.

Earth System Linkages will explore the relationships between the solid Earth, the hydrosphere, atmosphere, cryosphere, and biosphere.

Earth System Evolution will examine the way in which processes controlling the nature of the planet have changed since the birth of the solar system 4.5 billion years ago.

The meeting will be limited to four parallel sessions, so the number of oral presentations will be strictly limited to some of the topics of most general interest. However, there will also be a major emphasis on poster presentations.

The detailed shape of the meeting will be determined by autumn 2000 by interaction between the Technical Committee and the geoscience community. **If you are interested in making a contribution, suggesting ideas, or organizing a session, please contact one of the co-chairs or members of the Technical Committee.** The topics following each name refer to a broad area of interest, not to titles of specific sessions. They are listed to help you decide who might be the best person to contact with your ideas.

Sedimentary Systems
continued from p. 13

- How accurate are concepts and empirical rules constructed to represent conditions and processes?
- To what extent can parameters be combined?

INITIATIVE 2: SEDIMENTARY SYSTEMS THROUGH TIME

Sedimentary deposits are the record of past events at Earth's surface. From global to microscopic scales, sedimentary rocks document the interaction and co-evolution of Earth's lithosphere, biosphere, hydrosphere, cryosphere, and atmosphere, the primary components of the exogenic system over the last 3.9 billion years. This rich historical record provides sedimentary geologists the opportunity to explore and interpret both the long- and short-term environmental evolution of our planet, the formation, interactions, and evolution of the lithosphere, biosphere, ocean, and atmosphere, the evolution of life and its influence upon the global environment, and the stability and response of the biota to major environmental events. Knowledge of these past events and interactions will ultimately improve our ability to assess the nature of present-day global change and to forecast the impact of global change and anthropogenic processes on biodiversity and the environment today and in the future.

A comprehensive understanding of Earth's environmental and biological evolution as preserved in the sedimentary record must derive from interdisciplinary studies in which sedimentary geologists work in concert with paleobiologists and biologists, tectonicists and structural geologists, geochemists, petrologists, and geochronologists. The Sedimentary Systems Through Time (SSTT) initiative proposes such an interdisciplinary study aimed at documenting, interpreting, and synthesizing the evolution of Earth's environment and biota as recorded in the stratigraphic record.

SSTT is made possible at this time by a number of improvements in technology and methodology and advances in our overall knowledge of geologic history. Our developing understanding of the major events of Earth history and their causes and relationships provides a platform from which both highly focused studies can aim at better resolving critical events and from which efforts can begin to synthesize and understand long-term interactions and evolutionary trends within the exogenic system. High-precision geochronology now makes possible precise dating and resolution of events in Earth history. Isotopic geochemistry is increasingly providing means to trace geochemical cycles and resolve the evolution of geochemical systems based on extremely small quantities of material analyzed at very small spatial scales. Sequence stratigraphy and chemical markers offer means of correlation and definition of stratigraphic architecture in the absence of useful fossils. As a result of these advances, it is becoming possible to resolve the rates at which environmental and biological changes have occurred over Earth history and to begin efforts at quantitative modeling of environmental change over the entire course of Earth history.

Major research themes

(1) Improved resolution and understanding of the Precambrian sedimentary record. Precambrian sedimentary rocks document the evolution of Earth's environment and biota through a series of major global "revolutions" that transformed the surface from one that more closely resembled that of another planet, such as Mars, into one characterized by a fundamentally modern terrestrial environmental and biological system. The resolution, characterization, and interpretation of these events lie at the heart of understanding the driving forces behind global environmental and biological change up to the present day. An understanding of early terrestrial environments, biota, and events can also help constrain models of other planetary surfaces as possible sites for biological evolution.

(2) Reconstruction of selected major global environmental and biological events throughout geologic time. Geologic history contains evidence of global, long-term lithospheric, biological, and environ-

Technical Committee Co-chairs:

Ian Dalziel, University of Texas at Austin, Ian@utig.ig.utexas.edu
Tectonics and Earth history

Ian Fairchild, Keele University, i.j.fairchild@keele.ac.uk
Earth surface geochemical processes; climate change

Technical Committee Members:

Richard Alley, Penn State University, rba6@psu.edu
Cryosphere and Earth system models

Chris Barnes, University of Victoria, Crbarnes@uvic.ca,
Paleoceanography and paleobiology

Elly Brouwers, USGS, Denver, brouwers@usgs.gov
Hydrology and catchment systems: interactions and impacts

Julian Dowdeswell, University of Bristol, j.a.dowdeswell@bristol.ac.uk
Cryosphere and oceans

Mike Edmunds, BGS, Wallingford, wme@bgs.ac.uk
Groundwater, hydrogeochemistry, and paleohydrology

Jim Kasting, Penn State University, jfk4@psu.edu
Earth and planetary system sciences

Andrew Knoll, Harvard University, aknoll@oeb.harvard.edu
Biology and the Earth system through time

David Macdonald, University of Aberdeen, d.macdonald@abdn.ac.uk
Petroleum geology, sedimentology, and tectonics

Richard O'Connell, Harvard University, oconnell@geophysics.harvard.edu
Geodynamics

Kathy Campbell, University of Auckland, ka.campbell@auckland.ac.nz
Hydrothermal systems

Andrew Watson, University of East Anglia, a.j.watson@uea.ac.uk
Atmosphere and ocean compositions through time

Rob van der Voo, GSA Annual Program Chair, Voo@umich.edu
Supercontinents: assemblies, evolution, and break-up

Edinburgh Representatives

Roger Scrutton, University of Edinburgh, Roger.Scrutton@glg.ed.ac.uk
Marine geophysics

Andrew McMillan, BGS, Edinburgh, A.McMillan@bgs.ac.uk
Field excursions

Meeting sponsors: Geological Society of America, Geological Society of London, British Geological Survey, U.S. Geological Survey, University of Edinburgh, Edinburgh Geological Society

More information and updates available at www.geosociety.org, or www.geolsoc.org.uk.

mental evolution, and of short-term, catastrophic perturbations superimposed on these long-term trends that can profoundly alter subsequent long-term evolution. The interpretation and discrimination of these types of events necessarily constitutes an important aspect of any attempt to explore the secular development of the ocean, atmosphere, environment, and biota.

(3) The evolution of the interface between the lithosphere and the atmosphere (the soil or regolith zone) and the lithosphere and the hydrosphere (sediment-water interface) at which the sedimentary record is formed and within and through which most of the interactions between the lithosphere and the surrounding biological, oceanic, and atmospheric envelopes take place.

(4) The history of microbial influences on the sedimentary record. It is now suspected that microbes regulate and mediate surface processes from kilometers below to kilometers above Earth's surface. An understanding of the distribution and effects of microbes over time will help to better define the degree of coupling between microbial and environmental evolution.

(5) Reconstruction of higher resolution paleoclimate records than previously obtained by "conventional" paleoclimate indicators—at time scales much beyond that of current interests in present and future global change.

Potential benefits

The reconstruction of high-resolution paleoclimate records far back in time is a way of seeing at what temporal scales Earth is affected by natural perturbations and how quickly various systems can recover from such perturbations. To put it another way, through its history, Earth has run several large-scale experiments of change. We can learn much about those issues confronting contemporary society by understanding the recorded results.

The study of microbial influences on the sedimentary record will directly enhance our understanding of the role of sedimentary basins as incubators of microbial life today.

Community framework

Key tools for this new generation of paleoenvironmental and paleoclimatic studies include greatly improved chronostratigraphic resolution and parallel developments in molecular biology. The process of fossilization provides further new opportunities for advances in model testing.

The record of Earth's history is spotty. Learning how to extract meaningful signals of rates and directions of secular change will be challenging because most solutions are non-unique. Inverse modeling methodologies, akin to the community sedimentary model of initiative 1, is a key element of this proposed study of sedimentary systems through time.

Finally, a much closer collaboration between soft- and hard-rock geology and the geophysics and paleoceanography communities is needed to make substantive progress in this area.

ACTION ITEMS

As a community, we need to build on the momentum generated at the Boulder workshop. Most important, we need to generate broader community involvement. Therefore, we propose the following next steps to be carried out in relatively short order.

- Submit editorial to *JSR, GSA Today,* and *Eos* (this will be based on fine-tuning this report).
- Post initiative on NSF's and GSA's Web pages.
- Hold a series of workshops with 20 to 30 invited attendees for each one. Four potential workshop themes would be:
  - Predictive sedimentary basin dynamics—the science and the program; selection of the basin(s);
  - Sedimentary systems through time—pick key intervals; invite members from GOCI initiative on new trends in geobiology;
  - Community sedimentary database; and
  - Community sedimentary model.
- From these workshops, prepare formal, substantive research initiative documents to NSF. ■

GSA ELECTION GOES ELECTRONIC

Attention voting members:

This year we'll be using a new electronic balloting process to elect officers for 2001 and councilors for the term 2001–2003.

In late July, you'll receive a postcard with instructions on how to access our secure Web site and your electronic ballot listing the officer and councilor nominees. Biographical information on each candidate and the 1999 GSA Annual Report will also be available on the site.

Paper versions of ballots, candidate information, and the 1999 Annual Report will be readily available for those without Web access.

Your Vote Is Important!

GSA's elected officers (Executive Committee and Council) control the management of its affairs, and the success of the Society depends on the work of these members. Make your wishes for the society known—exercise your right to vote!

Ballots must be submitted electronically or postmarked by September 14.

Job Seekers: Get National Exposure

Are you seeking a new position in the geosciences? The GSA Employment Service offers an economical way to look for one. Let employers know what you can offer. Your name and résumé will be provided to participating employers who seek individuals with your qualifications. You may register at any time. Complete the application form on page 18, prepare a one- to two-page résumé, and mail both with your payment to GSA. A one-year listing for GSA Members and Associates in good standing is $35; for nonmembers the cost is $65. Let GSA help you find the right job!

Employers: Find the Perfect Match

You can save time and resources in your search for qualified employees by using GSA's database of job-seeking geoscientists. Complete the Employer's Request for Earth Science Applicants form on page 19. Specify educational and professional experience requirements as well as the areas of expertise your applicant should have. GSA will take it from there. You'll receive a list of matching applicants that includes names, addresses, phone numbers, areas of specialty, type of employment desired, degrees held, years of professional experience, and current employment status. Applicants' résumés are sent with each list at no additional charge. You'll also be eligible to post position announcements for three months on the GSA Web site at no additional cost.

The cost of a listing of one or two specialty codes is $175. Each additional specialty is $50. A printout of the entire applicant database is available for $350. (Please note: Specialty codes printed in boldface type are considered major headings. If you request a listing of one of the subspecialties, applicants coded under the major category will be included, but those coded under the other related subspecialties will not.) It is solely the employer's decision to contact applicants; GSA does not notify applicants of computer matches.

Schedule Your Personal Summit at the GSA Annual Meeting

GSA's Employment Interview Service at the 2000 GSA Annual Meeting, November 12–15 in Reno, Nevada, brings employers and employees together for face-to-face interviews.

Applicants: If we receive your materials by September 30, your file will be included in the information employers receive *prior* to the meeting. Indicate on your application form that you would like to interview in November. If you register after September 30 or at the GSA Annual Meeting, employers will have on-site access to your information.

Employers: When you rent interview space at GSA's Annual Meeting, our staff will schedule all interviews for you. Plus, you'll have access to the entire applicant listing and résumés, a message center, ongoing posting of job openings, on-site applicant registration and résumé updating, and photocopying services. Space is rented in half-day increments.

More information and online forms are posted at the GSA Web site (www.geosociety.org).
Or, contact Nancy Williams, Director of Member Services, GSA, P.O. Box 9140, Boulder, CO 80301-9140,
(303) 447-2020, or nwilliams@geosociety.org.

The Geological Society of America

3300 Penrose Place • P.O. Box 9140 • Boulder, CO 80301-9140

303/447-2020 • FAX 303/447-1133 • E-mail member@geosociety.org

FOR ACCOUNTING USE ONLY

Current? __________ $35 $65

Ck # ____________________

Acct. # 1-000-4086-000

No. ____________________

APPLICATION FOR EMPLOYMENT MATCHING SERVICE

(Please type or print legibly)

TITLE: ☐ Dr. ☐ Mr. ☐ Ms. ☐ Mrs. ☐ Miss

NAME ______________________________ **DATE** __________

Family/Last Name First

MAILING ADDRESS ______________________________

CITY ____________________ **STATE** __________ **ZIP CODE** __________

DATE AVAILABLE __________ **CONTACT TELEPHONE (** **)** __________ **or (** **)** __________

list one only area code Business Home

E-MAIL ____________________ **VISA** (If not U.S. citizen, list visa) __________

I ☐ HAVE ☐ HAVE NOT PREVIOUSLY BEEN REGISTERED WITH THE EMPLOYMENT MATCHING SERVICE

EXPERIENCE Must use specialty codes listed below.
Choose **THREE** that best describe your expertise in order of importance.
1. __________ **2.** __________ **3.** __________

PRESENT SPECIALTY
Choose **ONE** from codes listed below __________

YEARS EXPERIENCE IN THIS SPECIALTY __________

PRESENT EMPLOYER ______________________________

TYPE OF POSITION DESIRED (Check as many boxes as apply.)

Interested in: ☐ Academic ☐ Government ☐ Industry ☐ Other

Specific interest: ☐ Administration ☐ Exploration/Production ☐ Field ☐ Research ☐ Teaching

Will accept employment in: ☐ U.S. only ☐ U.S. with foreign assignments ☐ Either

GIVE NUMBER OF YEARS EXPERIENCE FOR ANY OF THE FOLLOWING THAT ARE APPLICABLE

Administrative_____ Exploration/Production_____ Field_____ Research_____ Teaching_____ Total geological experience______

KNOWLEDGE OF FOREIGN LANGUAGES: ☐ French ☐ German ☐ Russian ☐ Spanish ☐ Other __________

ACADEMIC TRAINING

College or University	Degree (rec'd or expected)	Year	Major	Minor

Postdoctoral research: Field __________ **Institution** __________ **Number of years** ______

SPECIALTY CODES Select those that best describe your ability. Use codes in bold face only when other breakdowns are inadequate.

100 Economic Geology
101 coal geology
102 geothermal, etc.
103 metallic deposits
104 nonmetallic deposits
105 mining geology
120 Engineering Geology
150 Environmental Geology
160 Public Education & Communication
200 General Geology
220 Geochemistry
221 organic
222 high temperature
223 low temperature
224 stable isotopes
225 geochronology
250 Geomorphology
300 Geophysics
301 seismic
302 gravity/magnetics
303 seismicity
304 paleomagnetism
320 Hydrogeology
321 hydrochemistry
322 ground water
323 surface water
330 Library
350 Mathematical Geology
351 computer science
352 statistical geology
400 Mineralogy
401 crystallography
402 clay mineralogy
410 Museum (curator)
420 Oceanography
421 marine geology
422 coastal geology
450 Paleontology
451 invertebrate
452 vertebrate
453 micropaleontology
454 paleobotany
455 paleoecology
500 Petroleum Geology
501 exploration
502 subsurface strat.
520 Petrology
521 igneous
522 metamorphic
523 sedimentary (clastic)
524 sedimentary (carb.)
525 experimental
550 Planetology
575 Quaternary Geology
600 Regional Geology
620 Remote Sensing
621 photogeology
622 photogrammetry
630 Science Editing
650 Sedimentology
651 sed. processes
652 sed. environments
720 Stratigraphy
750 Structural Geology
751 tectonics
752 tectonophysics
753 rock mechanics
800 Volcanology

Résumé must be attached, ***limited to two pages,*** typewritten on one side only, to be acceptable for reproduction to employers. Include your name, address, and phone number; concise details of work experience; and majors/minors on degrees.

Fee: $35 if you are a Member or Student Associate of GSA in good standing (Member #__________), $65 if you are not a member of GSA. Payment in U.S. funds (check, money order, or charge information ***must accompany form).***

Make check payable to the Geological Society of America. This application will be active for 1 year.

☐ Check / Money Order ☐ MasterCard ☐ VISA ☐ Diners Club ☐ American Express or Optima ☐ Discover

Card Expires (Mo/Yr) Card Number

Signature ______________________________
Required for credit card payment Date

I agree to release GSA or their representatives from responsibility for errors that may occur in processing or distributing this data. I understand that GSA makes ***no guarantee*** of contact by an employer in this service. I agree to notify GSA Employment Service immediately of change of address or acceptance of a position.

Signature ***(required)*** ______________________________ I will/will not attend the 2000 GSA Annual Meeting in Reno.

The Geological Society of America
3300 Penrose Place • P.O. Box 9140 • Boulder, Colorado 80301-9140 • (303) 447-2020 • Fax 303-447-1133 • E-mail: member@geosociety.org

EMPLOYER'S REQUEST FOR EARTH SCIENCE APPLICANTS

(Please type or print legibly)

NAME ______________________________ **DATE** __________

ORGANIZATION ______________________________

MAILING ADDRESS ______________________________

CITY ____________ **STATE** _____ **ZIP CODE** ________ **TELEPHONE (** area code **)** __________ Number

E-MAIL ______________________________ **FAX (** **)** __________

SPECIALTY CODES (see list below) 1–2 Codes, $175; additional codes, $50 each; entire list, $350
List the specialty code numbers that you wish to order, or ☐ check here if you want the entire file of applicants in *ALL* specialties.

1. ________ 2. ________ 3. ________ 4. ________ 5. ________ 6. ________

POSITION DATA: What position(s) do you expect to fill? ______________________________

In what area(s)? ______________________________

Degree requirements ______________________________ Number of positions available ________

SPECIALTY CODES

100 Economic Geology
101 coal geology
102 geothermal, etc.
103 metallic deposits
104 nonmetallic deposits
105 mining geology
120 Engineering Geology
150 Environmental Geology
160 Public Education & Communication
200 General Geology
220 Geochemistry
221 organic
222 high temperature
223 low temperature
224 stable isotopes
225 geochronology
250 Geomorphology
300 Geophysics
301 seismic
302 gravity/magnetics
303 seismicity
304 paleomagnetism
320 Hydrogeology
321 hydrochemistry
322 ground water
323 surface water
330 Library
350 Mathematical Geology
351 computer science
352 statistical geology
400 Mineralogy
401 crystallography
402 clay mineralogy
410 Museum (curator)
420 Oceanography
421 marine geology
422 coastal geology
450 Paleontology
451 invertebrate
452 vertebrate
453 micropaleontology
454 paleobotany
455 paleoecology
500 Petroleum Geology
501 exploration
502 subsurface strat.
520 Petrology
521 igneous
522 metamorphic
523 sedimentary (clastic)
524 sedimentary (carb.)
525 experimental
550 Planetology
575 Quaternary Geology
600 Regional Geology
620 Remote Sensing
621 photogeology
622 photogrammetry
630 Science Editing
650 Sedimentology
651 sed. processes
652 sed. environments
720 Stratigraphy
750 Structural Geology
751 tectonics
752 tectonophysics
753 rock mechanics
800 Volcanology

Applicants seeking employment in:
☐ Academic ☐ Government ☐ Industry ☐ Other ________

***Minimum* degree required:**
☐ None ☐ B.A. or B.S. ☐ M.A. or M.S. ☐ Ph.D.

***Minimum* professional experience:**
☐ None ☐ 1–5 years ☐ 6-plus years

Experience desired (years):

	None	**1–5**	**6-plus**
Administrative	☐	☐	☐
Exploration/Production	☐	☐	☐
Field	☐	☐	☐
Research	☐	☐	☐
Teaching	☐	☐	☐

Employment in: ☐ U.S. only ☐ U.S. with foreign assignments ☐ Either

Foreign Languages: ☐ French ☐ German ☐ Russian ☐ Spanish ☐ Other ______________ ☐ Not required

I am interested in interviewing applicants through the GSA Employment Service at the 2000 Annual Meeting in Reno.

1. I agree to use this service for valid recruiting purposes.
2. I agree that no placement charges will be assessed to any applicant participating in the GSA Employment Matching Service.

Signature (required) ______________________________

Date ______________________________

Total fee enclosed .... **$** ________

Or invoice requested .... **$** ________

GSA FOUNDATION UPDATE

Donna L. Russell, *Director of Annual Giving*

Bromery Fund for Minorities Established

Randolph W. “Bill” Bromery and Cecile T. Bromery have established the Bromery Fund for Minorities with the GSA Foundation. The intent of the fund is to support minorities who have made significant contributions to research in the geological sciences or those who have been instrumental in opening the geoscience field to other minorities. The Foundation is grateful to the Bromerys for their generosity.

Bromery has a long history of service to GSA. He has served on Council, chaired the Audit and Nominating Committees, was a leading member of the Committee on Committees, and played a prominent role in the recognition and advancement of minorities in geology. Bromery was GSA’s 101st president, and from 1992 to 1996 he chaired the Society’s first major capital campaign, the Second Century Fund for Earth, Education, and the Environment.

Bromery was the first black scientist and educator to be involved in a large number of organizational and geographic venues. His career paralleled the giant advances in race relations and recognition in the years following World War II, and his achievements served as a model for the members of minority groups who now populate science, education, and business. In 1997, Bromery was named an outstanding black scientist by the National Academy of Sciences. His most recent role was president of Springfield College in Massachusetts.

Bromery has served on the boards of many large and a few small corporations in the industry. Among the former were Exxon, Chemical Bank, NYNEX, John Hancock, Singer, New England Telephone, and Northwestern Life. He has served as president for two Massachusetts companies—Weston Geophysical International and Geoscience Engineering.

Born in Cumberland, Maryland, Bromery served as one of the Tuskegee airmen during World War II. He began working for the U.S. Geological Survey in 1948 as a geophysicist, and during the next 19 years also earned B.S., M.S., and Ph.D. degrees from Howard, American, and Johns Hopkins Universities, respectively. He entered the academic world at the University of Massachusetts at Amherst and has continued with that state university for most of the balance of his career as professor, department chair, vice chancellor for student affairs, chancellor, and senior vice president with the Office of the President. He also served as chancellor for the Board of Regents for Higher Education in Massachusetts.

Bill and Cecile Bromery were married in 1947. They raised five children and are grandparents of seven grandchildren. They now split their time between two residences—one in Amherst, Massachusetts, and the other on Hilton Head Island, South Carolina.

Cecile and Bill Bromery

“We are strong advocates of W.E.B. Dubois’ concept of the ‘talented tenth,’ a cadre of educated leaders who will devote their talents to racial uplift,” Bromery said. “We hope that this fund will encourage such leadership within our minority communities.”

GSA and the Foundation are fortunate that Bill Bromery has found a place in his very full life for the Society. ■

Digging Up the Past

Most memorable early geologic experience:

“During the president’s address, *This Stable Earth,* at the 1958 GSA Annual Meeting in St. Louis, the area was noticeably shaken by an earthquake—magnitude ~3.0–3.5.”

—James R. Underwood, Jr.

Donors to the Foundation, April 2000

G.H. Cady Memorial Fund and Award
Edward C. Dapples*

Doris M. Curtis Memorial Women in Science Fund
R. Heather Macdonald
Grover E. Murray *in memory of Melvin L. Hill, Russell M. Jeffords, Richard W. Lounsberry, and Troy L. Pewe*

Dwornik Planetary Geoscience Award
Ted A. Maxwell
Roberta Score

Farouk El-Baz Fund
Ted A. Maxwell

History of Geology Award
Pembroke J. Hart
Ursula B. Marvin
Sarah E. Newcomb*

Institute for Earth Sciences & the Environment
National Science Foundation*◆

International Division Award
L. Lynn Chyi
Pembroke J. Hart *in honor of Charles L. Drake*
International Division*
Suzanne Mahlburg Kay*
John Rodgers
Brian J. Skinner
E-an Zen

Meetings Support
Department of Energy
EarthSoft, Inc.

Minority Fund
R. Heather Macdonald

Publications
Jon Olsen*

Research Grants
Christopher M. Dail
National Science Foundation*◆

SAGE
National Science Foundation*◆

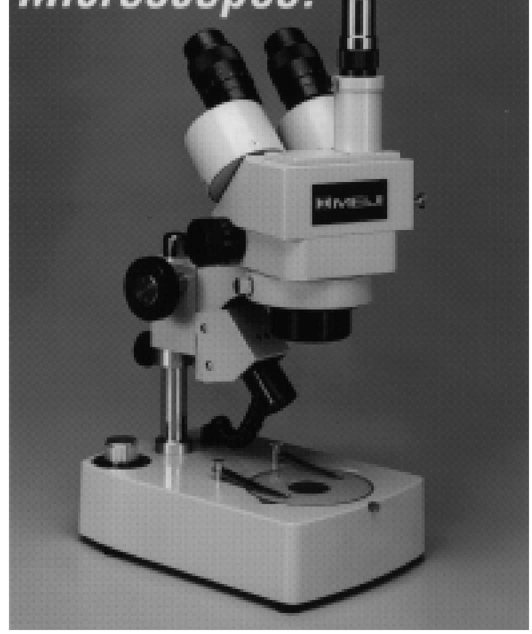
Roy J. Shlemon Mentor Program in Applied Geology
Russell G. Slayback*

Shoemaker Memorial Fund for Crater Studies
David H. Palmer

Southeastern Section Endowment
R. Heather Macdonald*

Unrestricted
Allen M. Alper
John W. Anthony
Phillip A. Armstrong
Ivan P. Colburn
Charles W. Collinson
James W. Collinson
Department of Energy*
Albert B. Dickas
John G. Elliott
Jose L. Escriba Moran
Fannie Mae Foundation
Gerald H. Haddock
Richard K. Hose
Robert D. Jarrett
Robert O. Karsian
Jeffrey Klein Annual*
Mitchell W. Lyle
James P. Minard
Mobil Foundation, Inc.*
David A. Phoenix*
Nolan G. Shaw
Joshua B. Smith
Richard G. Stearns
Lee J. Suttner*
Ray Edward Wells
E-an Zen*

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



GSA will feature great science at Summit 2000!

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

For easy submittal of abstracts for Topical and Discipline Sessions, use the electronic abstract form.

Pardee Keynote Sessions
(invited speakers)

Nuclear Waste Disposal: Bridging the Gap Between Science and Policy

Causes and Consequences of Floods: Geologic, Climatologic, Ecologic, and Human Dimensions

Great Science in the Great Basin

Living with Uncertainty: Scientific, Political, and Societal Perspectives

Lamont and Plate Tectonics: GSA History of Geology Division Millennium Symposium: Lamont 1949–1999

Sedimentary Extremes: Modern and Ancient

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

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

Short Courses Offered at GSA Annual Meeting in Reno

Registration information, course descriptions, and details on student scholarships and subsidies were published in the June issue of *GSA Today*. For additional information, contact Edna Collis at GSA Headquarters, (303) 447-2020, ext. 134, ecollis@geosociety.org, or see GSA's Web site, www.geosociety.org.

Preregistration deadline: October 6

1. Characterization and Modeling Fluid Flow in Fault and Fracture Zones: The Reality and the Idealized

Saturday–Sunday, November 11–12, 8:00 a.m. to 5:00 p.m. both days. Reno Hilton. Cosponsored by *GSA Structural Geology and Tectonics Division*.

Faults and fracture zones significantly affect rates and patterns of fluid flow in Earth's crust. Understanding how to characterize and model fluid flow and solute transport in faults and fracture zones aids in numerous applications. For professionals in the environmental, resource extract, and geotechnical fields; professors of structural geology, geology for engineers, and hydrogeology; and researchers in structural geology, hydrogeology, petroleum geology, sedimentologists, and economic geologists.

Faculty: James P. Evans—Utah State University; Ph.D., Texas A&M University; Jonathan S. Caine—U.S. Geological Survey, Denver; Ph.D., University of Utah; Craig B. Forster—University of Utah; Ph.D., University of British Columbia.

Limit: 40. Fee: $470, students $450; includes course manual and lunches. CEUs: 1.6.

2. Digital Mapping Systems: Digital Data Capture and Analysis for the Field Geoscientist

Saturday–Sunday, November 11–12, 8:00 a.m. to 5:00 p.m. both days. Reno Hilton. Cosponsored by *GSA Structural Geology and Tectonics Division*.

This course will integrate practical "hands-on" data acquisition and map generation with an overview of the technology (GPS, lasers, and data management). Case histories will illustrate mapping methodology and analysis, from the most sophisticated and expensive to the most basic, least expensive system configurations. For geoscientists with an interest in field studies; it is assumed that participants will have an undergraduate geology background and a basic knowledge of computer applications.

Faculty: Kent Nielsen—Dept. of Geosciences, University of Texas at Dallas; Ph.D., University of British Columbia; Carlos Aiken—Dept. of Geosciences, University of Texas at Dallas; Ph.D., University of Arizona; Xueming Xu—Dept. of Geosciences, University of Texas at Dallas; M.S., Chinese Academy of Science.

Limit: 30. Fee: $470, students $450; includes course manual, lunches, and field trip transportation. CEUs 1.6.

3. Science of Earthquakes: Earthquake Geology and Paleoseismology

Saturday, November 11, 8:00 a.m. to 5:00 p.m., Sunday, November 12, 8:00 a.m. to 12:00 noon. Reno Hilton. Cosponsored by *GSA Structural Geology and Tectonics Division; GSA Engineering Geology Division*.

Characterizing the likelihood of future seismicity for fault systems is difficult without long histories of past earthquakes. Recommended for those who have a strong background in either geology or geophysics, this short course will address the long-term permanent deformation that accumulates from seismic processes, as studied at trench scales. Also case studies of historic surface ruptures along well-characterized active faults.

Faculty: Charles M. Rubin—Central Washington University, Ellensburg; Ph.D., California Institute of Technology; Thomas K. Rockwell—San Diego State University; Ph.D., University of California, Santa Barbara.

Limit: 40. Fee: $370, students $350; includes course manual and lunch on Saturday. CEUs: 1.6.

4. Applications of Environmental Isotopes in Groundwater Studies

Sunday, November 12, 8:00 a.m. to 5:00 p.m. Reno Hilton. Cosponsored by *GSA Hydrogeology Division*.

Recommended for those with a senior undergraduate or graduate background in physical science who wish to apply isotope techniques in groundwater studies, this course will provide practical information about the use of environmental isotopes in key issues that have relevance for groundwater management. These include evaluation of recharge areas, groundwater residence time, surface water–groundwater interaction, and evaluation of sources and behavior of contaminants associated with agriculture, industry, and urban development.

Faculty: Ramon Aravena—University of Waterloo, Waterloo, Ontario; Ph.D., University of Waterloo; Ian D. Clark—University of Ottawa, Ottawa, Ontario; Ph.D., Université de Paris-Sud, Orsay, France.

Limit: 50. Fee: $340, students $320; includes course manual and lunch. CEUs: 0.8.

5. Field Methods for Estimation of Spatial Variations in Hydraulic Conductivity: Recent Advances and Practical Ramifications

Sunday, November 12, 8:00 a.m. to 5:00 p.m. Reno Hilton. Cosponsored by *GSA Hydrogeology Division*.

Designed to attract a wide range of hydrogeologists, this introductory course will be an overview of methods for estimation of hydraulic conductivity in saturated formations. Techniques in current use as well as promising methods under development will be considered. Particular emphasis on practical issues of test design and data interpretation. All methods will be illustrated with case studies.

Faculty: James J. Butler, Jr.—Kansas Geological Survey; Ph.D., Stanford University; Vitaly A. Zlotnick—University of Nebraska—Lincoln; Ph.D., National Institute of Hydrogeology and Engineering Geology, Moscow, Russia.

Limit: 40. Fee: $350, students $330; includes course manual and lunch. CEUs: 0.8.

6. Mobilization of Metals from Fossil Fuels: Impacts to the Environment and Human Health

Sunday, November 12, 8:00 a.m. to 12:00 noon. Reno Hilton. Cosponsored by *GSA Coal Geology Division*.

Appropriate for those with little or no prior experience in energy geology, this course will examine the sources of metals in fossil fuels and their combustion products, and related environmental and health effects. Issues include toxic elements such as mercury and arsenic, particulate matter, and regulatory aspects. Case studies of health impacts in the U.S. and abroad.

Faculty: Robert B. Finkelman—U.S. Geological Survey, Reston, Virginia; Ph.D., University of Maryland; Allan Kolker—U.S. Geological Survey, Reston, Virginia; Ph.D., State University of New York at Stony Brook; Leslie Ruppert—U.S. Geological Survey, Reston, Virginia; M.S., George Washington University.

Limit: 40. Fee: $230, students $210; includes course manual. CEUs: 0.4.

7. Practical Methods in Applied Contaminant Geochemistry: From Characterization to Remediation

Sunday, November 12, 8:00 a.m. to 5:00 p.m. Reno Hilton. Cosponsored by *GSA Hydrogeology Division*.

Geochemical data obtained as part of regulatory-driven hydrogeologic investigations are commonly too incomplete, of scant number, and of insufficient quality to use the kinds of geochemical approaches that are normally learned in university courses on acid-base and chemical-equilibrium geochemistry. This course will teach the "practical" essentials of contaminant geochemistry and how to effectively apply them in consulting (and, arguably, academic!) practice.

Faculty: Donald I. Siegel—Dept. of Earth Sciences, Syracuse University; Ph.D., University of Minnesota.

Limit: 40. Fee: $300, students $280; includes course manual and lunch. CEUs: 0.8.

8. GIS for the Geosciences

Friday–Saturday, November 17–18, 8:00 a.m. to 5:00 p.m. both days. Reno Hilton. Cosponsored by *GSA Planetary Geology Division*.

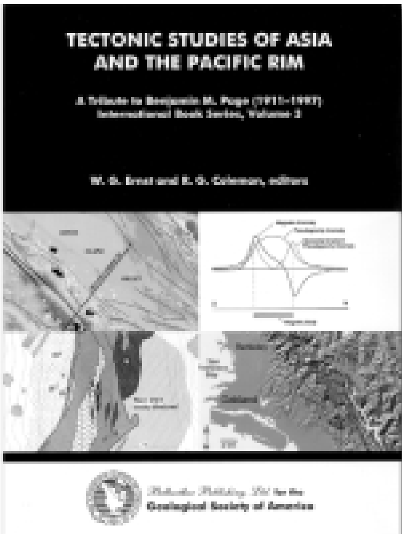
Aimed at teaching the practicing and student geoscientist about GIS methods without being specific to any software or product, this course will include: case studies, data availability, spatial data models, attribute databases, map projections, datums and GPS, spatial error and rectification, spatial statistics, sampling and interpolation, analytical GIS, probability theory applied to geoscience problems, and modeling (maximum likelihood, weights of evidence, fuzzy logic).

Faculty: Richard Bedell—Homestake Mining Company, Sparks, Nevada; M.Sc., University of London; M.Sc., University of Toronto.

Limit: 60. Fee: $370, students $350; includes course manual and lunches. CEUs: 1.6.

Available now …

Bellwether Publishing, Ltd. FOR The Geological Society of America



Tectonic Studies of Asia and the Pacific Rim, IBS 003, Volume 3

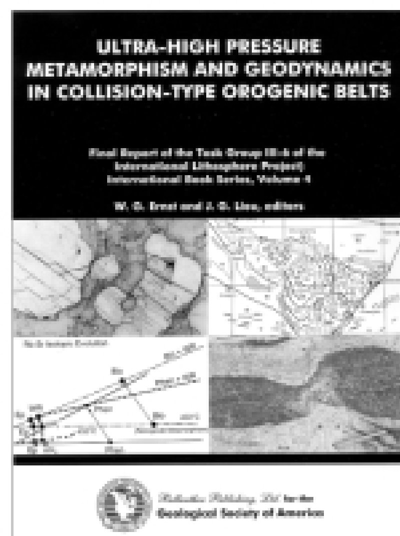
W.G. Ernst and R.G. Coleman, editors

The late Benjamin M. Page, professor of geology of Stanford University, was a geologic mapper, regional geologist, and plate tectonician *par excellence.* His many research areas included western Nevada, the Apennines, southern Taiwan, and southwestern Japan, but Page's most notable and extensive works involve elucidation of the geology of the California coast ranges. Page devoted a lifetime to unraveling the geologic architecture and plate-tectonic evolution of this continental-margin mountain belt. Indeed, nearly half of the papers in this volume, including a posthumous contribution by Page, involve the tectonic history of the central California coast ranges. Topics of special concentration include the origin, evolution, and geologic occurrence of ophiolites, accretionary mélanges, continental-margin structural and/or geophysical transects, transform faults, and convergent-margin mountain belts. In 1993, the Geological Society of America recognized Page's numerous seminal scientific papers with the Career Award in Structural Geology and Tectonics.

336 p., soft cover
ISBN 0-9665869-2-1
$89.95, member price $71.96

Ultra-High Pressure Metamorphism and Geodynamics in Collision-Type Orogenic Belts, IBS 004, Volume 4

W.G. Ernst and J.G. Liou, editors



Collisional belts that retain the effects of Phanerozoic ultra-high pressure (UHP) metamorphism are increasingly being recognized, especially in Eurasia. Neighboring regions generally lack evidence of coeval arc volcanism or plutonism. Following the consumption of intervening oceanic lithosphere, each UHP orogen marks the site of astonishingly deep subduction of a microcontinental promontory or island-arc fragments. Mafic and ultramafic rocks are volumetrically minor in such belts. Maximum recorded pressures in UHP complexes approach or even exceed 2.8 GPa at temperatures of 600–900 °C. Subduction zones involve low-*T* prograde trajectories, and constitute the only plate-tectonic environment where such conditions exist. Internal portions of descending lithospheric plates may be characterized by yet lower geothermal gradients, but the crustal upper margins are typified by less extreme high-*P*, low-*T* paths of 5–10 °C/km. Mineral parageneses, physical conditions of recrystallization, and the tectonics of subduction and exhumation are thoroughly documented in this volume. Extensional collapse and erosion of rising sialic masses evidently aid in the continued ascent of deeply subducted but buoyant material. Surviving UHP terranes consist of relatively thin slabs of continental crust. Slices evidently rose to midcrustal levels rapidly at remarkably high exhumation rates—approaching or exceeding 10 mm/yr. Back reaction attending decompression in all cases was nearly complete; where UHP relics have persisted, retrogression evidently was limited by declining temperatures, coarse grain size of host minerals, and relative impermeability of the rocks to catalytic aqueous fluids. Clearly, UHP terranes provide important new constraints on the origin and tectonic evolution of collisional mountain belts.

304 p., soft cover
ISBN 0-9665869-3-X
$89.95, member price $71.96

The Geological Society of America

TOLL-FREE: 1-888-443-4472 • FAX: 303-443-1510 • WEB: www.geosociety.org
GSA PUBLICATION SALES: P.O. Box 9140 • Boulder, CO 80301-9140

House damaged by sudden collapse of karstic cavity, Pasvalys.

MONITORING RAPID GEOLOGICAL CHANGE IN EASTERN EUROPE

REPORT ON GSA-IUGS WORKSHOP HELD IN VILNIUS, LITHUANIA, OCTOBER 11–16, 1999

Peter Bobrowsky, *COGEOENVIRONMENT, Victoria, British Columbia, Peter.Bobrowsky@Gems7.gov.bc.ca, and* ***Antony Berger,*** *Geoindicator Initiative, Victoria, British Columbia, aberger@uvic.ca*

The International Union of Geological Sciences is continuing its efforts to ensure that geological processes are properly incorporated into environmental monitoring and reporting for parks and protected areas, towns and urban areas, and regions where natural resources (e.g., forests, wetlands) are being developed or otherwise subject to change on the scale of a normal human life span. The geoindicator concept has been formulated for this purpose (see Berger 1998, and www.gcrio.org/geo/title), and it is now being used in national state-of-the-environment reporting in Australia, land-use monitoring in areas of rapid urbanization around Kuala Lumpur, Malaysia, and elsewhere.

In order to test the relevance of geoindicators to Eastern Europe, the Geological Survey of Lithuania (LGT) organized a regional workshop in Vilnius in the fall of 1999, with support from IUGS and GSA, through its Science and Outreach program. The aim of the workshop was to introduce the concept and some of its applications to some 40 participants from Belarus, Bulgaria, Estonia, Finland, Latvia, Lithuania, and Poland. Among the 20 posters and papers presented were reviews of groundwater as a "universal geoindicator of environmental processes" (A. Domaševičius et al., Lithuania), human-induced geomorphological changes in the Vistula Bay (M. Graniczny, Poland), local effects of remote earthquakes (V. Ilgintyé, S. Šliaupa, A. Pačėsa, and L. Korabliova, Lithuania), neotectonic hazards in Bulgaria (M. Matova, Bulgaria), geochemistry of surficial deposits (R. Salminen et al., Finland), and EIA and landscape change in Belarus (S. Sauchyk, Belarus).

The meeting was organized by Jonas Satkunas, deputy director of the Lithuanian Geological Survey, and his colleagues. Despite the mixture of languages and cultures represented, there was little difficulty in communicating in English. The discussions emphasized the need for an algorithm to relate individual geoindicators to financial gains and losses for easier comprehension and use by decision-makers. Action plans should be set up to avoid the negative consequences of harmful processes measured by geoindicators, and a detailed inventory should be compiled for the Baltic region listing past, current, and planned geoindicator-based studies. Other recommendations were to expand the existing list of geoindicators, with a clearer determination of critical values (thresholds), a better identification of those who would use the results, and the establishment of priorities for geoindicator monitoring based, at least in part, on risk to human life and potential economic loss.

During a field excursion to northern Lithuania, we saw many features related to active and semi-active karst phenomena related to near-surface gypsum deposits. Karstification is actively monitored by observation of karst sinkholes (53 new ones formed near one village between 1997 and 1999), groundwater levels and chemistry, and hydrochemistry of surficial water draining the area. Measurements of the quantity of dissolved gypsum per square kilometer shows that the intensity of contemporary karst denudation (chemical subrosion) is increasing (now 120t/km^2/yr in one drainage basin), and there are many examples of recent sinkholes causing the subsidence of houses, roads, and agricultural fields. The field trip demonstrated the value of monitoring karst activity geoindicators, in an effort to anticipate active dissolution and subsidence processes. We met with local authorities and residents who were very interested not only in the actual surface hazards involved, but also in the scientific research being carried out. These included staff members from a local health spa where patients go for the healing qualities of the karst springs, and the owner of a local brewery who was following closely the LGT research on groundwater chemistry and its relevance to the quality of his (mighty tasty) beer.

Geology has quite a high public profile in Lithuania, and the workshop attracted much interest from local and national media. There were many interviews in local newspaper, radio and television, and the field trip was accompanied by a cameraman from one of the national television stations. The LGT is well regarded both at home and abroad, as is borne out by its involvement with many international projects. Though the process of rebuilding

Monitoring Change *continued on p. 26*

Workshop participants in front of a mineral spring outlet, Pasvalys, northern Lithuania.

Geology in the Parks and Forests: Summer Internship Programs

GSA's summer internship program offers opportunities to a diverse group of talented undergraduate students. The program began in 1997 with two interns placed in two National Parks and has since expanded to include 13 National Parks, four National Forests, and a developing collaboration with the National Association of Black Geologists and Geophysicists.

National Park Service interns work from 10 to 14 weeks in positions ranging from resource management, field mapping, and working with the geographic information systems, to doing bibliographic and curatorial work and ecosystem research. Interns who work with interpretive staff members to include geology in visitor education programs have daily contact with the public. With approximately 270 million people visiting National Parks each year, the potential for public education is significant.

Forest Service interns enjoy a 10-week, one-on-one relationship with a mentor. They work on projects—both in the field and in the office—that provide exposure to the principles of multiple-use and ecosystem management. These partnerships build awareness of the importance of geology to park visitors and administrators alike, emphasizing links between science and resource management within the geoscience community and promoting career options among geoscience students.

The program is highly competitive, with an average of 35 applications received for each available position. Students receive a $2,500 stipend and either on-site lodging or an additional housing per diem and gain valuable life and work experience while working to advance the missions of the organizations involved.

Check the GSA Web site at www.geosociety.org/science/intrnshp.htm for more information about the program. Position announcements for 2001 will be posted on the site in the early fall. If you would like information sent to you, please contact the Internship Coordinator, GSA Science, Education, & Outreach, (303) 447-2020. ■

Summer 2000 Intern Update

The following interns have been dispatched to parks and forests nationwide, from crests to caves, sand dunes to seashores. Photos and news from the field will be posted at www.geosociety.org/science/intrnshp.htm.

Amanda Kolker	Assateague Island National Seashore
Brien Park	Bryce Canyon
Brooke Swanson	Fossil Butte National Monument
Christine Wennen	Capulin Volcano
Andrew Irvine	Denali National Park and Preserve
Clifton Koontz	Grand Canyon National Park
Michael Canerdy	Greater Sand Dunes National Monument
Stephanie Larsen	Oregon Caves National Monument
Christine Jan	Ozark National Monument
Kathryn Roberts	Redwood National Forest
Audrey Sherry	Florissant Fossil Beds National Monument
Jonathan Pennington*	Lake Roosevelt National Monument
Ann Finocchio	Sierra National Forest
Jaime Piver	Klamath National Forest
Todd Gillihan	El Dorado National Forest
Brian Seneker	Los Padres National Forest

**GSA and National Association for Black Geologists and Geophysicists supported intern.*

Monitoring Change *continued from p. 25*

national capacity following the dissolution of the U.S.S.R. is still in progress, Lithuania is clearly interested in expanding its links, and is now applying for membership in the European Union, preparing its laws, regulations, and administration to meet the required standards. For a rather flat-lying agricultural country, we were impressed at the detailed knowledge of the subsurface geology, and were told that this came in part from the systematic program of holes drilled for scientific purposes at 10-km-grid spacing across the country—a legacy of the Soviet "command economy." Also noteworthy were the extensive efforts that Lithuanian authorities have made to protect geological "monuments," including individual sinkholes and glacial erratics!

The main outcome of the meeting was a decision to set up an Internet-based network to improve communications, provide information and ideas, and promote the use of geoindicators. The GEOIN network will also disseminate case studies of successful applications of geoindicator monitoring and assessment. Future regional workshops will be organized to review specific parameters, bearing in mind the needs and priorities of national monitoring programs, European Union standards, and environmental legislation. GEOIN will circulate "bad news" examples through the media to shock authorities and politicians into action. It will also expand on the economic and social consequences of each geoindicator in the checklist and will clarify how to measure individual parameters. It will also provide information on potential sources of funding for individual projects, and will work to create an inventory of international experts on specific geoindicators. The Geological Survey of Lithuania agreed to take responsibility for the design and maintenance of the Web site.

References Cited

Berger, A.R., 1998, Environmental change, geoindicators, and the autonomy of nature: GSA Today, v. 8, no. 1, p. 3–8. ■

Shlemon Workshops: A Success at 2000 Section Meetings

The Roy J. Shlemon Mentor Program, held in conjunction with GSA section meetings, bridges the gap between applied and academic geology communities. Participating mentors are experienced geologists currently practicing in various fields of applied geology. Workshop venues vary, depending upon the wishes of the mentors and GSA section coordinators.

Mentor workshops are available to all sections, and five elected to participate in 2000. Evaluations from students, section coordinators, mentors, and the outreach project officer deemed the workshops very successful. Without exception, the professionals who volunteered to lead this year's workshops defined the spirit of mentoring, sharing generously their personal time, professional experiences, advice, and resources.

While successful workshops depended on participation of students and mentors, the Shlemon workshops in 2000 were promoted and facilitated by key people at each section meeting. These pivotal players shared the titles of faculty coordinator and on-site coordinator. Several were fortunate to have help from student coordinators. Without the tireless backstage organization and efforts of these volunteers, the workshops would have failed.

This year's Shlemon events began at the Northeastern Section Meeting in New Brunswick, New Jersey. A team of mentors, including Randy S. Kertes of Omni Environmental Corporation of Princeton, New Jersey, and Evelyn M. Maurmeyer of Coastal & Estuarine Research, Inc., of Lewes, Delaware, addressed the topic "Some Practical Advice." One student remarked of the interactive sessions, "... it was a good format to have presentations, group questions and answers, and then an individual questions-and-answers time." Kathleen Browne of Rider University served as faculty coordinator, and Cynthia Liutkus was student coordinator for this workshop.

Next came the South-Central Section Meeting, held in Fayetteville, Arkansas. This workshop featured four geoscientists from Southwestern Energy Company in a panel discussion called "Energy Resources: Opportunities for Geologists." Participating as mentors were Ronald R. Foshee, Phillip R. Shelby, William J. Winkelmann, and John Thaeler. Students gained valuable career information during this luncheon program. Dianne Phillips, lab coordinator for the University of Arkansas, facilitated arrangements for this workshop as the on-site coordinator.

At the North-Central Section Meeting in Indianapolis, Indiana, Steve Sittler from Advanced Pollution Technologists, Ltd., of Mishawaka, Indiana, shared sandwiches and cookies with participants during an extended lunch workshop entitled "Getting a Job in the Geosciences." Steve encouraged participation in the roundtable discussion of job skills versus educational goals. One student commented, "The most valuable aspect of the program was the résumé discussion and the straightforward information about career opportunities." Gabriel Filippelli from Indiana University–Purdue University at Indianapolis served as faculty coordinator.

The Rocky Mountain Section Meeting's workshop in Missoula, Montana, was held during extended lunch hours over the course of two days and involved lots of pizza, salad, and cookies. On April 17, Mary Lou Sullivan from URS Corporation, Seattle, Washington, addressed the topic "Opportunities for Geoscientists and Environmental Scientists in the Consulting World." The following day, Brad E. Dingee with Peabody Coal Company of Gillette, Wyoming, talked about "Opportunities for Geologists and Hydrogeologists in Energy Resources." Geoffrey Gilbert, the student coordinator for the workshop, wrote in a follow-up note, "From input during and after [the workshops], I have found that students truly appreciated and gained from the program." Christine Brick from the University of Montana served as faculty coordinator for these workshops.

The final workshop of the year was an all-day event at the Cordilleran Section Meeting in Vancouver, B.C., led by Jeffrey Fillipone from Golder Associates, Victoria, B.C. The morning was filled with discussion of careers and career paths, job opportunities, and resources. After a lunch-on-the-run, the students piled into vans that transported them to an active geotechnical project site (Seymour Falls Dam–Greater Vancouver Regional District) where Fillipone is currently providing professional services. The students were treated to a brief overview of the site by Jason Wright, a structural engineer with GVRD, and then they toured the dam inside and out. It was a special treat for the students to witness applied geology firsthand. When asked to comment on what aspect of the workshop was most valuable, one student answered, "Encouragement!" Another commented on the value of "real examples of employment possibilities versus the skills in hand." Mitch Mihalynuk from the British Columbia Geological Survey served as the on-site coordinator.

If you are interested in participating as a mentor in these workshops during 2001, please contact Project Officer Karlon Blythe at kblythe@geosociety.org, or (303) 447-2020, ext. 136. ■

Call for Mentor Volunteers for 2001

Perhaps the best way to repay a mentor from the early days of your professional life is to become a mentor yourself. As planning begins for the 2001 mentor programs, now is the time to seize your opportunity to participate in these gratifying programs and help students who are seeking real-life advice about professional development in the geosciences.

Two mentor programs are offered through GSA's Science, Education, & Outreach group—the John F. Mann Mentor Program in Applied Hydrogeology (two program sites to be determined) and the Roy J. Shlemon Mentor Program in Applied Geology (offered only at GSA Section Meetings). While these programs are implemented in different ways and vary subtly in their objectives, both extend the mentoring reach of individual professionals into students' academic world by offering a "glimpse through the window" on careers in applied geology. As you may remember from your student days, this real-world advice is as valuable as the best coursework.

Consider sharing your insight, knowledge, and experience with undergraduate and graduate students. You can make a difference in someone's professional life. Contact Program Officer Karlon Blythe at kblythe@geosociety.org, or (303) 447-2020, ext. 136, for information.

2000 GeoVentures

Cliffs of Moher. Photo by Jay Gregg.

Giant Steps Through Time

Dublin, Ireland

September 16–October 1, 2000

Scientific Leaders

John Morris, Barry Long, Brian McConnell, Conor MacDermot, and Pat O'Connor, Geological Survey of Ireland, Dublin; Patrick McKeever, Ian Mitchell, and Terry Johnston, Geological Survey of Northern Ireland. Coordinators: Enda Gallagher, Geological Survey of Ireland, gallaghe@tec.irlgov.ie; Jay M. Gregg, Dept. of Geology and Geophysics, University of Missouri—Rolla, greggjay@umr.edu

This cooperative trip between the Geological Surveys of Ireland and Northern Ireland will be led by eight professional geologists. All are experienced field trip leaders and acknowledged as leading experts in their respective fields within Irish geology.

Description

Participants will be introduced to the wonderful diversity of Ireland's geology, contained within a surprisingly small area. To examine the same assortment of geological localities in the United States would require a considerable trek—perhaps from coast to coast. Not only is Ireland's geology diverse, it also contains numerous classic geologic localities, many of which we will visit during this trip. Participants will see the rocks that neptunists and vulcanists argued over, including Ireland's geologic jewel—the Giant's Causeway in Antrim. Equally impressive are the classic igneous ring complexes and volcanic centers of counties Louth, Armagh, and Down, including Slieve Gullion and Carlingford, which were among the first such features described anywhere in the world. The granites of counties Donegal and Galway exhibit a variety of granite emplacement mechanisms and include the localities where granitization was first proposed. How exactly does an orogeny work? The story of the Grampian orogeny can be read in rocks from Antrim in the northeast across to Galway on the west coast. Ireland's west coast, from Donegal to Clare, reveals many other geologic treasures, including a prograding deltaic sequence, exceptional fossil preservation, and karstic features. All these features are contained in a spectacular glaciated landscape, which, when combined with Ireland's unique culture, history, and folklore, adds a delightful extra dimension to the trip.

Fees and Payment

$4,300 for GSA members; $4,400 for nonmembers. A $300 deposit is due with your reservation and is refundable through July 10, less $50 processing fee. The total balance is due August 1, 2000. FIRM minimum: 20; maximum: 25. Included: Round-trip airfare from Atlanta to Dublin; guidebook; ground transportation; lodging for 14 nights, based on double occupancy; and meals for 14 days. Not included: airfare to Atlanta and alcoholic beverages.

GeoVentures Registration

Send a deposit to hold your reservation; please pay by check or credit card. You will receive further information and a confirmation of your registration within two weeks after your reservation is received.

Name ______________________

Institution/Employer ______________________

Mailing Address ______________________

City/State/Country/ZIP ______________________

Phone (business/home) ______________________

Guest Name ______________________

GSA Member # ______________________

	Deposit Per Person	No. of Persons	Total Paid Deposit
GT005—Ireland	$300	____	$________
	TOTAL DEPOSIT		$________

☐ VISA ☐ MasterCard ☐ American Express ☐ Discover ☐ Diners Club

Credit Card # ______________________ Exp. Date ________

Signature ______________________

☐ I've enclosed no deposit, but I'm interested. Please send information.

MAIL OR FAX REGISTRATION FORM AND CHECK OR CREDIT CARD INFORMATION TO:
2000 GSA GeoVentures, Member Services
P.O. Box 9140, Boulder, CO 80301
fax 303-447-1133 or 303-443-1510

MAKE CHECKS PAYABLE TO: GSA 2000 GeoVentures

SPREAD THE WORD: EARTH SCIENCE WEEK IS OCTOBER 8–14!

Earth Science Week moves into its third year of observance in the year 2000. Although it is GSA's mission to promote the geosciences in service to society every week of the year, we have planned special events for this celebratory week. We urge you to do the same by planning outreach efforts in your own communities. Community field trips, school visits, and open houses at your institutions are all effective ways to bring attention to Earth Science Week and the geosciences. You'll find lots of great ideas at our Web site, www.geosociety.org/educate/earthweek.htm, plus links to other geoscience sites celebrating Earth Science Week. An online forum lets you share your ideas in advance of Earth Science Week, then report on your activities as they happen.

Also posted (www.geosociety.org/educate/earthbooks.htm) is our member-picks book list of recommended reading with something for every age and interest. Our intent is not to suggest scientific textbooks, but rather good general reading that presents earth and environmental sciences as an integral part of story lines for adults, as well as stories and activities for children. If you know of a book you think should be included, e-mail GSA at member@geosociety.org, or call (303) 447-2020, ext. 774, or 1-888-443-4472.

Help for schools and libraries

GSA is sending packets to Colorado libraries and schools that include the book list, display materials, ideas for activities, and the first annual GSA Earth Science Week poster. This poster is a high-quality, photo poster featuring a geologically interesting Colorado scene. The packets also will be available on request from GSA headquarters. As an incentive to promote geoscience, needy libraries can apply for a $25–$50 stipend to acquire a book from the list of recommended reading.

Calling in reinforcements

We're encouraging our National Park Service interns to work with the parks to arrange for displays or special events to occur during Earth Science Week. Although most interns will have returned to their classes by then, we are hopeful that the legacy of their work this summer will endure and bring Earth Science Week to the attention of park visitors across the country. ■

2001 • Boston

2001 GSA Annual Meeting
Boston, Massachusetts

November 5–8, 2001
John B. Hynes Veterans Memorial Convention Center

General Chair
Christopher Hepburn
Boston College

Technical Program Chair
Robert S. Young
Western Carolina University

Due Date for Pardee Keynote Symposia and Topical Proposals:
January 9, 2001

For More Information:
Call: (303) 447-2020 or 1-800-472-1988
Fax: 303-447-0648
E-mail: meetings@geosociety.org
Web site: www.geosociety.org

Call for Field Trip Proposals
We are interested in proposals for half-day, single-day, and multi-day field trips, beginning or ending in Boston and dealing with all aspects of the geosciences.

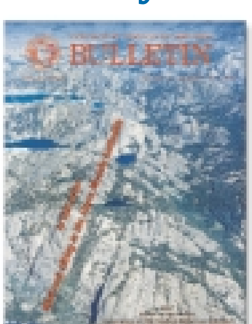
Please Contact Field Trip Co-Chairs

David P. West, Jr.
Department of Geology
Earlham College
Richmond, IN 47374
(765) 983-1231, fax 765-983-1497
westd@earlham.edu

Richard (Dick) Bailey
Department of Geology
Northeastern University
Boston, MA 02115
(617) 373-3181, fax 617-373-4378
r.bailey@nunet.neu.edu

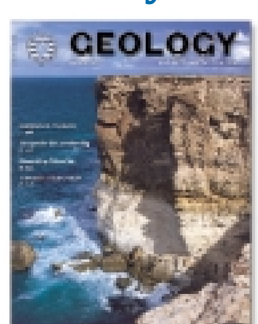
JULY *Bulletin* and *Geology* Highlights

In July *Bulletin*



- Wall-rock tilting in the Sierra Nevada batholith
- Uplift of the Andes
- Emergence of the Central American Isthmus
- Thrust faults in the Transverse Ranges, California

In July *Geology*



- Magmas in collision
- An apatite for weathering
- Hazarding Vesuvius
- The fault of the oracle

Visit *Bulletin* and *Geology* at www.geosociety.org.
This online service is free for a limited time.

For subscription information,
call toll-free 1-888-443-4472 or e-mail member@geosociety.org.

CALENDAR

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

2000 Meetings

September

September 19–22, Mining 2000, Melbourne, Australia. Information: Mining 2000 Pty. Ltd., P.O. Box 607, West Perth, WA 6872, Australia, 61-8-9485-1166, fax 61-8-9481-8023, enquiries@mining2000.com.au, www.mining2000.com.au.

November

November 6–9, American Water Resources Association's Annual Water Resources Conference, Miami, Florida. Information: Michael J. Kowalski, AWRA Director of Operations, AWRA, 4 West Federal Street, P.O. Box 1626, Middleburg, VA 20118-1626, (540) 687-8390, fax 540-687-8395, mike@awra.org.

December

December 2–7, Geochemistry of Crustal Fluids, Fluids in the Crust and Chemical Fluxes of the Earth's Surface, Granada, Spain. Information: J. Hendekovic, European Science Foundation, 1 quai Lezay-Marnésia, 67080 Strasbourg Cedex, France, 33-388-76-71-35, fax 33-388-36-69-87, euresco@esf.org, www.esf.org/euresco. *(Application deadline: September 4, 2000.)*

2001 Meetings

March

March 26–31, Fourth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, San Diego, California. Information: Shamsher Prakash, Civil Engineering Dept., University of Missouri–Rolla, 1870 Miner Circle, Rolla, MO 65409-0030, (573) 341-4489, fax 573-341-6553 or 573-341-4729, prakash@novell.civil.umr.edu.

April

April 5–6, The Geologic and Climatic Evolution of the Arabian Sea Region, London, United Kingdom. Information: Peter Clift, Dept. of Geology and Geophysics, MS 22, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, (508) 289-3437, fax 508-457-2187, pclift@whoi.edu; Christoph Gaedicke, Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Stilleweg 2, D-30655 Hannover, Germany, Gaedicke@bgr.de.

May

May 11–21, 15th International Senckenberg Conference, Mid-Palaeozoic Bio- and Geodynamics: The North Gondwana-Laurussia Interaction, Frankfurt am Main, Germany. Information: G. Plodowski, 49-69-97075127, fax 49-69-97075137, gplodows@sngkw.uni-frankfurt.de; P Königshof, 49-69-7542257, fax 49-69- 7542242, pkoenigs@sng.uni-frankfurt.de; E. Schindler, 49-69-97075132, fax 49-69-97075137, eschindl@sngkw.uni-frankfurt.de; Forschungsinstitut Senckenberg, Senckenberganlage 25, D-60325 Frankfurt am Main, Germany. *(Abstract deadline: November 1, 2000.)*

June

June 10–15, 5th International Conference on Diffuse Pollution, Milwaukee, Wisconsin. Information: http://www.mu.edu/environment/iwa-page.htm. *(Abstract deadline: September 30, 2000; contact mburkart@nstl.gov.)*

June 11–13, 2001 International Containment & Remediation Technology Conference and Exhibition, Orlando, Florida. Information: Skip Chamberlain, U.S. Department of Energy, Cloverleaf Building, EM-53, 19901 Germantown Road, Germantown, MD 20874-1290, (301) 903-7248, fax 301-903-1530, grover.chamberlain@em.doe.gov, www.containment.fsu.edu.

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

CLASSIFIED ADVERTISING

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

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

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

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

Positions Open

U-PB SPECIALIST, MIT

The Department of Earth, Atmospheric, and Planetary Sciences at MIT has an immediate opening for an individual with experience in low-blank, high-precision U-Pb geochronology to manage laboratory. Duties will include all aspects of zircon preparation and analysis as well as ordering supplies and supervision of students and visitors. Interested candidates should submit a resume and cover letter referencing Job No. 00-0456 to: James McCarthy, MIT Personnel, PO Box 391229, Cambridge, MA 02139-0013. To apply on-line: web.mit.edu/personnel/www/resume.htm. MIT is an Equal Opportunity/Affirmative Action Employer. MIT is a non-smoking environment.

EXPERIMENTAL GEOPHYSICS AND GEOCHEMISTRY FACULTY POSITION, MIT

The Department of Earth, Atmospheric, and Planetary Sciences at MIT seeks an outstanding scientist in the area of Experimental Geophysics and Geochemistry who studies the physics and chemistry of Earth materials. The successful candidate will have a strong record of research and potential to be an excellent teacher. Junior candidates (tenure track) are encouraged to apply. Areas of interest include, but are not limited to: 1) mechanical properties including the study of multiphase materials or materials undergoing chemical reactions; 2) thermal transport, fluid transport, acoustic and/or electrical properties including flow of granular material, fluid flow through porous materials, transport of magma and flow in the mantle; 3) high pressure mineralogy, mineral physics, and phase transitions in planetary interiors. Candidates should be interested in the relating laboratory and computational experiments, field relations, and tectonic scale processes.

Interested individuals should send curriculum vita and the names of three references to: Professor Ron Prinn, Department Head; Attention EGG Search; Department of Earth, Atmospheric, and Planetary Sciences; Massachusetts Institute of Technology; 77 Mass. Avenue; Cambridge, MA 02139-4307.

MIT is an Equal Opportunity/Affirmative Action Employer. MIT is a non-smoking environment.

SENIOR GEOLOGIST, CASCADE EARTH SCIENCES (CES)

Cascade Earth Sciences (CES), a Valmont Industries Company, is seeking qualified candidates for Senior Geologist positions in our Albany, OR and Spokane, WA offices. Requirements include a BS or MS degree in Geology, and professional registration. Six to ten years professional experience desired with education, training, and experience conducting hydrogeologic investigations including demonstrated experience and training in groundwater modeling. Duties include project scoping, fieldwork, data analysis, technical report writing, client and regulatory relations, and project management. Knowledge of PC's and applicable software (Word, Excel) emphasized. Competitive salary and benefits package. Full-time positions include major medical, 401(k), and profit sharing. Send resumes to: Cascade Earth Sciences, Human Resources, 7150 Supra Drive SW, Albany, Oregon 97321. www.cascade-earth.com.

EDUCATION AND OUTREACH PROGRAM SPECIALIST, THE INCORPORATED RESEARCH INSTITUTIONS FOR SEISMOLOGY (IRIS)

The Incorporated Research Institutions for Seismology (IRIS) seeks a dynamic individual with a background in science and educational qualifications or interest to participate in a rapidly evolving suite of activities related to educational interfaces to seismic data sets and involvement in national digital libraries initiatives. IRIS is a 93-member consortium of institutions with research programs in seismology. Its core programs involve seismic data collection and archiving, and education and outreach.

The successful applicant will assist with the IRIS Education and Outreach program at IRIS headquarters in Washington DC, specifically in the area of digital libraries. The applicant will interact with IRIS member institutions, with the IRIS DMS, GSN and PASSCAL programs and with the Albuquerque Seismological Laboratory. Some domestic travel is required in conjunction with IRIS activities, digital libraries initiatives and national scientific and educational meetings. Job responsibilities will include: (1) participation in the Geoscience Digital Library project, in particular in ensuring liaisons between IRIS, the GDL and the Digital Library for Earth System Education (DLESE, http://www.dlese.org); (2) design and development of educational interfaces to seismic data sets, in particular those maintained by the IRIS consortium (www.iris.edu).

Applicants should have a bachelors or masters degree in science or computing, expertise or a strong interest in education, and experience in one or more of the following: experience with large scientific data sets (especially seismological data sets) and design of interfaces to such data sets; Java, C-shell, UNIX programming; design of educational web-based materials; experience or research in earth science.

Salary is dependent on qualifications and experience. The appointment will be for an 18 month period and may be extended, contingent on funding.

For more information please contact Catherine Johnson: catherine@iris.edu. To apply please send a curriculum vitae, supporting documentation (e.g. publication list), the names of five referees and statement of interest by August 1st, 2000, to: The IRIS Consortium, Attn Human Resources–Search for Education and Outreach Specialist, 1200 New York Ave, #800, Washington DC 20005.

GEOCHEMIST, MACTEC-ERS

MACTEC-ERS is seeking a geochemist to conduct investigations of contaminated groundwater. The geochemist will participate independently, and as a team member, in the acquisition and interpretation of groundwater geochemical data; evaluate groundwater remediation strategies; prepare reports, regulatory documents, journal publications, and proposals; design and develop new groundwater remediation technologies; conduct field investigations; model the geochemistry of groundwater systems; and conduct laboratory and field tests of new or unproven technologies. Many of the projects involve assessments of former uranium mill tailing sites.

Position requires a minimum of a M.S. degree in geochemistry with an emphasis on low-temperature inorganic processes in groundwater, or equivalent; experience with geochemical speciation modeling using codes such as PHREEQE; and good communication skills. Knowledge of and/or experience with uranium geochemistry are beneficial. The successful candidate will possess a high level of motivation and initiative.

Competitive salary and benefits offered. Please send resume, academic transcripts, and references to: MACTEC-ERS, Human Resources Dept., 2597 B 3/4 Road, Grand Junction, CO 81503, fax to: 970/248-7682. We are an Equal Opportunity Employer.

U.S. GEOLOGICAL SURVEY MENDENHALL POSTDOCTORAL RESEARCH FELLOWSHIP PROGRAM

The U.S. Geological Survey (USGS) invites applications for a new postdoctoral program, the Mendenhall Postdoctoral Research Fellowship Program, during fall 2000. The program is named in honor of Walter C. Mendenhall, the fifth Director of the USGS. Mendenhall, appointed Director in 1930 by President Hoover, mapped Appalachian coal fields, did pioneering work on the geology of Alaska, and was one of the first groundwater specialists at the USGS whose work helped to establish groundwater hydrology as a field of scientific endeavor. In spite of the difficult times during the Depression and the beginning of World War II during his tenure, Mendenhall encouraged the Survey to emphasize the necessity of basic research and created an environment in which scientific research, technical integrity, and practical skill could flourish.

The Mendenhall Postdoctoral Research Fellowship Program is envisioned to bring current expertise in the earth sciences to assist in the implementation of the strategic plan of the USGS and the science strategy of its geologic programs. The program is also intended to provide postdoctoral fellows a research experience that enhances their personal scientific stature and credentials. For fall 2000, opportunities for research are available in a wide range of the areas including: (i) sediment transport modeling in coastal environments, (ii) remote sensing, (iii) seismic hazard studies, (iv) economic modeling of resources, (v) geologic processes and human health, (vi) environmental geochemistry, (vii) impacts of climate change in arid and semi-arid lands, (viii) geologic controls and ecosystem processes, and (ix) sustainable development and resource extraction.

The postdoctoral fellowships are to be 2-year term appointments in the Federal Civil Service. A complete description of the program, research opportunities, and application process are available via the WWW at: http://geology.usgs.gov/postdoc. Qualified candidates are encouraged to submit their applications by the deadline on August 4, 2000. As the nation's largest water, earth and biological science and civilian mapping agency, the USGS works in cooperation with many organizations across the country to provide reliable, impartial, scientific information to resource managers, planners, and other customers. Information is gathered by USGS scientists to minimize the loss of life and property from natural disasters, contribute to the sound conservation, economic and physical development of the nation's natural resources, and enhance the quality of life by monitoring water, biological, energy and mineral resources.

Applicants must be U.S. Citizens. All qualified applicants may apply. The U.S. Geological Survey is an Equal Opportunity employer. Selection for these positions shall be determined on the basis of merit without discrimination for any reason such as race, color, age, religion, sex, national origin, political preference, labor organization affiliation or nonaffiliation, marital status, or nondisqualifying handicap.

POSTDOCTORAL RESEARCH SCIENTIST POSITION LDEO OF COLUMBIA UNIVERSITY.

Lamont-Doherty Earth Observatory invites applications for a Postdoctoral Research Scientist in Isotope Geochemistry of Sedimentary Systems. The research will focus on the extraction of dust from ice-cores and measurement of its mineralogic and radiogenic isotope compositions. These analytical results will be compared to fractions of sediments from possible source areas of the dust to try to determine the provenance of the latter. The main responsibilities of the PDRS will be laboratory manipulation of the samples and analysis. Due to the extremely small quantities of dust available and therefore the need for extreme cleanliness and care, a high level of manual facility and an attitude of caution is required; clumsy or careless persons need not apply. Analytical capabilities required are familiarity with digestion and chemical separations for radiogenic isotopes, and TIMS (Thermal Ionization Mass Spectrometry). Familiarity with X-ray diffraction is desireable. The PDRS will be expected to participate in the interpretation of the data. Duties may also include participation in additional sample collection under arduous, cold-weather field conditions in polar regions.

The position requires a Ph.D. in Geochemistry or in a related field with experience in the analytical and interpretive requirements outlined above

To apply, please send a curriculum vitae including an e-mail address, a publication list, a statement of research interests, and the names and addresses (including e-mail, if known) of three references to: Dr. Pierre E. Biscaye, Lamont-Doherty Earth Observatory of Columbia University, 61 Route 9W, Palisades, New York 10964 USA. Inquiries may also be sent to biscaye@ldeo.columbia.edu. Consideration of applications will begin on 15 Aug 2000 and will continue until the position is filled. Minorities and women are encouraged to apply.

Columbia University is an equal opportunity/ affirmative action employer.

Services & Supplies

GEOSCIENCE BOOKS: Specializing in out-of-print and rare publications in Geology and related sciences. Now in our 10th year of full-time service to the profession. Over 75,000 titles in stock. Michael Dennis Cohan, Bookseller, 319 Mineral Ave., Libby, MT 59923-1953. Phone (406) 293-2982, fax 406-293-2983. E-mail: mdc@geosciencebooks.com. Free printed catalogs or visit the website at www.geosciencebooks.com for online catalogs and special sales. Want lists welcome, collections purchased.

RECENT, RARE, AND OUT-OF-PRINT BOOKS. Find our on-line catalog at http://home.earthlink.net/~msbooks for books on Geology, Mining History, USGS, and Western Americana; e-mail: msbooks@earthlink.net. For free printed catalogs send your request and area(s) of interest to MS Book and Mineral Company, P.O. Box 6774, Lake Charles, LA 70606-6774.

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

Opportunities for Students

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

California Institute of Technology, Postdoctoral Scholars in Tectonics. The Division of Geological and Planetary Sciences at Caltech seeks outstanding candidates for postdoctoral positions in the broad field of Tectonics. Areas of interest include: geodynamics, seismology, neotectonics, regional geology, geodesy, and paleoseismology. Utilization of modern techniques and data (e.g., satellite/airborne imaging, GIS, numerical modeling, seismic arrays) will be essential. The start date is flexible but applications must be received by Sept. 1, 2000. The duration of the appointment is two years, contingent upon good progress in the first year. Completion of the Ph.D. is required. Applications may be obtained on the web at: http://www.gps.caltech.edu/forms/postdocform.html or by writing to: Tectonics Postdoctoral Search Committee Division of Geological & Planetary Sciences, 170-25 Caltech, Pasadena, California 91125. For further information, please contact: Marcia Hudson, GPS Division Office, 170-25 Caltech, Pasadena, CA 91125 (tel: 626/395-6111, email: marcia@gps.caltech.edu). Postdoctoral Scholars are eligible to participate in Caltech health plans. Caltech is an Equal Opportunity/Affirmative Action Employer. Women, minorities, veterans, and disabled persons are encouraged to apply. ■