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INSIDE

Gas Hydrates: Greenhouse Nightmare? Energy Panacea or Pipe Dream?

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ABSTRACT

Recent interest in methane hydrates has resulted from the recognition that they may play important roles in the global carbon cycle and rapid climate change through emissions of methane from marine sediments and permafrost into the atmosphere, and in causing mass failure of sediments and structural changes on the continental slope. Their presumed large volumes are also considered to be a potential source for future exploitation of methane as a resource.

Natural gas hydrates occur widely on continental slope and rise, stabilized in place by high hydrostatic pressure and frigid bottom-temperature conditions. Change in these conditions, either through lowering of sea level or increase in bottom-water temperature, may trigger the following sequence of events: dissociation of the hydrate at its base, weakening of sediment strength, major slumping, and release of significant quantities of methane in the atmosphere to affect enhanced greenhouse warming. Thus, gas-hydrate breakdown has been invoked to explain the abrupt nature of glacial terminations, pronounced ^{12}C enrichments of the global carbon reservoir such as that during the latest Paleocene thermal maximum, and the presence of major slides and slumps in the stratigraphic record associated with periods of sea-level lowstands. The role of gas hydrates in controlling climate change and slope stability cannot be assessed accurately without a better understanding of the hydrate reservoir and meaningful estimates of the amount of methane it contains. Lack of knowledge also hampers the evaluation of the resource potential of gas hydrates, underscoring the need for a concerted research effort on this issue of significant scientific importance and societal relevance.

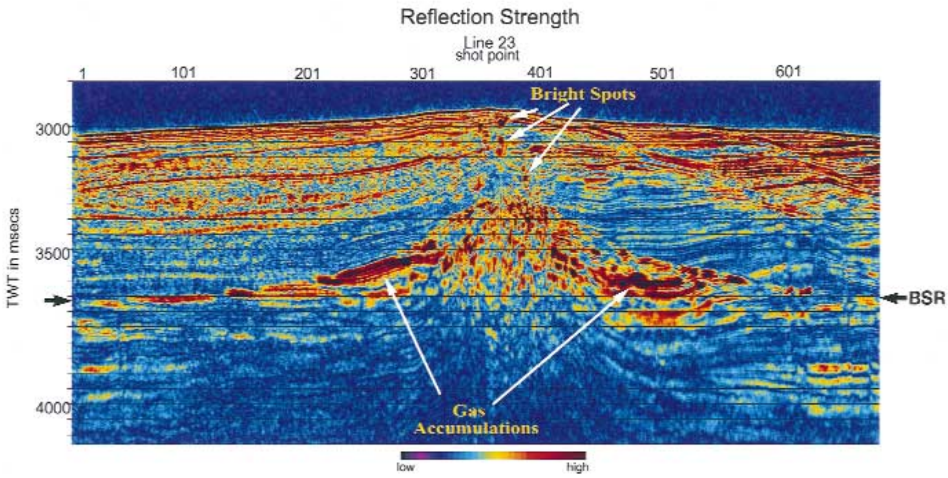

Figure 1. This seismic profile, over the landward side of Blake Ridge, crosses a salt diapir; the profile has been processed to show reflection strength. The prominent bottom simulating reflector (BSR) swings upward over the diapir because of the higher conductivity of the salt. Note the very strong reflections of gas accumulations below the gas-hydrate stability zone and the “blanking” of energy above it. Bright Spots along near-vertical faults above the diapir represent conduits for gas venting. (After Taylor et al., 1997. Courtesy of W. P. Dillon, USGS.)

INTRODUCTION

Recently, politicians have joined scientists and engineers in their interest in gas hydrates. The 105th Congress of the United States is on the verge of enacting a bill to promote gas-hydrate research under the aegis of the Department of Energy. Scientists view gas hydrates (also known as clathrates) as potential *agents provocateurs* for global climate change and continental margin tectonics. Politicians' interest is predicated on the premise that gas hydrates may represent a huge untapped source of energy for their constituents.

Natural gas hydrates (crystalline solids composed mostly of methane and water) are present in marine sediments on the continental slope and rise (Fig. 1) under the dual conditions of high hydrostatic pressure (>50 bar) and low ambient temperature at the sediment-water interface (<7 °C). They also occur associated with permafrost and at shallower submarine depths in the high latitudes of the Arctic. The hydrate consists of a lattice of water molecules enclosing gas molecules (usually methane, but also higher-order hydrocarbons), and at least three structures have been identified (e.g., Sloan, 1998). Methane in hydrates is commonly of biogenic origin, but thermogenic methane also occurs in hydrates, vented to shallower depths through subsurface conduits (e.g., MacDonald et al., 1994). Estimates of total hydrate volumes vary widely, but even the relatively conservative estimate of Kvenvolden (1988), 10^4 Gt (gigaton) of methane carbon (1 Gt = 10^{15} g), exceeds estimates of organic carbon from all other sources, with the exception of dispersed carbon in the lithosphere, and is approximately double the estimate of carbon from known fossil-fuel sources (Kvenvolden, 1988). Whether or not these estimates of large amounts can be translated into a viable energy source is a crucial question that has been the focus of researchers in many countries. The petroleum industry to date has largely ignored methane hydrates because of the difficulties in estimating and extracting the resource and distributing it to consumers.

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DISTRIBUTION AND ESTIMATES OF GAS HYDRATES

The requirements for the stability of gas hydrate (low bottom water and thus low sediment temperature, as well as high pressure [Fig. 2]; see also, Ruppel, 1997) are theoretically met over a high percentage of the seafloor of the continental slope and rise where water depth exceeds 530 m in the low latitudes and 250 m in high latitudes. Rapidly deposited sediments with high biogenic content are well suited for the genesis of large quantities of methane by bacterial alteration of the buried organic matter. Relatively high gas content in pore waters (i.e., amount of methane dissolved in pore waters is in excess of local solubility of methane) is considered to be a prerequisite for the formation of hydrate (Kvenvolden and Barnard, 1983; Zatsepina and Buffett, 1997).

Gas hydrates in marine sediments have been detected since the 1970s (e.g., Markl et al., 1970; Shipley et al., 1979) by the presence of the so-called bottom simulating reflectors (BSRs). BSRs usually delineate the top of the free-gas zone that may occur at or below the base of the gas-hydrate stability zone (GHSZ) (Fig. 1). A significant quantity of free gas must be present below the hydrate to provide the velocity contrast for a BSR, as revealed by Ocean Drilling Program (ODP) drilling on the Blake Plateau, off the southeast coast of the United States. There, hydrate also exists with no discernible BSRs at its base when a significant amount of free gas is lacking below the base of the GHSZ (Paull et al., 1996b).

BSRs have been observed on many continental margins of the world (e.g., Kvenvolden, 1993), but hydrates have been sampled only rarely. In spite of the new data from recent ODP drilling in hydrate fields (e.g., Legs 141, 146, 164),

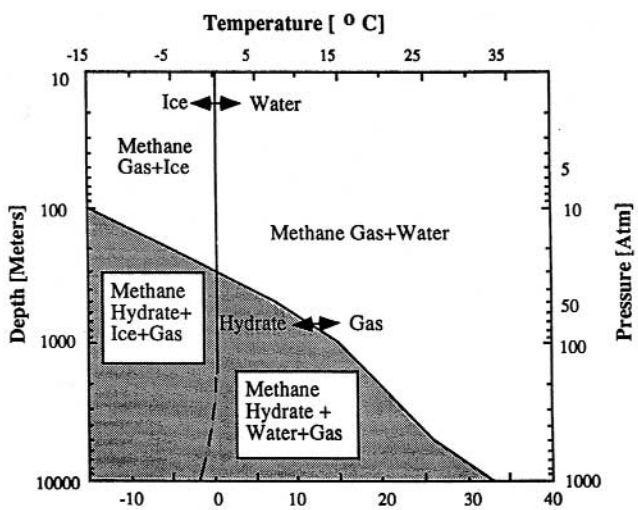

Figure 2. A gas-hydrate phase diagram illustrating the temperature- and pressure-dependent boundaries between the hydrate (shaded) and free methane gas and between ice and water. (After Kvenvolden, 1988.)

the general lack of ground-truthing means that the volumes of methane trapped in hydrates, or in associated free gas, remain largely speculative. Blake Ridge remains the only hydrate field where multiple estimates of the volume of hydrate are available from seismic reflection profiling, vertical seismic profiling, and direct measurements on cores obtained from the GHSZ and below (Paull et al., 1996b; Holbrook et al., 1996; Dickens et al., 1997). The in situ measurements indicate that as much as 35 Gt of methane carbon may be tied up in the Blake Ridge clathrates, equal to about 7% of the carbon in total terrestrial biota (Dickens et al., 1997).

Gas hydrates can also be detected through well-log response; high electrical resistivity, high acoustic (P-wave) velocity, and significant release of gas during drilling are known to characterize the presence of gas hydrate (Collett et al., 1988; Bangs et al., 1993). Reduction in pore-water chlorinity during drilling can also indicate dissociation of gas hydrate and therefore its recent presence (Hesse and Harrison, 1981). Chloride anomalies occur when the hydrate molecule crystallizes and expels salts, causing surrounding pore water to become more saline initially. Subsequently, advection and diffusion homogenize the salinity gradient, and later dissociation of gas hydrate will lead to apparent freshening of pore water. Such chloride anomalies within the GHSZ depths have been observed in the sites drilled by ODP on the Blake Ridge and elsewhere (Dickens et al., 1997). Other indications of the presence of gas hydrates at depth may include gas-escape features such as mud volcanoes and other diapirs. On some areas of the continental slope of the Gulf of Mexico with high gas flux, hydrates crop out on the seafloor. There, they are commonly associated with a diverse and specialized biota, with gas-hydrate–associated chemosynthetic bacteria at the base of the food chain (MacDonald et al., 1994) (see Fig. 3).

Global estimates of the total methane trapped in and beneath gas-hydrate reservoirs vary widely. Guesstimates of amounts trapped in marine sediments range from 1700 to 4,100,000 Gt of methane carbon (Kvenvolden, 1993), variations reflecting effects of many simplifying assumptions. For example, one estimate includes only areas characterized by >1% organic matter, a 0.5 km gas hydrate zone, and a porosity of 50%, hydrate occupying 10% of pore space (Kvenvolden and Claypool, 1988). In contrast, another estimate is based on porosity of 2% to 4%, with clathrate in only 1% of the pore space (MacDonald, 1990). Application of disparate assumptions over large but potentially heterogeneous areas is problematic, and lack of information on the amount of free gas trapped underneath the gas hydrates only compounds the uncertainty in estimating the total gas reservoir.

SCENARIOS OF RAPID CLIMATE CHANGE

The pressure and temperature conditions necessary for the stability of the gas hydrate (see Fig. 2) imply that any major change in these controlling factors will tend to alter the zone of gas-hydrate stability. For example, a significant drop in sea level will reduce hydrostatic pressure on the slope and rise. This will cause the GHSZ to thin by dissociation of the hydrate at its base. Dillon and Paull (1983) suggested that the sea-level drop of about 120 m during the last glacial maximum reduced hydrostatic pressure sufficiently to raise the base of the GHSZ by about 20 m. The basal destabilization would have created a zone of weakness where sedimentary failure could take place. This may have led to major slumping, documented by the presence of common Pleistocene slumps worldwide—e.g., the North Sea, the Bering Sea, offshore West Africa, U.S. Atlantic margin, Gulf of Mexico, and elsewhere (Bugge et al., 1987; Collett et al., 1990; Kayen and Lee, 1991; Kvenvolden, 1993; Booth et al., 1994; Paull et al., 1996a).

Submarine slumping related to gas-hydrate dissociation may cause rapid terminations of glacial events (Paull et al., 1991). At some stage during the glaciation, slumping may liberate significant amounts of methane, causing greenhouse warming. As the frequency of slumping and methane release increases, a threshold eventually may be reached above which added methane could cause glacial melting. Paull et al. (1991) attributed the abrupt terminations of Pleistocene glacial events to such a process.

During glaciation, more methane would be released at lower latitudes than at higher latitudes, where glacially induced freezing would inhibit hydrate dissociation. However, once deglaciation begins, a small increase in atmospheric temperature at higher latitudes could cause significant methane release (and warming). For example, a small triggering event leading to liberation of one or more Arctic gas pools could initiate massive release of methane from the permafrost, ushering in accelerated warming. This mechanism has been invoked to explain the abruptness of the end of the Younger Dryas (~10,000 yr ago), and it has been suggested that gas hydrates may play a dominant role in recharging the biosphere with carbon dioxide (the main oxidation product of methane) near a glacial termination (Nisbet, 1990).

It is conceivable that a combined effect of sea-level-lowstand–induced slumping and methane release in low latitudes triggers a negative feedback to glaciation as suggested by Paull et al. (1991), and the ensuing degassing of carbon dioxide from the ocean and eventual warming in the higher latitudes leads to further release of methane from near-surface sources, as envisioned by Nisbet (1990). In this feedback-loop scenario, the former would help force a reversal of the glacial episode, and the latter could reinforce the trend, resulting in apparent rapid warming observed at the end of the glacial cycles (Haq, 1993).

Kennett et al. (1996) found evidence in Santa Barbara Basin for rapid warming episodes in the late Quaternary that are synchronous with warming associated with Dansgaard-Oeschger (D-O) events in the Greenland ice record. The ice cores indicate that the D-O events were commonly characterized by rapid warming, transitions from glacial to interglacial modes lasting only a few decades. In the Santa Barbara Basin cores, relatively large excursions of $\delta^{13}C$ (up to 5‰) in benthic foraminifera are associated with the D-O events. During several brief intervals the planktonics also show large negative shifts in $\delta^{13}C$ (up to 2.5‰), implying that the entire water column may have experienced rapid ^{12}C enrichment. One plausible mechanism for these changes may be the liberation of methane from clathrates during the interstadials. Thus, abrupt warmings at the onset of D-O events may have been forced by dissociation of gas hydrates, modulated by temperature changes in overlying intermediate waters.

At least one modeling study has played down the role of methane release from hydrate sources as a major climate modulator. Harvey and Huang (1995) modeled heat transfer and methane destabilization processes in oceanic sediments in a coupled atmosphere-ocean model and found hydrate dissociation effects to be less important than the effects of increased carbon dioxide emissions resulting from anthropogenic activity. In a worst-case scenario, global warming increased by 10%–25% more with gas-hydrate destabilization than without. These models, however, did not take into account the associated free gas beneath the hydrate zone that may play an additional and significant role as well.

Several unresolved problems remain with the rapid-climate-change models. The feedback scenario assumes a time lag between events as they shift from lower to higher latitudes, but the duration of the lag remains unknown. A short duration (tens to hundreds of years) is implied by the ice-core records, but fine-scale time resolution (50 years or better) needed to clarify the leads and lags is not available. Another large uncertainty is

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the fate of methane released from hydrate sources in the water column. How much of this is dissolved in the water and what proportion is emitted to the atmosphere?

Changes in $\delta^{13}C$ composition of the carbon reservoir may provide a signature preserved in the longer-term geological record of significant methane release into the ocean. The $\delta^{13}C$ of methane in gas hydrates averages about –60‰ (PDB) (Kvenvolden, 1993), perhaps the lightest (most enriched in ^{12}C) carbon anywhere in the Earth system. Dickens et al. (1995) argued that massive methane release from gas-hydrate sources is the most likely mechanism for the pronounced input of carbon enriched in ^{12}C during a period of rapid bottom-water warming.

In the latest Paleocene, bottom-water temperature increased rapidly (in <10,000 yr) by as much as 4 °C, with a coincident excursion of up to –3‰ in $\delta^{13}C$ of all carbon reservoirs worldwide (Kennett and Stott, 1991). Dickens et al. (1995) maintained that this rapid excursion cannot be explained by the usual suspects of increased volcanic emissions of carbon dioxide, changes in oceanic circulation, and/or increased terrestrial and marine productivity. However, the recorded rapid warming of bottom waters at this time from 11 to 15 °C could have altered the sediment thermal gradients leading to methane release from gas hydrates. Increased flux of methane into the ocean-atmosphere system and its subsequent oxidation to CO_2 is sufficient to explain the –2.5‰ excursion in $\delta^{13}C$ in the inorganic carbon reservoir. Adding large quantities of carbon dioxide to the ocean should also increase its acidity, leading to elevation of the lysocline and greater carbonate dissolution. Although there is some indication of increased carbonate dissolution in the late Paleocene, its extent and magnitude are unclear. Dickens et al. (1995) suggested that explosive volcanism, rapid release of carbon dioxide, and changes in the sources of bottom water during this time are plausible triggering mechanisms for the peak warming that may have led to gas-hydrate dissociation.

SLOPE STABILITY ISSUES

Decomposition of gas hydrates and weakening of the mechanical strength of sediments that encourages failure along low-angle faults may produce more coherent slides and slumps rather than chaotic debris flows (Haq, 1998). Examples include: (1) slump features expressed as low-angle faults that sole out at or above BSR levels in the Carolina Trough area (Paull et al., 1989), and (2) a series of slumps with a composite slump scar of 290 km and a runoff of 800 km off the Norwegian continental margin (Storregga) which have been ascribed to earthquakes and gas-hydrate dissociation (Bugge et al., 1987; Jansen et al., 1987).

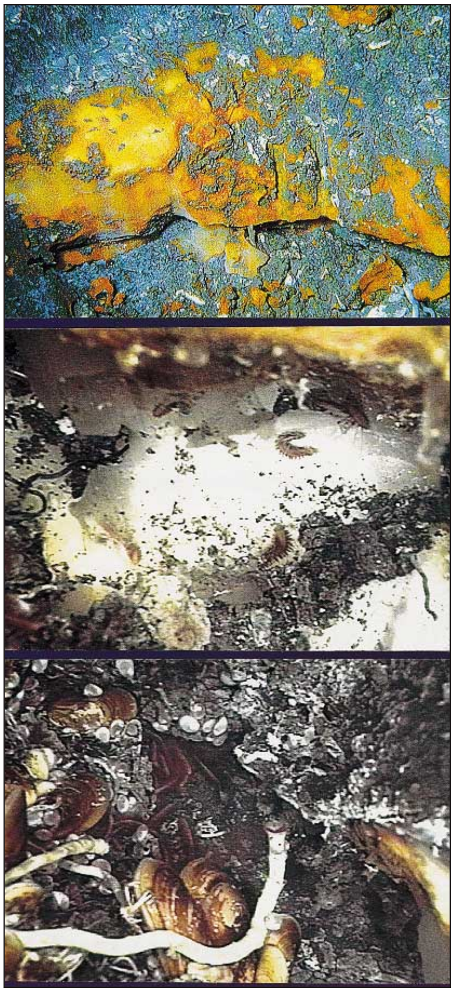

Figure 3. Outcrops of gas hydrates on the floor of the Gulf of Mexico at about 535 m water depth. Top: "Yellow ice" represents a hydrate formed from methane vented to the seafloor via subsurface conduits. The hydrate lens is about 150 cm across and 50 to 75 cm thick. Middle: "White" hydrate with the newly discovered polychaete worms on its surface. The worms, which are 2–3 cm long, forage on the chemosynthetic bacteria associated with the gas hydrate. Bottom: Commonly, a diverse biotic assemblage is associated with outcropping hydrate; this photo shows tubeworms, mussels, orbinid polychaetes, gastropods, Alvinocaris shrimp, and Munidopsis crabs. (Photos by I. MacDonald and S. Mackovoy. Courtesy of I. R. MacDonald, Texas A&M University.)

Is there geological evidence of increased slump frequency associated with major sea-level drops in the sedimentary record that can be ascribed to gas hydrate breakdown? In a seismic stratigraphic study, Mountain and Tucholke (1985) and Mountain (1987) documented four periods of Paleogene slumping and infilling along the New Jersey slope (at the Cretaceous-Tertiary boundary, the Paleocene-Eocene boundary, the top of the lower Eocene, and in the middle Eocene) and a widespread unconformity near the Eocene-Oligocene boundary. Near the top of the lower Eocene, a megaslump that is compositionally similar to enclosing sediments seems to have traveled several kilometers downslope to its present position. Mountain and Tucholke (1985) and Mountain (1987) suggested slope failure related to episodic collapse of the underlying Mesozoic carbonate margin as the probable cause. However, all events except the K/T boundary event documented on this margin occur close to major sea-level lowstands (see Haq et al., 1988). Some slump blocks maintain their original bedding. These features can be readily explained in terms of gas-hydrate destabilization, following sea-level falls and reduced hydrostatic pressure. This could also explain the apparent coeval shelf and slope erosion associated with some of these events, since during lowstands the subareally exposed shelf would be prone to extensive erosion while the slope will suffer from accelerated slumping caused by gas-hydrate dissociation.

These ideas, nevertheless, are largely conjectural and require testing. A reexamination of seismic and stratigraphic data for evidence of low-angle normal faults, major slumping and sliding within gas hydrate field depths along continental margins, and associated large negative $\delta^{13}C$ excursions could point to causal linkages between gas hydrates and sedimentary tectonic processes (Haq, 1998).

EXPLOITATION OF GAS HYDRATE AS A RESOURCE

Methane is a clean-burning fuel, and clathrate concentrates >160 times more methane in the same space as free gas at atmospheric pressure. Thus, natural gas hydrates are considered by many to represent a viable, though as yet unproven, resource of methane.

Direct measurements of methane in hydrated sediments and the free gas below have been made only during ODP Leg 164 (Paull et al., 1996b; Dickens et al., 1997). These results indicate that large quantities of methane are stored in gas hydrates on the Blake Ridge, and even more as free gas below the hydrate. In the GHSZ (between 200 and 450 m below seafloor) the volume of the gas hydrate, on the basis of direct measurements, was estimated to be up to 9% of the pore space (Dickens et al., 1997), and between 5% and 7% on the basis of vertical seismic profile velocity data (Holbrook et al., 1996). Though the clathrate is mostly finely disseminated in the sediment, there are also intermittent hydrate bodies up to 30 cm thick. Below the GHSZ, pore spaces are saturated with free gas. Thus, the total

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To Develop New Publication Series

GSA Field Guide Editor Named

David R. Lageson has been appointed editor of the new GSA Field Guide series by the GSA Council. Lageson, a professor of geology at Montana State University (Bozeman), will initiate the series with the 1999 GSA Annual Meeting in Denver. His appointment is effective through 2001.

Previously, Tommy Thompson of Colorado State University edited some field guides for GSA meetings, and these were published through the Society of Economic Geologists (SEG) guidebook series. Lageson plans to incorporate Thompson's high standards and consistent format into the new GSA series.

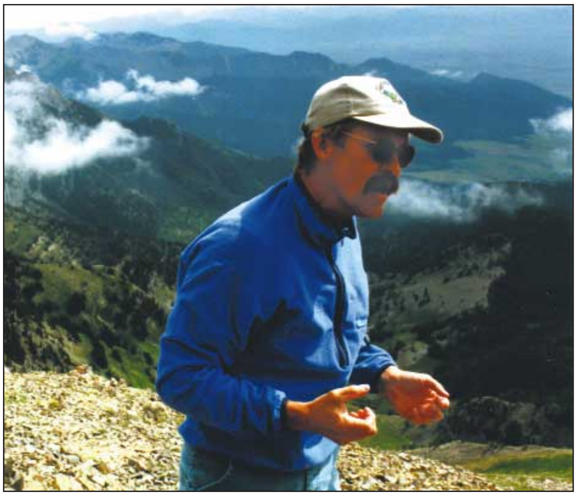
Plan for the New Series

The GSA Field Guide series will reflect the Society's mission in several ways. The series will foster understanding of the earth by documenting important field localities and relationships in a format that is accessible to a broad spectrum of people, extending beyond the community of professional earth scientists.

As the first editor of the GSA Field Guide series, Lageson says he hopes that the publications will be much more than a collection of road logs and field reports, "which admittedly have had their place in the spectrum of professional literature, but are often too limited in substance and readership appeal." Lageson's plan includes the following goals:

- To develop a series that disseminates field guide data in an exciting, readable format that appeals to professional earth scientists, educators, and non-geologists;
- To avoid the conventional road log format;
- To develop a parallel series of field guides for K–16 educators with "active" learning modules for students and teachers;
- To set a standard for consistently high-quality, refereed field guide products;
- To publish only the highest quality maps, diagrams, photographs, computer-generated illustrations, and other graphics;
- To explore new, innovative ways to translate geologic field guides into educational, interactive products that have wide appeal to the scientifically literate public;
- To encourage field trips and guides for national meetings that capture the excitement and appeal of field-based geologic inquiry.

"This is a wonderful opportunity for the Society to launch a new publication series, at a turning point when many changes are taking place in how science is being conducted in the public eye and how information is made accessible," Lageson said. "As professional earth scientists we hold a responsibility to promote public outreach and education, to address those geological issues that affect the greater good of society, and to disseminate information about the earth in formats that do the greatest good to the greatest number. Field geology is the historical essence of our discipline, and it will surely remain a vital component of future research and discoveries that shape the way we view the earth. The new field guide series will comprise important publications that will, I hope, not only serve our profession well, but also serve the needs of field-based public education and outreach."



New GSA Field Guide series Editor Dave Lageson leads a field trip in the Bridger Range, southwest Montana.

In the Field

Lageson, a GSA Fellow, has been a professor of geology at Montana State University for 18 years; he was department head for 5 years. He earned a Ph.D. in structural geology at the University of Wyoming in 1980. His areas of interest are structural geology and tectonic evolution of the northern Rocky Mountain region with emphasis on neotectonics and active tectonics surrounding the contemporary Yellowstone hotspot. He has led structural field trips for regional and national meetings of various geological societies, oil and gas companies, and minerals exploration companies, as well as numerous academic field trips at Montana State University. ■

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volume of methane on the Blake Ridge may be significantly larger than that inferred from seismic data and may be as large as 12% (Dickens et al., 1997).

From the point of view of recoverability, the free gas below the GHSZ, if it is present in sufficient quantities, could be recovered first. Eventually, the gas hydrate may itself be dissociated artificially and recovered through injection of hot water or through depressurization.

Although the hydrocarbon industry has had a long-standing interest in clathrates (largely because of their nuisance value in clogging up gas pipelines in colder high latitudes and in seafloor instability for rig structures), their reluctance to give whole-hearted support to gas-hydrate research as an energy resource stems from several factors. Many in the industry believe that the widely cited large estimates of methane in gas hydrates on the continental margins may be grossly overstated (e.g., Hovland and Lysne, 1998). Moreover, if the hydrate is mostly thinly dispersed in the sediment rather than concentrated, it may not be easily recoverable, and thus not cost-effective to exploit. One suggested scenario for exploitation of such dispersed resources is excavation (open-pit style) rather than through drilling, which is environmentally a least acceptable option. Finally, if recovering methane from hydrate ever becomes feasible, it may have important implications for slope stability. Because most hydrates are on the continental slope, extracting the hydrate or recovering the free gas below the GHSZ could cause slope instabilities of major proportions, which may not be acceptable to coastal communities. Producing gas from gas hydrates locked up in the permafrost may also be difficult, as the unsuccessful Russian efforts to do so in the 1960s and 1970s imply. The present low price of oil is another impediment to a wider industry interest in developing an alternative resource such as gas hydrate.

THE FUTURE

It is obvious that much of the uncertainty concerning the value of gas hydrates as a resource is a result of lack of information on the nature of the gas-hydrate reservoir. Understanding the characteristics of the reservoir and find-

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ing ways to image and evaluate its contents remotely may be the two most important challenges in gas-hydrate research and development. Research plans that target this goal are in the offing in many countries. With the promise of funding as a result of the U.S. Congress initiative, starting in the year 2000, the Department of Energy has begun to plan an ambitious program of gas hydrate R&D for the next 10 to 15 years. The plan includes focused efforts in five major components of gas-hydrate research (resource characterization, production, global climate change, safety, and seafloor stability) and is being conceived as a combined industry, academia, and government effort aimed at determining the efficacy of methane hydrate as a resource by the year 2010.

Some of the scenarios concerning the role of gas hydrate in rapid climate change and slope instability have been touched upon here, but many major questions remain unanswered. Whether clathrates will prove to be an enormous untapped source of energy for the future, as many hope, can only be resolved after a better knowledge of the gas hydrate reservoir and more meaningful global estimates have been acquired. This underscores the need for more focused and accelerated research on this issue of fundamental importance to sedimentary geology.

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In Memoriam

I. Enver Altinli
Istanbul, Turkey

Joseph W. Berg, Jr.
Falls Church, Virginia

Steven F. Caldwell
London, Kentucky

William K. Liddicoat
Clarkston, Michigan
May 3, 1998

Louis Lippitt
Santa Maria, California

Henry J. Moore II
Menlo Park, California
September 21, 1998

S. Spencer Nye
Brownsville, Texas

Loris S. Russell
Toronto, Ontario
September 1998

Harold E. Vokes
New Orleans, Louisiana
September 16, 1998

W. Arthur White
Urbana, Illinois
August 13, 1998

Marion I. Whitney
Shepherd, Michigan
September 16, 1998

GSA Grants Support Student Research

__Leah J. Carter,__ Research Grants Administrator

Grants for Graduate Students

The purpose of the general research grants program is to provide partial support of master's and doctoral thesis research in earth science for graduate students at universities in the United States, Canada, Mexico, and Central America. GSA strongly encourages women, minorities, and persons with disabilities to participate fully in this grants program. Applicants need not be members of GSA. Funding for this program comes from several sources, including GSA's Penrose and Pardee endowments, the National Science Foundation, industry, individual GSA members through the Geostar and Research Grants funds, and numerous dedicated research funds that have been endowed at the GSA Foundation by members and families.

Applications

Applications must be on current GSA forms, available in geology departments in the United States and Canada, or from the Research Grants Administrator, GSA, P.O. Box 9140, Boulder, CO 80301-9140, lcarter@geosociety.org. Application forms and information will be available on GSA's Web page, http://www.geosociety.org, as of December 1, 1998. Evaluations from two faculty members are required on GSA appraisal forms. Applications and appraisals may be downloaded from the Web but will *not* be accepted by e-mail or facsimile. The deadline is *February 1* each year for grants awarded in April. In 1998, 443 proposals were received, 187 of them were funded. A total of $309,315 was awarded.

Specialized Grants

Recipients of special named awards are selected by the Committee on Research Grants from applicants to the general research grants program; the same application forms are used, and they must also be postmarked by February 1. It is not necessary for applicants to indicate that they wish to be considered for a specialized grant. The committee considers all qualified applicants when selecting recipients for special awards.

The Gretchen L. Blechschmidt Award supports research by women interested in achieving a Ph.D. in the geological sciences and a career in academic research, especially in the fields of biostratigraphy and/or paleoceanography, and who have an interest in sequence stratigraphy analysis, particularly in conjunction with research into deep-sea sedimentology.

The aim of the John T. Dillon Alaska Research Award is to support research that addresses earth science problems particular to Alaska, especially field-based studies dealing with structural and tectonic development, and those that include some aspect of geochronology (either paleontologic or radiometric) to provide new age control for significant rock units in Alaska.

The Robert K. Fahnestock Memorial Award is made annually to the applicant with the best application in the field of sediment transport or related aspects of fluvial geomorphology.

The Lipman Research Award is intended to promote and support graduate research in volcanology and petrology.

The Bruce L. "Biff" Reed Award is for graduate students pursuing studies in the tectonic and magmatic evolution of Alaska and also can fund other geologic research.

The Alexander Sisson Award supports research for students pursuing studies in Alaska and the Caribbean.

The Harold T. Stearns Fellowship Award is given annually in support of research on one or more aspects of the geology of Pacific islands and of the circum-Pacific region.

Division Grants

Nine of the 12 GSA divisions award grants for outstanding student research within the respective division's field of interest. The Committee on Research Grants will select candidates from the general research grant applicants for awards by the Engineering Geology, Geophysics (Allan V. Cox Award), Hydrogeology, Sedimentary Geology, and Structural Geology and Tectonics Divisions.

The Archaeological Geology Division awards the Claude C. Albritton, Jr. Scholarships for graduate students in the earth sciences and archaeology. Contact Reid Ferring, Institute for Applied Sciences, Box 310559, University of North Texas, Denton, TX 76203.

The Coal Geology Division awards the A. L. Medlin Scholarship Award and a Field Research Award to students who submit the best proposals of research projects in the field of coal geology. Guidelines are available from the division secretary.

The Planetary Geology Division offers two S. E. Dwornik Student Paper Awards in the field of planetary geology annually. Contact Cassandra R. Coombs, Department of Geology, College of Charleston, 58 Coming Street, Charleston, SC 29424-0001.

The Quaternary Geology and Geomorphology Division awards the J. Hoover Mackin and Arthur D. Howard Research Grants to support graduate student research on Quaternary geology or geomorphology. Applications are available from the division secretary, J. Steven Kite, Department of Geology and Geography, West Virginia University, P.O. Box 6300, Morgantown, WV 26506-6300. The deadline for applications is February 15; the grants are awarded in April.

The Geoscience Education, History of Geology, and International Divisions do not currently award grants for student research.

Section Grants for Undergraduate and Graduate Students

Recipients for graduate research grants from the South-Central Section are selected from applicants to the GSA general research grants program who are recommended by the Committee on Research Grants to the Management Board of the section for final selection. Eligibility is restricted to graduate students attending a college or university within the geographic area of the section.

The South-Central Section also awards grants to undergraduate students; applications are available from the section secretary, Rena M. Bonem, Department of Geology, Baylor University, P.O. Box 97354, Waco, TX 76798-7354. The deadline is October 15; the grants are awarded in December.

The North-Central Section awards grants to undergraduate students within the geographic boundary of the section. For further information contact the section secretary.

The Southeastern Section awards grants for both undergraduate and graduate student members of GSA who are enrolled in institutions within the geographical boundaries of the section. Application forms can be obtained from the section secretary, Harold H. Stowell, Department of Geology, Box 870338, University of Alabama, Tuscaloosa, AL 35487-0338. The deadline is February 1 for grants awarded in April.

The Northeastern Section offers research grants for undergraduate students who are enrolled at institutions within the section and are Student Associates of GSA. Contact the section secretary, Kenneth N. Weaver, Maryland Geological Survey, 2300 St. Paul St., Baltimore, MD 21218-5210, for application forms. Applications must be postmarked by February 7 for grants awarded in April.

The remaining two sections—Rocky Mountain and Cordilleran—do not currently offer research grants. ■

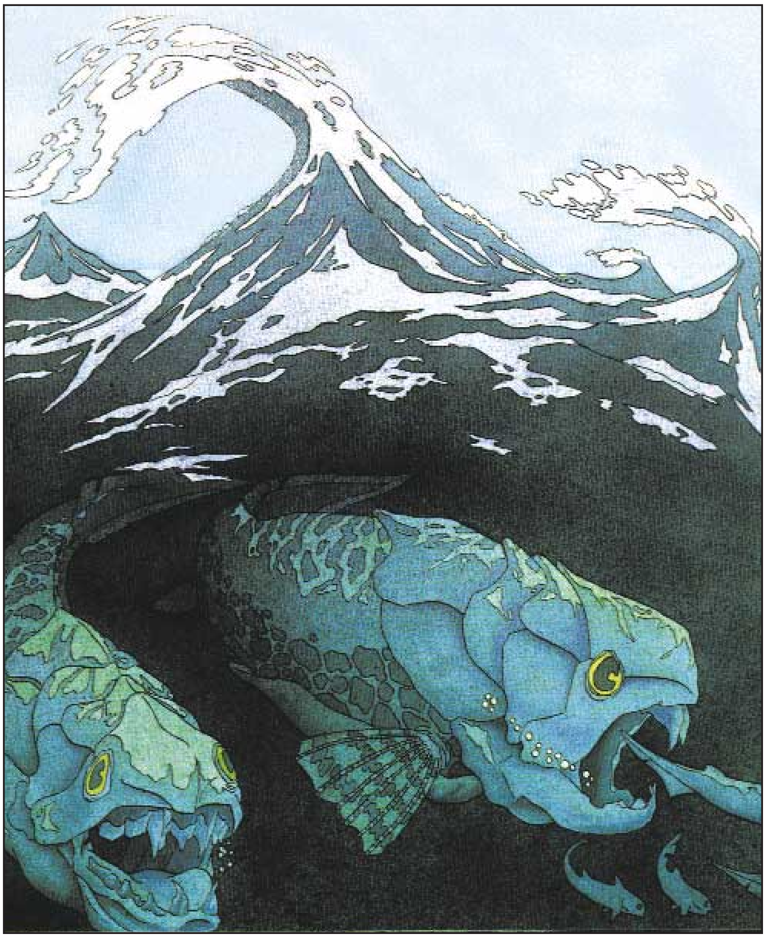
Robert Thorson, *University of Connecticut, Storrs, CT 06269, thorson@geol.uconn.edu*

Stone Wall Secrets: Geology as Environmental History

We geologists live by our stories. We believe that everyone, especially all school-age children, should be exposed to the abyss of time, the history of life, and the vision of Earth as a complex machine. So, how can we best reach our nation's children and their teachers? We must reach them by linking earthly matters to human affairs. The stone walls of New England, which stand guard over the region's past agricultural heritage, can be used to achieve this goal.

Many of the stone walls are little more than crude stacks of stone surrounding abandoned agricultural fields where oxen strained against clanking chains and where a new nation drew its sustenance from the soil. As a landform, each wall is a low, artificial ridge composed entirely of stones that were first quarried by the Laurentide ice sheet from the hard, foliated, Paleozoic bedrock, then scattered over the surface as melt-out till. Early American farmers, after clearing the forest, reversed this Pleistocene process by picking up the litter of glacial stones, then scuttling them sideways to fence lines and property boundaries, often one hand-held stone at a time. Some stones were hauled to mark the edge of private land, but most were removed as obstructions to cultivation and simply tossed beneath a wooden fence. As these linear piles of stone grew larger, and as they took up more and more of the arable space, the rubble was often restacked, and the pile realigned to form the archetype New England stone wall, held together by gravity rather than by mortar.

Stone Wall Secrets, a nonfiction geology book masquerading as literary fiction, is our attempt to capitalize on the romance, historic significance, and ecological ubiquity of stone walls in telling the geologic story of America. In our book, we deal with two broad themes: (1) environmental ethics and (2) landscape transformation, which, in our case, concerns the impact of 17th century European immigrants on the hard-rock, glaciated terrain of northeastern North America.



The Devonian placoderm *Dunkleosteus*, an illustration by Gustavus Moore, in *Stone Wall Secrets* by Kristine and Robert Thorson. Used by permission of the publisher, Tilbury House.

Walls as Teaching Tools

The plot revolves around an old man who must pass his New England farmstead down to his grandson Adam. Specifically, the old man must respond to a letter from a stonemason asking him to sell the stones from his walls. Grampa's task is to teach his grandson that their land has value not just for the raw material it contains, and not just for its real estate value, but also for the hidden story it holds: a landscape history in which geology, archaeology, and the early American experience are woven together in such a way that to sell the stones would be tantamount to selling the common heritage of all people and all time. On the pretense of an afternoon chore, the old man takes his grandson on a geology field trip, showing him that each stone wall is "like a library, stacked high with earthen books." Eventually, Grampa achieves his teaching objective, but only by urging his grandson to look closely at the stones for the clues they hold inside, to perform hand-specimen petrography without calling it that.

For geologists living and working in the forested uplands of New England, each stone wall provides a highly local, numerically integrated, random sample of the unseen bedrock below, an oracle that has been consulted by every generation of geologists since James Hutton. Collectively, they provide the window through which we can see the crust of Earth, the actual rock beneath our till-smeared and luxuriously vegetated world. By viewing stone walls as outcrops, instead of merely as cultural artifacts, we can integrate human history with natural history, and, in the process, render geology more palatable to the child not yet ready to work on the isotopic signatures of Proterozoic tectonic events. To this extent, our book is about geology everywhere, even in the "built environment" of urban settings, where exposure to rock is via that of architectural stone from buildings, graveyards, bridge abutments, sea walls, pavements, and monumental statues. The techniques geologists use—observation, uniformitarianism, induction, explanation—and the stories we tell—mountain building, denudation, climate change, human prehistory, and contemporary environmental problems—are universal ones.

Geological Stories

These are the geological stories embedded within our text:

Landscape recovery: The contemporary disintegration and weathering of stone walls, their effects on contemporary slope processes, and the development of forest entisols has taken place during the late 19th and early 20th centuries, ever since the adventure of the untamed West and the allure of growing industrial cities caused New England farms to be abandoned, then overgrown by what is now a closed-canopy second-growth forest of hickory, oak, maple, beech, and pine.

Deforestation: The period of stone wall construction, between the American Revolution and the opening of the Erie Canal, was initiated by nearly wholesale deforestation; about three-fourths of southern New England was at one time denuded of trees. Removing the canopy affected the flood runoff and base-flow hydrology of streams as well as microclimates at a variety of scales. Most significantly, however, European-style livestock husbandry altered the physics of the soil in ways that would enhance the stoniness of the landscape through rill-erosion, frost-heave, and compaction mechanisms.

Native America: The succession of Native American cultures during the past 11,000 years had little impact on the terrain of upland regions. Unglazed ceramic pottery, lithic artifacts, and fire-cracked rocks, which constitute the nonbiodegradable residue of their lifeways, have found their way, inadvertently, into stone walls throughout the region.

Glacial-interglacial transition: The ecological response of the terrain to deglaciation includes a periglacial period, a complex, no-analog period of reforestation, and the stabilization of the Holocene deciduous ecosystem; all took place between about 20,000 and 8,000 yr. B.P. Throughout the Holocene the stones from the till were progressively buried by a fine-textured solum of biological origin which, in turn, developed beneath the thick deciduous litter. These layers effectively isolated all but the largest glacial stones from the frost-heave mechanism until the forest was taken away, and with it the insulating value of mulch and forest-held snow.

Postorogenic denudation: The first-order regional physiography is dominated by a Neogene dendritic drainage network now incised deeply into a relict erosional surface that had been developing since Triassic time. The metamorphic and plutonic bedrock at the surface was created in the mountain root of the once-lofty Appalachian-Caledonian chain, and is now exposed after kilometers of denudation and isostatic compensation.

Phanerozoic mountain building took place during the Precambrian Grenville orogeny as well as during the middle and late Paleozoic Appalachian orogenies (Taconic, Acadian, Allegehenian) responsible for closing the Iapetus Ocean as Pangea was being assembled.

Planetary geology: The Hadean origin of early Earth from planetesimals, including the probability of rare, but globally significant, comet and asteroid impacts, is discussed in the context of the contemporary solar system.

Our geological stories are carefully illustrated by Gus Moore's watercolors. We used a fictional, historical, and literary style, rather than a technical one, in order to capture the attention of young students (grades 3–8). More detailed explanations of geological phenomena, classroom exercises, and additional references are provided by *Stone Wall Secrets Teachers Guide; Exploring Geology in the Classroom*, which was written by another geologist, Ruth Deike, who recently retired after more than 30 years with the U.S. Geological Survey. A dozen professional geologists either reviewed or contributed to the teachers guide.

Six Stones

Our story models the discovery process most commonly used in geology education—observation, induction, and explanation. The illustrations were drawn specifically to reinforce the geological details of the text. The rock collection we bring with us to classroom demonstrations is a simple one. Only six stones are needed to carry the story into the hands of waiting children.

Orthoquartzite: A stone interpreted as an ancient beach facies is used to evoke a scene of ancient oceans, which, in our case, features the extinct armored fish *Dunkleosteus*, a Devonian placoderm.

Gneiss: A heavy gray slab of stone is used to tell the story of continental collision and regional (orogenic) metamorphism. The illustration features a talus-littered, serrated mountain range with a smoking volcano and an ocean receiving mud destined to be pelitic rock.

Conglomerate: With this stone, we tell the story of postorogenic denudation. The illustration shows a turbulent river draining down to a gravel delta on the continental shelf.

Tillstone: From the scratches and the flat-iron shape of the stone, Adam learns that "a giant glacier oozed southward over all New England, smothering even the tallest mountains with ice." This section also includes the sequence of deglaciation, postglacial tundra, and eventual return of the forested ecosystem.

Fire-cracked Rock: Adam picks from the wall a glacial cobblestone in which iron-bearing, mafic minerals were oxidized by the high heat of a campfire. This stone informs us that, like the European immigrants, early humans also used stone as a resource, modifying it in the process.

Meteorite: Just before ending our story, we jump back to the beginning of geologic time by focusing on an iron meteorite, one too heavy to move. We use this stone to focus on the origin of Earth and the extraterrestrial origin of at least some of Earth's organic matter. The meteorite also presents an opportunity to discuss the bolide hypothesis for dinosaur extinction at the Cretaceous-Tertiary boundary, and for alluding to future, globally destructive events.

Variety of Uses

Stone Wall Secrets can be used in the classroom at different levels, and in a variety of ways.

Early elementary students benefit most when the story is read to them as they view the illustrations. It helps if they have a chance to touch and examine the stones before the reading begins, and are told that they can handle the stones later. Because they are not likely to make it through the whole story in one sitting, the text can be broken up into the separate topics of mountain building and erosion, glaciation and archaeology, and stone wall construction and abandonment.

Students at the *middle level* of ability and maturity (grades 4–6) are likely to learn best if they are asked to imagine scenes from the book. After each scene they can listen to the text, then examine the lithological evidence on which it is based.

The *maturest* students can read the book for themselves either aloud or silently. Classroom exercises and out-of-class trips to stone walls can be used to enhance learning, either individually, or in groups.

If you use *Stone Wall Secrets* or supervise its use in a classroom setting, we would appreciate hearing comments from you about what worked, and what did not. Together, we have a responsibility to tell our stories to young people everywhere.

Editor's Note

Stone Wall Secrets, by Kristine and Robert Thorson (ISBN 0-88448-195-6), is available in the children's trade section of bookstores nationwide. It can also be ordered directly from the publisher, Tilbury House, Gardiner, Maine, by phone (1-800-582-1899) or from their Web page at http://www.tilburyhouse.com. ■

WASHINGTON REPORT

Bruce F. Molnia, *bmolnia@erols.com*

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

NRC Report Finds That Radon in Drinking Water Constitutes Small Health Risk

In general, much more radon enters households through soil beneath the home than through water supplies. Radon in water does increase people's overall exposure to the gas, but radon in indoor air is the biggest public health threat. Nevertheless, the government and water suppliers should work together to develop strategies that limit potentially harmful amounts of radon in homes.

—John Doull, National Research Council Committee chair

In the winter of 1985, mine was the first home in Sioux Falls, South Dakota, to have its basement air tested for radon. The result, which indicated the presence of about one millicurie per liter of radon gas more than the Environmental Protection Agency (EPA) acceptable standard delayed the sale of the house by more than a year and resulted in local reports of "poisonous gas found in local residence." No one in the community was sure what the finding meant, whether the house was a safe place to live, or what to do about the situation. Now, a newly released National Research Council (NRC) report dealing with another aspect of household radon, radon in household water supplies, finds that waterborne radon increases people's overall exposure to the gas, but that it poses few risks to human health. The report reinforces the much higher risk posed by airborne radon.

The report, "Risk Assessment of Radon in Drinking Water," a congressionally requested study, funded by the EPA, found that drinking water that contains radon is much less of a health risk than inhaling radon. In fact, the risk of stomach cancer—the most likely health threat from consuming radon in water—is extremely small. The report estimates that about 0.0015% (20 of 13,000) of U.S. stomach-cancer deaths each year may result from consuming water that contains radon. It also found no evidence to suggest that radon causes any reproductive problems or birth defects, regardless of whether it is ingested or inhaled.

The report was prepared by the NRC Committee on Risk Assessment of Exposure to Radon in Drinking Water, a component of the Board on Radiation Effects Research. The 12-member committee, chaired by John Doull of the University of Kansas Medical Center, included U.S. Geological Survey geologist Linda Gundersen. The NRC is the principal operating arm of the National Academy of Sciences and the National Academy of Engineering. It is a private, nonprofit institution that provides independent advice on science and technology issues under a congressional charter.

The report describes radon as a gas produced from the radioactive decay of uranium that occurs naturally in rock and soil. Outside air contains very low levels of radon, but in low-circulation indoor areas, the gas builds to higher concentrations. Radon is also found in groundwater tapped by wells, which supply about half the drinking water in the United States. Water from wells usually has higher concentrations of radon than does surface water such as lakes and streams. Small amounts of radon in water can escape into the air whenever the water is used—for example, when showering or washing dishes. But because of the relatively small volume of water used in homes, the large volume of air into which radon is emitted, and the exchange of indoor air with outside air, radon in water typically adds only a small increment to overall indoor concentrations of the gas.

About 160,000 Americans, mostly smokers, die from lung cancer each year. About 8.4% (19,000) of these deaths are attributable to a combination of indoor radon and smoking. The committee estimated that about 0.01% (160) of the deaths result from inhaling radon that is emitted from household water.

In 1991 and 1994, the EPA performed its own analyses of the risks posed by radon in drinking water. The NRC committee's estimates of health risks from ingesting radon in water are lower than the EPA's. The EPA calculated that about 100 stomach, colon, and liver cancer deaths annually would result from ingesting radon—compared to the committee's estimate of 20 stomach cancer deaths per year. The committee's estimates of risks posed by inhaling radon released from water are higher than the EPA's earlier analyses; this indicated that only 86 deaths each year may result from inhaling radon emitted from household water supplies, whereas the committee estimated 160 deaths per year. The committee's risk estimates differ because it developed new models with updated biological data on the cancer-causing effects of ingesting radon. The committee also drew upon findings of a recent NRC report on health risks posed by radon in air.

The report states that to lessen the health risks posed by radon, mitigation efforts should focus on removing radon from indoor air. Reducing radon in homes can be achieved by using ventilation systems. Except in rare situations where concentrations of radon in water are very high, bringing levels of radon down in water alone will generally not significantly reduce radon-related health risks for most individuals.

Based on its own risk estimates, in 1991 the EPA proposed that the maximum contaminant level, the acceptable limit for radon in drinking water, be 11 becquerel per liter. Only about one in 14 U.S. households exceed this concentration. Next year, the EPA is required to propose a new standard for radon in water, based in part on the findings of the NRC report. Additionally, the agency must set an alternative maximum contaminant level, which provides options for mitigation in communities that have water with radon levels above the current standard. To meet this goal, the NRC Committee analysis recommends that EPA's alternative standard be set more than an order of magnitude higher, at 150 becquerel per liter of water. In water supplies containing levels of radon between the two standards, risk could be reduced by using a combination of strategies—called a "multimedia approach"—to lower the level of radon in water, lower the level of radon in homes that have high concentrations of the gas in the air, or both.

States that choose multimedia programs will need to reduce public health risks to the EPA's current standard. To meet this requirement, state plans would have to identify homes with high con-

Washington Report *continued on p. 11*

CALL FOR NOMINATIONS REMINDERS

Penrose and Day Medals, and Honorary Fellowship

Nominations for 1999 Penrose and Day Medals and for Honorary Fellowship in the Society are due by FEBRUARY 1, 1999.

Young Scientist Award (Donath Medal)

The Young Scientist Award was established in 1988 to be awarded to a young scientist (35 or younger during the year in which the award is to be presented) for outstanding achievement in contributing to geologic knowledge through original research that marks a major advance in the earth sciences. The award, consisting of a gold medal called the Donath Medal and a cash prize of $15,000, was endowed by Dr. and Mrs. Fred A. Donath.

For the year 1999, only those candidates born on or after January 1, 1964, are eligible for consideration. In choosing candidates for the Young Scientist Award, scientific achievement and age will be the sole criteria. Nominations for the 1999 award must include

- biographical information,
- a summary of the candidate's scientific contributions to geology (200 words or less),
- a selected bibliography (no more than 10 titles),
- supporting letters from five scientists in addition to the person making the nomination.

Deadline for nominations for 1999 is FEBRUARY 1, 1999.

Officers and Councilors

The GSA Committee on Nominations requests your help in compiling a list of GSA members qualified for service as officers and councilors of the Society. The committee requests that each nomination be accompanied by basic data and a description of the qualifications of the individual for the position recommended (vice-president, treasurer, councilor).

Deadline for nominations for 1999 is FEBRUARY 15, 1999.

Distinguished Service Award

The GSA Distinguished Service Award was established by Council in 1988 to recognize individuals for their exceptional service to the Society. GSA Members, Fellows, Associates, or, in exceptional circumstances, GSA employees may be nominated for consideration. Any GSA member or employee may make a nomination for the award. Awardees will be selected by the Executive Committee, and all selections must be ratified by the Council. Awards may be made annually, or less frequently, at the discretion of Council. This award will be presented during the annual meeting of the Society. Deadline for nominations for 1999 is MARCH 1, 1999.

National Awards

The deadline is April 30, 1999, for submitting nominations for these four awards: William T. Pecora Award, National Medal of Science, Vannevar Bush Award, Alan T. Waterman Award.

Materials and supporting information for any of the nominations may be sent to GSA Executive Director, Geological Society of America, P.O. Box 9140, Boulder, CO 80301. For more detailed information about the nomination procedures, refer to the October 1998 issue of *GSA Today,* or call headquarters at (303) 447-2020, extension 140.

Washington Report *continued from p. 10*

centrations of indoor radon, and mitigate those concentrations. The committee said that on their own, education and outreach programs designed to entice homeowners to reduce indoor radon would probably not be effective. Moreover, state plans would need to include air-monitoring programs to identify the homes with high concentrations of radon in air. Trained staff would be required to regularly evaluate the performance of ventilation equipment and other systems to ensure that multimedia programs meet federal requirements. Although reducing high concentrations of radon in a few homes rather than reducing radon in the water supply might meet public health standards, only the residents in these homes would receive health benefits. The cost implications for homeowners, water utilities, and state governments of reducing radon in private homes should be considered, the committee said.

Copies of "Risk Assessment of Radon in Drinking Water" are available for sale from the National Academy Press at (202) 334-3313 or 1-800-624-6242. ■

GSA would like to thank the following who have generously donated funds or services that helped support the 1998 GSA Annual Meeting in Toronto.

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Women Geoscientists in Academe: 1996–1997

Lois K. Ongley, Matthew W. Bromley, Katherine Osborne
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ABSTRACT

According to data acquired in May 1997 from the American Geological Institute's Directory of Geoscience Departments database, women constitute 12% of 7,595 geoscience teaching faculty in the United States. Among the geoscience faculty, 22% hold nontenurable positions (adjunct, visiting, lecturer, and instructor). The ranks of assistant professor, associate professor, and professor are held by 15%, 20%, and 43% of the faculty, respectively. Women occupy 17% of the nontenured positions and 22% of the assistant professor, 14% of the associate professor, and 5% of the professor positions. At most institution types, women are disproportionately employed in the lowest status positions. At two-year and undergraduate institutions (A.A. or A.S. and B.A. or B.S.), 40% of the women geoscientists are in nontenurable positions compared with 21% of the male geoscientists. At universities awarding graduate degrees (M.A. or M.S. and Ph.D.), 26% of the women and 21% of the men hold nontenurable positions.

INTRODUCTION

The distribution of women in the geoscience profession has been a topic of research for at least 50 years. A U.S. Department of Labor (1949) report notes that 3% of those geologists earning doctorates between 1931 and 1940 were women. The report also states that in 1942 women represented 7% of the college teachers.

More recent studies include those of Crawford et al. (1977, 1987) and Bunning and Sand (1985). Crawford et al. (1977) showed that from 1964 to 1975 women held fewer than 2% of the professor and associate professor positions at graduate institutions. During that same period the percentage of female assistant professors climbed from about 2% to just over 5%. On average, women were less than 3% of the geoscience faculty.

Bunning and Sand (1985) extended the work to include 1977, 1979, and 1981. By 1981, the overall percentage of women faculty at institutions granting graduate degrees was almost 5%. Women held about 8%, 5%, and 2% of the assistant professor, associate professor, and professor positions, respectively.

Crawford et al.'s 1987 study expanded to consider those persons in lecturer or instructor positions and undergraduate institutions. In 1986–1987 women held fewer than 5% of all faculty positions at graduate institutions but more than 8% of those at undergraduate institutions.

TABLE 1. RELATIVE PERCENTAGES OF WOMEN FACULTY IN U.S. DEPARTMENTS OF GEOLOGICAL SCIENCES IN 1986–1987

	Lecturer or instructor	Assist. prof.	Assoc. prof.	Prof.	Overall
Undergraduate	18.9	13.3	8.1	3.2	8.5
Graduate	12.6	11.8	6.3	0.8	4.6
All faculty	16.9	12.2	6.7	1.4	5.8

Note: Data are from Crawford et al. (1987) and were used to calculate the "All faculty" data.

Women held relatively more of the faculty positions at undergraduate institutions (see Table 1). Overall, in 1987 women were almost 6% of the geoscience faculty.

This study examines the distribution of women geoscience faculty during 1996–1997.

METHODS

The data used for this study were acquired courtesy of Nicolas Claudy of the American Geological Institute. The data were first sorted by rank. Persons whose title indicated that teaching was not a primary activity were removed from the list—e.g., administrative assistants, curators, librarians, secretaries, and research staff. Some entries appeared to be duplicates, and the lowest ranking entry was deleted.

Sex identification was assigned on the basis of first-name recognition and personal acquaintance. In many cases, the geoscientists listed were unknown to us, so we sought assistance from colleagues, from departmental secretaries, and from those professors who answered the departmental telephones. We were unable to determine the sex of 14 faculty members. There are undoubtedly a few errors as well.

Faculty were ranked as nontenure, assistant professor, associate professor, and professor, depending on their self-designated title. Nontenure includes lecturer, adjunct faculty, affiliated faculty, instructor, lab instructor, or visiting faculty, as well as those with more obscure titles. Some of the faculty and staff rankings may be incorrect. Professors and associate professors were assumed to be tenured.

Institutions were defined by the degrees awarded. Two-year institutions were assumed to award the A.A. or A.S. degrees. Undergraduate institutions are those that award a B.A. or B.S. degree.

TABLE 2. FACULTY IN U.S. GEOSCIENCE DEPARTMENTS 1996–1997

	Nontenure	Assist. prof.	Assoc. prof.	Prof.	Overall
All faculty					
Men	1409	860	1292	3100	6661
Women	289	245	209	178	921
Total*	1706	1107	1503	3279	7595
% women	17	22	14	5	12
Ph. D.					
Men	848	420	722	1957	3947
Women	121	111	123	103	458
Total	972	532	846	2061	4411
% women	12	21	14	5	10
M.A. or M.S.					
Men	210	150	222	500	1082
Women	48	61	37	29	175
Total	261	211	259	529	1260
% women	18	29	14	6	14
B.A. or B.S.					
Men	205	257	301	507	1270
Women	66	66	43	31	206
Total	273	324	345	538	1480
% women	24	20	12	6	14
A.A. or A.S.					
Men	146	33	47	136	362
Women	54	7	6	15	82
Total	200	40	53	151	444
% women	27	18	11	10	18

*Total faculty includes those persons with identifiable rank but undetermined sex.

Graduate institutions award M.A. or M.S. and Ph.D. degrees.

We used Microsoft Excel to manipulate and process the data. Some totals do not add to 100% because of rounding errors.

RESULTS AND DISCUSSION

Of the original data set of 11,937 persons, 1,871 were researchers, 629 were administrators, 661 were chairs or directors, 332 were other support staff, and 8,663 were teaching faculty. Some chairs were also considered teaching faculty and counted in both staff categories. Of the geoscience teaching faculty 989 (11%) were emeritus. For ease of comparing this work with earlier studies, emeritus professors were not included in the balance of the discussion, nor were faculty with unknown rank, leaving a total of 7,595 geoscience teaching faculty (Table 2).

Ph.D.-granting institutions employ the largest percentage of geoscience teaching faculty at 58%, M.A. or M.S.–granting institutions employ 17%, B.A. or B.S.–granting institutions employ 19%, and A.A. or A.S.–granting institutions employ the remaining 6%.

Almost two thirds (63%) of the geoscience faculty is tenured. Twenty-two percent of the faculty hold nontenure positions.

Gender

Women compose 12% of the non-emeritus geoscience teaching faculty in the United States (Table 2). At two-year institutions 18% of the faculty are female. B.A. or B.S. and M.A. or M.S. faculties are both 14% female. Only 10% of the faculty at Ph.D. institutions are women.

In spite of the relatively low percentage of women on Ph.D. faculties, those institutions employ the greatest number of the women geoscience faculty (49% of the female faculty, 474 persons). B.A. or B.S. institutions employ 20% of the female geoscience faculty (188 persons). A.A. or A.S. institutions employ the fewest women geoscientists at 9% (90 persons). The employment of male geoscientists follows the same trend, although the relative proportions vary somewhat.

Tenure and Rank

Although approximately two-thirds of geoscience faculty are tenured, there are significant variations in the rank distributions at the different types of institutions. The two-year institutions have the smallest percentage of tenured faculty and the largest percentage of nontenured faculty and staff (Table 3). At undergraduate institutions, increasing rank correlates with an increasing fraction of faculty at a given rank.

At graduate institutions, professors dominate the ranks; at two-year and undergraduate institutions, professors constitute about one-third of the faculty. The B.A. or B.S.–and A.A. or A.S.–awarding colleges employ about as many assistant professors as associate professors. The major difference between B.A. or B.S. and A.A. or A.S. institutions is in the larger fraction of nontenured faculty at the two-year colleges.

Relation Between Gender and Tenure Status

In general, the percentage of women geoscientists decreases up the academic ranks from assistant professor to professor (Fig. 1). The overall percentage of women faculty members also decreases with increasing institution "status," from 18% female faculty at two-year institutions to 10% at Ph.D.-granting institutions (Table 2).

The relative concentration of female faculty in lower ranks at lower-status institutions is confirmed by considering the employment of women geoscientists as a group. Nine percent of all women faculty members are employed by two-year institutions, and Ph.D.-granting institutions employ 50% of the women faculty members. This compares with 5% of male geoscientists being employed by two-year institutions and 59% of the men being employed at Ph.D. institutions.

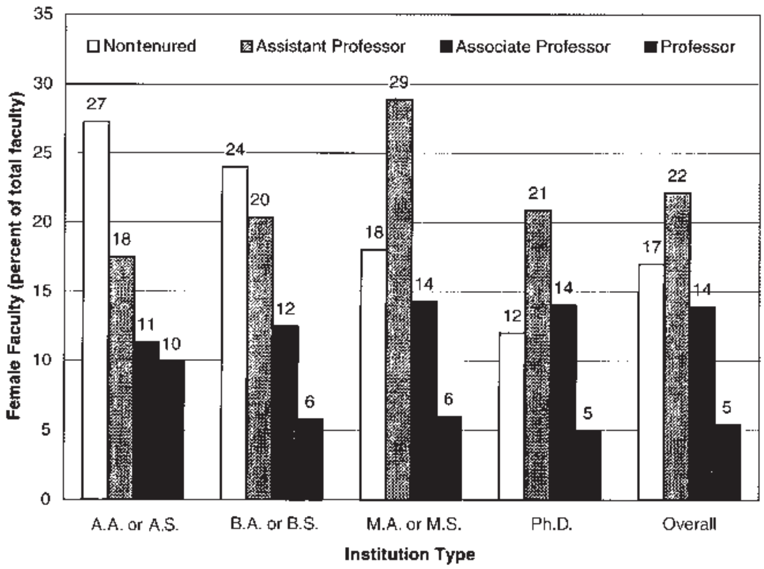

Figure 1. Relative percentage of women geoscientists by rank and institution type.

TABLE 3. PERCENTAGE OF GEOSCIENCE TEACHING FACULTY AT RANK BY INSTITUTION TYPE

Rank	A.A. or A.S.	B.A. or B.S.	M.A. or M.S.	Ph.D.	Overall
Nontenure	45.0	18.4	20.7	22.0	22.5
Assistant professor	9.0	21.9	16.7	12.1	14.6
Associate professor	11.9	23.3	20.6	19.2	19.8
Professor	34.0	36.4	42.0	46.7	43.2

CONCLUSIONS

Male geoscientists constitute about 88% of teaching faculty; therefore, that population heavily weights the overall sex distributions. In spite of this, it appears that women geoscientists are not uniformly distributed in all aspects of geoscience faculty. For example, although Ph.D.-granting institutions employ the largest percentage of geoscience faculty (66%) they employ the lowest percentage of women among degree-granting institutions (10% of their faculty is female). However, Ph.D. institutions do employ the largest number of women geoscience faculty (50% of female geoscience teaching faculty).

In general, the percentage of women geoscientists decreases as the academic rank increases. The higher ranks have fewer female faculty and more male faculty. Also, the percentage of women faculty members decreases as institution status increases. In other words, there are relatively more male faculty members at higher-status institutions than there are female faculty members.

The relative percentage of geoscience teaching-faculty women has increased since 1964. However, it appears that the participation of women as geoscience teaching faculty declined in the 1950s and 1960s and did not regain the 7% mark of 1947 until sometime between 1987 and 1997.

Women *continued on p. 14*

GSA Offers Awards in Geomorphology and Micropaleontology

Two GSA awards for support of research are a testimony to the generosity of the late W. Storrs Cole. The Gladys W. Cole Memorial Research Award provides support for the investigation of the geomorphology of semiarid and arid terrains in the United States and Mexico. It is to be given to a GSA Member or Fellow between 30 and 65 years of age who has published one or more significant papers on geomorphology. Funds cannot be used for work already accomplished, but recipients of a previous award may reapply if additional support is needed to complete their work. The amount of this award in 1999 will be $11,000.

The second award, the W. Storrs Cole Memorial Research Award, was established to support research in invertebrate micropaleontology. This award will carry a stipend of $9,000 in 1999 and will be given to a GSA Member or Fellow between 30 and 65 years of age who has published one or more significant papers on micropaleontology.

Additional information and application forms may be requested from the Research Grants Administrator, Geological Society of America, P.O. Box 9140, Boulder, CO 80301, e-mail lcarter@geosociety.org.

All applications must be postmarked on or before *February 1, 1999*. Actions taken by the Committee on Research Grants will be reported to each applicant in April.

These are two of GSA's most prestigious awards; all qualified applicants are urged to apply.

BOOK REVIEWS

In the Shadow of the Dinosaurs: Early Mesozoic Tetrapods. *Edited by Nicholas C. Fraser and Hans-Dieter Sues. Cambridge University Press, New York, 1997, paperbound, 435 p., $40.*

During the Golden Age of dinosaur collecting, from sometime after the middle of the last century until about the middle of this one, field crews filled eastern museums with giant skeletons from western badlands. It made for some spectacular displays, but skewed our perspective on the relative importance of large vertebrates. In the 1940s Hibbard, Henkel, and others developed a technique using wooden boxes, window screen, and water for concentrating the remains of small-vertebrate fossils. Our perspective changed—and continues to change as more localities are examined.

In the Shadow of the Dinosaurs is a report from the field of small-vertebrate paleontology. As such, it is in the tradition of *Mesozoic Mammals: The First Two-Thirds of Mammalian History* (edited by J. A. Lillegraven, Z. Kielan-Jaworowska, and W. A. Clemens, 1979, University of California Press). Both books owe much to the hundreds of students who screened and washed and picked through tons of fossil-poor sediments from around the world, collecting the tiny teeth and bones of small tetrapods. *In the Shadow* also continues the tradition of *The Beginning of the Age of Dinosaurs: Faunal Change across the Triassic-Jurassic Boundary* (edited by K. Padian, 1986, Cambridge University Press). Both of these books examine the changing fauna of small reptiles and amphibians across temporal boundaries defined by changes in larger animals. This tradition traces to work by J. T. Gregory and R. Estes, among others. Their students and grandstudents are important contributors to all of these books.

In the Shadow of the Dinosaurs is a well-edited compilation of contributions to a 1991 meeting in Front Royal, Virginia. The volume appeared in hard cover in 1994, but its cost ($90) kept it from students. This paperback edition is more reasonable at $40 and should provide an excellent source of readings for advanced undergraduate or graduate seminars. It is not intended as a text for an introductory class with an interest in dinosaurs.

The first quarter of the book discusses the phylogeny of Mesozoic amphibians, squamates, sphenodonts, and crocodilians, and concludes with a chapter on mammalian characters. The book's core is a baker's dozen of chapters on faunal assemblages in North America, Europe (especially Britain), and Asia. The concluding section contains more general discussions of faunal change. A final chapter provides a field guide to fossil tetrapod sites in Virginia and North Carolina.

The editors have used a consistent style for text and citations throughout, and most chapters have clear drawings of specimens. The labeling of anatomical features is uniform from chapter to chapter, and this is an advantage. Small, black and white photographs are not as helpful. The book provides an exhaustive taxonomic index, but no index at all of geographic or stratigraphic terms. It was unfortunate that this defect was not corrected in this paperback edition.

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When Geologists Were Historians, 1665–1750. *Rhonda Rappaport, Cornell University Press, Ithaca, New York, 1997, $39.95.*

The science of geology had a great awakening in the late 18th and early 19th centuries, and during this time there was a marvelous expansion in our knowledge of Earth and the processes that shape its surface. This nascent flowering of the earth

Book Reviews *continued on p. 15*

Women *continued from p. 13*

ACKNOWLEDGMENTS

We thank all our colleagues who helped us with gender identification. We take responsibility for any errors. Osborne was supported by a grant from the Hoffman-Mellon Fund for Student Research at Bates College. Bromley was also supported by Bates College. This work is dedicated to the memory of Judith B. Moody.

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Correction

In th story "1998 Honorary Fellows Named" (*GSA Today*, v. 8, no. 10, October 1998), the second sentence of the second paragraph for Werner-Friedrich Schreyer should be: "He received his doctorate from the University of Munich in 1957, and honorary doctorates from the universities of Hannover and Liege."

Book Reviews *continued from p. 14*

sciences was built on the foundation created by the preceding events and people. Yet, seldom does this period of time get the credit or scrutiny it deserves. In addition, most geologists do not fully appreciate that before the modern science of geology could develop and be understood, monumental changes had to occur in the fundamental philosophical view of our science. Rappaport has provided a unique look at this important period of time with detailed, multicontinental scholarship. She eruditely presents the relevant documentation that displays the transition to an appreciation for the human-independent, physical reality of geologic processes rather than the previous, more historical viewpoint that past geological events were subject to human witness—i.e., no different from any other past happening for which there were human records. In other words, during the time period studied by Rappaport, geologists changed from being historians in their approach and developed into true physical scientists following the pioneering work and admonition of Buffon, which is why Rappaport's inquiry stops at 1750.

Although this volume covers part of the time period described by Roy Porter (*The Making of Geology: Earth Science in Britain 1600–1815*, Cambridge University Press, 1977), Rappaport concentrates on, but does not limit her research to, events and scholars of the European continent. Also, Rappaport's fine scholarship nicely sets the stage for Mott Greene's *Geology in the Nineteenth Century: Changing Views of a Changing World* (Cornell University Press, 1982). Rappaport skillfully explores the changing view of fossils and their origin. Her sections on Diluvialism provides fresh insight on the eighteenth century debate as to whether the Great Flood was only a "miracle" of the Bible or a "fact" of history.

Anyone who has a deep interest in how the science of geology really came into its own in the late 1600s and early 1700s should look no further than Rappaport's very detailed work.

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Airborne Remote Sensing Conference Slated for June 1999

GSA is a cosponsor of the Fourth International Airborne Remote Sensing Conference, organized by ERIM International. Talks will emphasize environmental planning, risk management, atmospheric and ocean measurements, and sensors and systems technology. The meeting, in conjunction with the 21st Canadian Symposium on Remote Sensing, will be in Ottawa, Ontario, June 21–24, 1999.

GSA Division News

The Structural Geology and Tectonics Division awarded its 1998 Best Paper Award to William R. Muehlberger, Department of Geological Sciences, University of Texas, Austin. Muehlberger received this honor for his 1992 (southern sheet) and 1996 (northern sheet) *Tectonic Map of North America* (published by the American Association of Petroleum Geologists). This is the first time that the division has given the award for a map.

GSAF UPDATE

Valerie G. Brown, Director of Development, GSA Foundation

PEP Rallies

GSA's Partners for Education Program (PEP) is a rousing success!

PEP was established in 1989 as an avenue for individual members of GSA to volunteer their time and talents in furtherance of K–12 earth science education. An immediate hit, PEP enrolled 762 partners in its first four years and then received a tremendous boost with important funding support from the EXXON Foundation and a private family foundation. These investments provided resources for increased recruitment and scientist-teacher workshops. Today the program has 1,800 active volunteers available for site-based activities, and 600 of these volunteers have also signed up as on-line e-mail consultants to answer earth science questions.

Volunteer partners include:

Carlon Ami at Dine College in Tsaile, Arizona, who teams with a fifth grade class at Lukachukai Boarding School. He has provided in-class presentations, conducted field trips for the school's K–8 teachers, and has brought students to his geology lab at Dine College. Additionally, he is a consultant to the Chinle, Arizona, school district, assisting with the development of earth science curriculum materials for K–12 teaching units.

Collins Chew of Kingsport, Tennessee, retired from Eastman Chemical Co., brings "Stories Told by Rocks" to fifth grade classes at Powell Valley Middle School. This program of slides and rock samples teaches students to "read" ripple marks, mud cracks, dinosaur tracks, and fossils in order to understand the geological history of the rocks. Collins has also donated to the school library copies of his books on the geology of the Appalachian Trail.

Norb Cygan, a retired Chevron geologist, commutes from his home in Castle Rock, Colorado, to the Colorado School of Mines and the University of Northern Colorado where he teaches the teachers of science. In his free time, he is a consultant in science education with Regis University's Independent Studies Program. Norb is also very active as a docent and member of the board at Dinosaur Ridge, a part of the Morrison and Dakota Formations, containing dinosaur tracks and fossils. He has helped to turn the ridge into an outdoor learning laboratory for the use of Denver area students, teachers, and the public.

Bill Houston and Colleen Riley have served as student partners throughout their graduate studies at Michigan Technological University. Most recently they participated in a dinosaur and fossil "fair" at the Houghton Public Library for 80 children ranging in age from 3 to 14. Activities included a dinosaur art contest, the resulting pictures being displayed at the library and at MTU's geology department.

John David McFarland, of Little Rock, Arkansas, helped teachers and sixth graders in a four-county rural area with an EPA-funded water-quality project testing water samples from the students' homes, with emphasis on determining the source and quality of well water. Students from participating schools gathered at a Water Congress to present and compare their test results and data analyses.

Lynette Seigley and Deb Quade, both of the Iowa Geological Survey, led high school science students on a field trip to a hog-confinement facility. Since 1994, the Iowa Survey has been monitoring the (shallow) groundwater near the facility's

Donors to the Foundation, August 1998

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manure storage basin for evidence of seepage and contamination. Students discussed the site geology, facility design, and water-quality samples with great enthusiasm—until the wind shifted.

These are just a very few of the many examples of the ingenuity and effectiveness of PEP volunteers in supporting formal and informal earth sciences education.

The volunteers, in turn, are supported by the commitment and generosity of the PEP Club—donors who share GSA's vision about the value of local person-to-person partnerships between geoscientist, teacher, and student. The donors' investment funds PEP's $100,000 annual budget for information materials, expense reimbursements, and program coordination.

GSA's goals for PEP are

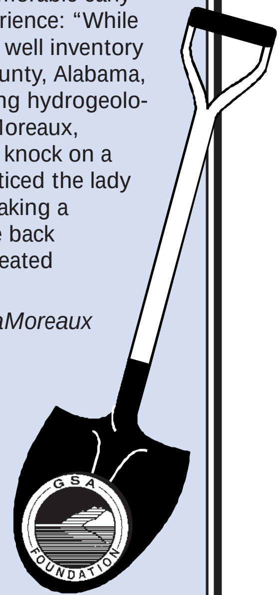
- to double participation in the next five years—to have 20% of GSA's members serving as ambassadors for the geosciences;
- to enhance collaborative activities with the community youth groups such as Boy Scouts of America, Expanding Your Horizons, a university-based program supporting middle school girls to meet women in science, and Teach for America, encouraging teachers to go into rural and inner-city schools;
- to develop collaboration with other geoscience societies;
- to expand PEP to the broad geoscience community, so that other geoscientists and organizations can share in the benefit of partnering.

That we have such dreams is a credit to all the PEP partners—volunteers and donors—whose dedication has contributed to this wonderful program. ■

Digging Up the Past

Most memorable early geologic experience: "While carrying out a well inventory in Baldwin County, Alabama, young, budding hydrogeologist Philip LaMoreaux, attempting to knock on a back door, noticed the lady of the house taking a shower on the back porch. He retreated modestly."

—*Philip E. LaMoreaux*



1999 John C. Frye Environmental Geology Award

In cooperation with the Association of American State Geologists (AASG), GSA makes an annual award for the best paper on environmental geology published either by GSA or by one of the state geological surveys. The award is a $1000 cash prize from the endowment income of the GSA Foundation's John C. Frye Memorial Fund.

Criteria for Nomination

Nominations can be made by anyone, on the basis of the following criteria:
(1) paper must be selected from GSA or state geological survey publications, (2) paper must be selected from those published during the preceding three full calendar years, (3) nomination must include a paragraph stating the pertinence of the paper, (4) nominations must be sent to Executive Director, GSA, P.O. Box 9140, Boulder, CO 80301. *Deadline: March 31, 1999.*

Basis for Selection

Each nominated paper will be judged on the uniqueness or significance as a model of its type of work and report and its overall worthiness for the award. In addition, nominated papers must establish an environmental problem or need, provide substantive information on the basic geology or geologic process pertinent to the problem, relate the geology to the problem or need, suggest solutions or provide appropriate land use recommendations based on the geology, present the information in a manner that is understandable and directly usable by geologists, and address the environmental need or resolve the problem. It is preferred that the paper be directly applicable by informed laypersons (e.g., planners, engineers).

1998 Award Recipient Named

The 1998 award was presented at the GSA Annual Meeting in Toronto, Canada, to David C. Noe, Candace L. Jochim, and William P. Rogers for their report, "A Guide to Swelling Soils for Colorado Homebuyers and Homeowners," Colorado Geological Survey Special Publication 43, 1997, 76 p.

New Director of Publications

Peggy S. Lehr

Electronic journals and speedier publication of journals and books are two of the challenges for GSA Publications Director Peg Lehr. Lehr, who began work at Boulder Headquarters in April, has 20 years of experience in publications, primarily in magazine and book publishing.

Lehr previously worked for 10 years at the Association of Operating Room Nurses in Denver, a nonprofit international nursing association with 48,000 members. There, as director of communications, she was responsible for editorial, advertising sales, public relations, production and art, circulation, marketing, and the mail and printing centers.

"I like association work because I like the commitment from the staff and volunteers—the staff tends to be service-oriented. I like the challenges of society publishing because they are diverse," Lehr said.

Lehr is enthusiastic about the changes at GSA.

"I am excited about working with a new membership and producing scholarly publications. I have always had an interest in education and GSA's publications are excellent examples of scholarly publication at its best," she said.

Lehr graduated from the University of Colorado, Boulder, with a B.S. in journalism and received an M.S. in communication from the University of Denver. Before working in the association industry, she worked in the editorial and production areas for several for-profit companies, in fields such as plastics, machinery, lifestyle magazines, and cable television marketing and engineering.

Penrose Conference Report

Processes of Crustal Differentiation: Crust-Mantle Interactions, Melting, and Granite Migration Through the Crust

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The origin and evolution of the continental crust pose intriguing questions that are being addressed by current research, and ideas on how melt segregates and migrates through the crust recently have been discussed in the literature. New insight has been triggered primarily by new laboratory and field observations. Within this context, we organized a GSA Penrose Conference to examine processes that contribute to the evolution of the continental crust. We started with six specific questions: (1)What are the dynamics of partial melting in the lower crust, and what is the rheological response of the crust to partial melting and melt transfer? (2) What is the role of crust-mantle interaction, and what geochemical signatures can be used to suggest additions of mass to the crust, crustal differentiation, and losses of mass from the crust during active deformation? (3) What are the specific links between the petrologic and structural, and the kinematic and dynamic expressions of melt migration?(4) What are the sources of heat to drive these processes? (5) What do we really need to know to test models of melt segregation and transfer in the continental crust? (6) What can we learn from recent results of research in the Ivrea-Verbano zone?

The conference, "Processes of Crustal Differentiation: Crust-Mantle Interactions, Melting, and Granite Migration Through the Crust," was held in Verbania, Italy, July 4–11, 1998. It brought together 83 geologists, with backgrounds ranging from petrology to geochemistry, from structural geology to geophysics, and from rock mechanics to magma dynamics, to consider the growth, modification, and differentiation of the continental crust. Participants came from 16 countries; 10 participants were students. Verbania is close by the Ivrea-Verbano zone, which is widely held to represent a section through the lower continental crust, uplifted and tilted to a near-vertical attitude during the Alpine orogeny. The Ivrea-Verbano zone is important because it is the putative example of magmatic underplating as the driving force for granulite facies metamorphism and depletion of lower crustal rocks by removal of a granite melt.

Field Excursions

Half the conference was devoted to field examination of rocks within the Ivrea-Verbano zone (and Permian granites within the adjacent Serie dei Laghi). An overview of the main units and structures of the Ivrea-Verbano zone is possible in the Valle d'Ossola, immediately to the west of Verbania, because of the wide valley produced by the River Toce, which cuts across the strike of the zone. Conference participants took part in an excursion along the Valle d'Ossola with field trip leaders Ernie Rutter and Rolf Schmid. On other excursions, participants examined the mafic complex and its roof rocks in the Val Sesia, saw the granulite facies "stronalites" (depleted granulites) and amphibolite facies migmatites in the Val Strona di Omegna and visited one of the Permian granites in the Serie dei Laghi, studied the migmatites in the Val Strona di Postua above the thickest part of the mafic complex, and examined peridotites within the mafic complex, particularly the Balmuccia peridotite, the top of which was once thought to represent the Moho. Two trips featured the geology next to the Insubric Line and structures within the mafic complex, including septa of depleted lower crustal rocks. These specialist field trips were based on detailed research by the leaders, their collaborators, and students.

Oral and Poster Sessions

The conference began with a presentation by Bruce Hobbs concerning fluid transport in the lithosphere, with particular reference to the influence of deformation. The traditional approach of representing the constitutive behavior of the lithosphere as either viscous at high temperature or brittle at low temperature disregards important aspects of constitutive behavior such as elasticity, yield, deformation-induced dilatancy, and strain-rate dependency. These behaviors are important in any consideration of fluid transport in real rocks. During Darcy flow, which depends on the presence within the rock mass of an interconnected pore space, the constitutive behavior is elasto-plastic with deformation-induced dilatancy. Fluid transport is focused by deformation-induced changes in pore pressure and permeability and not by the rheology of the material. Bruce introduced the term "Connolly flow" for fluid transport in rock masses with low intrinsic interconnected porosity, which is more realistic in the middle and lower crust. Fluid flow occurs through the propagation of high-permeability packets, the permeability distribution being controlled by deformation-induced permeability increases and decreases. In Connolly flow, the transport may or may not be focused, but the overall control on fluid transport is the rheology and state of stress of the material rather than the initial porosity and permeability distribution. These two modes of fluid transport have important geological consequences, since under conditions of Darcy flow, fluid is expected to be focused into rocks of high intrinsic permeability, which commonly are strong, whereas under conditions of Connolly flow, fluid is expected to be focused into rocks of low strength, which commonly have low intrinsic permeability.

A keynote presentation by Jean-Pierre Burg concerned feedback relations among migmatites, large-scale tectonics, and detachments in collisional orogens. He suggested that mid-crustal migmatites produced decoupling of upper from lower crust, explaining why the Moho is not observed in collisional orogens such as the Himalayas. He argued that the lower and upper crust thicken separately and by different mechanisms, an interesting hypothesis that carries the implication that the crust must have been hot before thickening if there existed a layer of migmatites with sub-horizontal fabrics. Specific examples of feedback relations between deformation and melt transport were provided by Gary Solar (crustal modification by anatexis in obliquely convergent [transpressive] orogens) and Chris Wareham (crustal growth in arcs). Gary Solar suggested that the geometry of melt batches during escape from the anatectic zone was controlled by strain, on the basis of granites with different shapes that reflect the strain field in zones of flattening and zones of constriction within a crustal-scale shear zone system. Jamie Connolly considered the influence of rheology on compaction-driven fluid flow in orogenic belts, and repeated the importance of including elasticity in rheological modeling; he pointed out that viscous models can fail. During dehydration reactions, the upward migration of the liberated metamorphic fluid is enabled by a solitary wave in porosity that occurs from an initial condition of no hydraulic connectivity at the reaction isograd. Mike Williams led a discussion focused on growth vs. modification of continental crust, a theme that would be central to discussions throughout the week. Bruce Hobbs attempted to explain how the porosity waves described by Jamie Connolly might be recorded in the geological record—possibly as a zone of veining, or as a shear zone or shear zone system, or as a fracture or set of fractures.

Mark Harrison addressed the petrologic and mechanical controls on episodic tectonics during continuous convergence, with particular reference to the India-Asia collision. He emphasized that if lithosphere history is an important control on orogenic processes, then young orogenic belts may not be good analogs for old orogens. Ed Sawyer considered closed-system crustal differentiation during large-scale anatexis. He emphasized the role of melt separation from residue during ascent, and how this process can cause late-stage modification of segregated melt by fractional crystallization. Jon Davidson addressed the issue of whether differences along strike in orogenic belts, such as the Andes, are controlled by source or by process. He emphasized the inevitability of crustal contamination, so that the important issue is how much contamination takes place in continental arcs, not whether it occurs. Furthermore, open-system differentiation is the rule rather than the exception in arcs, so that both additions to the crust and recycling of the crust occur. Fernando Bea used comparative geochemistry among Ivrea-Verbano zone granulites and Permian granites within the Serie dei Laghi, including Pb evaporation ages, to argue that the granites are older than the regional granulite-facies metamorphism and cannot be derived by closed-system melting of any known source. Thus, a simple link between depletion of the lower crust by loss of granitic melt during granulite-facies metamorphism, as previously postulated in this region, is brought into question. As an alternative, Bea postulated metasomatism of the lower crust due to fluid ingress from early mafic melts that underplated the crust. He suggested that melting of such a metasomatized fertile lower crust would yield granites consistent with the compositions of those in the Serie dei Laghi. The exposed lower crustal granulites are interpreted to reflect subsequent equilibration and cooling from granulite-facies conditions. Discussion was led by Mary Reid, who commented in particular on the need to have good data that address the absolute age of events and the distinction between growth and recycling of continental crust. Allen Glazner emphasized that mantle input to the crust is basaltic, which implies that a mafic-ultramafic component must lie below the Moho since the average crustal composition is broadly andesitic rather than basaltic. Thus, an important part of the crustal growth–crustal differentiation process concerns the mechanism by which this mafic or ultramafic material is returned below the Moho.

The poster session provided an opportunity for participants to present details of specific research on aspects of the crustal differentiation process. Thus, the content varied from what we can glean from particular minerals, whether a peritectic melting product in migmatites such as cordierite or the enigmatic rapakivi textures in which plagioclase forms a mantle around K-feldspar ovoids, to granulite facies metamorphism as viewed both from the field and the experimental capsule. Other posters presented results of research ranging from isotopic studies of rock suites and experimental melts, to geochronology, to microfabrics in migmatites and igneous rocks, and to the geochemistry of diatexites and ascent of granite.

The part of the program concerned with changes in crustal rheology with mineral reactions and triggers for active crustal growth began with a review of equilibrium melt distribution in partially molten systems. Although melt distribution at the grain scale is an important factor in controlling the segregation of granite melt from residue, low dihedral angles measured in all crustal analogs between melt and solid suggest that wetted grain boundaries are to be expected and interconnection of melt will be established at low volume % melt. Nonetheless, Didier Laporte argued that melt segregation may be inefficient at low volume % melting. He suggested there may be a range of melt fractions above the permeability threshold over which melt is interconnected but remains nearly stagnant. This raises the question of the role of deformation in the movement of granite melt at low volume % within a crustal source undergoing anatexis. The issue of deformation of partially molten synthetic granite was addressed by Julien Mecklenburgh, who described preliminary results of a laboratory study investigating granular flow of partially molten crustal analogs. Understanding the rheology and verifying flow laws of partially molten systems are important, and an interpretation of preliminary data suggests that at low melt fraction (~5–10 vol%), melt can be driven out of the source due to variations in deviatoric stress, whereas at moderate melt fraction (~20–30 vol%), the very low strength of the partially molten system allows en masse transfer by melt-assisted granular flow.

On a larger scale, preliminary results of three different approaches to modeling intrusive behavior were presented by Alison Ord. Many earlier treatments of this problem assumed nonelastic behavior for melts and a lack of yield behavior for crystal mushes or crystal-bearing magmas, both of which are unreasonable. For magmas with such behavior, a driving force for intrusion besides buoyancy is the shear stress induced by magma pressure differences or by deformation of the country rock. Alison Ord's models explored diapir structures, perhaps representative of magma intrusion in early Archean greenstone belts, and models to examine the effect of magma pressure on intrusion at high levels in the crust and the ascent of crystal-poor magmas by hydrofracture. The modeling theme was continued by Paul Bons, who described a model of deformation and melt accumulation by mobile melt fractures: movement of a package of melt with a fracture that is upward propagating ("hydro-fracture" propagation), but closing from behind. He suggested that melt segregations have to reach a critical size before the melt pocket can propagate upward as a crosscutting fracture. The chemical consequences of such a model depend on the rate of deformation; low rates of deformation lead to small variations in chemistry (equilibrium melting) and high rates of deformation leading to large variations in chemistry (fractional melting), because the former produce a batch of melt that reflects the integrated melting history, whereas the latter produce a batch of melt that preserves only a small part of the melting history. Alfons Berger and Jean Louis Vigneresse discussed the rheology of migmatites, partially molten systems, and partially crystallized systems, stressing that there are significant differences in behavior at any particular volume % liquid between partially molten and partially crystallized systems.

In starting the discussion, Ed Sawyer distinguished between melt-dominated and solid-dominated systems, and raised questions relating to the effect of the rate of melt production and the relationship to the rate of deformation. The question of what is represented by the leucosome in a migmatite was raised by Roger Powell. In his view, leucosomes are dominated by solid products of melting reactions and the melt itself is lost continuously or episodically from the reaction site. Migmatites are enigmatic, and whether they represent evidence of granite extraction from a source or failure of melt to escape from a source remains contentious, and both processes most likely occur in partially molten terranes. Several participants emphasized that leucocratic accumulations observed in relic anatectic systems may be produced by a combination of multiple processes. For example, migmatites may be produced by dehydration melting that leads to both a melt phase and peritectic solid products, and partial crystalliza-

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tion of the melt may lead to cumulate phases in the residue. In addition, melt may escape from the system, but an implication of such behavior is that melt may flow into the system to change again the composition of what ultimately becomes the leucosome.

The question of possible heat sources for crustal anatexis was addressed in a keynote lecture by Alan Thompson, who suggested that internal differentiation of the crust by anatexis is a localized phenomenon, that crustal evolution is dominated by the fractionation of hydrous mantle magmas in convergent arcs, and that remelting of lower crust in orogens must be common. These processes are driven either by crustal thickening, by invasion of mantle-derived magmas into the crust, or by lithospheric delamination and asthenospheric replacement. It was clear from this presentation and previous ones that melts derived from different sources within the crust-mantle system may coexist. Consequently, George Bergantz considered the constraints on communication between such melt batches. He focused on interfaces between batches and considered diffusive, convective, and chaotic regimes that lead to increased mixing efficiency. These results have considerable implications for magma mixing. John Foden addressed the issue of the changing composition of granite magmatism through time and its relationship to potential sources, given the decline in heat flow with increasing age of Earth. Foden emphasized that in the modern Earth, magmatism is concentrated at plate margins and catalyzed by water. He suggested that the proportion of crustal melting has decreased with the evolution of Earth, although evidence of mixing between mantle- and crust-derived magmas is common in continental arcs. Sue Debari emphasized that tonalite plutons in the North Cascades crystalline core are mixtures of mantle- and crust-derived melts, generated in the lower part of overthickened continental arc crusts. Debari also pointed out that the variation in geochemistry for these particular rocks exhibits some characteristics of adakites, although the magmas do not represent slab melts but simply were derived from a basaltic source. Here the tonalite is interpreted to be derived from garnet-bearing mafic granulite. In identifying topics for discussion, John Clemens asked the following questions: (1) In what tectonic setting do we get crustal growth? (2) What can we do with isotopic data? (3) Can felsic magma pond in the lower crust for periods ≥ 1 m.y. and interact extensively with mafic magma? (4) Do enclaves in granites reflect the sorts of mixing that might occur in the crust? In each of these questions, Clemens was drawing attention to the need for care in the interpretation of data gleaned from plutons emplaced in the upper crust when the magmas themselves were generated below the Moho, in the lower crust or by some combination of these sources, but some distance from the site of emplacement.

Another poster session addressed the role of hybridization by mixing and mingling and the petrogenesis of granites, as well as the relative roles of crustal stacking and radiogenic heating vs. basalt in providing the heat for crustal melting. The relationship between the extrusive products of crustal differentiation and their supposed intrusive equivalents was addressed in a study of the Fish Canyon magma, and the process of crustal differentiation in Cordilleran margins was contrasted with those that occur during orogenic collapse along collisional margins. Several posters addressed episodicity vs. continuity in tectonics and petrogenesis, and the roles of stress and lithospheric structure on processes of crustal differentiation.

Mike Sandiford addressed the question of continental heat flow and the role of radiogenic heat production in the crust in driving crustal differentiation. He emphasized how poorly we understand the three fundamental things we need to know: the vertical distribution of heat production; the heat production itself; and whether horizontal variability in heat production affects the response. This presentation emphasized the critical role played by concentration of heat production at particular levels within the crust, and how high continental heat flow observations do not require an enhanced mantle heat flux. On the contrary, Sandiford suggested that areas of high continental heat flow that result from a shallow concentration of heat production demand a lower mantle heat flux to avoid wholesale melting of the lower crust. Roger Powell introduced participants to THERMOCALC, a nonlinear equation solver that represents a powerful tool to investigate melting processes by forward modeling and calculation of phase diagrams. Mike Williams discussed geologic processes in the deep crust, with particular reference to the Snowbird tectonic zone, Canada. Williams emphasized that no matter what the history, slices of crust that cool isobarically at pressures appropriate to lower crustal conditions represent examples of the lower crust. Processes involved in the evolution of such slices of crust include underplating or intraplating, particularly through the involvement of basaltic dikes, and magma extraction, which relates to structural heterogeneities, involving both tectonic pumping of melt and opportunities for mixing between melts from different sources. He emphasized the heterogeneity of the crust and its overall block architecture.

Mike Dungan and Jon Davidson addressed the issue of crustal growth vs. crustal differentiation and emphasized that although we think of two end members (the mantle and the crust), most continental magmatism involves some interaction between these two. Underplating is a widely used term, but it is unclear why magma should pond at the Moho. Furthermore, we should remember that the average crustal composition requires a complementary mafic or ultramafic residue below the Moho. An important question is whether there are fundamental differences about the proportion of mantle and crustal contributions, the processes of magma generation, or the mechanisms of magma segregation, transport, and emplacement between large-volume silicic volcanic systems and Cordilleran batholiths. Perhaps, they suggested, there are no real differences, simply different perspectives based on different experiences. For example, although there is the same range of compositions in both volcanics and plutonics in continental arcs (basalt to rhyolite and gabbro to granite, respectively), the volcanic rocks are dominated by liquid processes whereas the plutonic rocks are dominated more by cumulate or intercumulate processes. In discussion, Allen Glazner emphasized the common chemical continuity within volcanic suites in contrast with the common chemical discontinuities within plutonic complexes.

Sue Debari and Alan Levander provoked further debate on the crustal composition paradox, the fact that the bulk composition of the continental crust is andesitic, whereas mantle additions to the crust in arcs are basaltic. In addressing the implied mass imbalance, three alternative explanations can be suggested. First, there may have been secular variation in plate tectonic processes leading to circumstances in which arcs include more basalt with evolution of the earth. Second, a mafic or ultramafic component may be hidden below the Moho; this could be of eclogitic composition or could comprise ultramafic cumulates. Third, a mafic or ultramafic component in orogens may have been lost by delamination. Bill Collins emphasized that modern Earth loses heat principally at plate boundaries and that orogens are thermally disturbed, structurally chaotic systems through which fluids, including melts, may pass. That such systems are open, he said, suggests that they may be dominated by disequilibrium rather than equilibrium processes, and the ultimate trigger for orogeny is likely to be in the mantle.

Jim Quick presented a model for the emplacement of the mafic complex in the Ivrea-Verbano zone based on detailed mapping over many years with several collaborators, extensive structural data and microstructural information, and numerical modeling. The model involves incipient extension of a continental crust, the start of emplacement of mafic magma leading to weakening and deformation under pure shear, the incorporation of melt-depleted granulite facies paragneiss septa within the mafic complex, and continuing deformation under left-lateral simple shear. Geochemical evidence in support of the model was presented by Silvano Sinigoi. Scott Barboza presented results of field work, petrology, and geochemistry designed to test the general model of underplating, as represented by the example of the mafic complex. He suggested that the regional-scale granulite facies metamorphism and depletion were not related to the mafic complex because the latter cuts discordantly the regional metamorphic isograds, the increase in regional metamorphic grade is related to increasing depth, not proximity to the mafic complex, the depleted granulites and septa within it exhibit similar levels of depletion, and the composition of leucosomes in migmatites immediately above it is inconsistent with the postulated composition of melt lost from the granulite facies terrane. Barboza concluded that widespread regional granulite facies metamorphism in the Ivrea-Verbano zone may not be directly related to the mafic complex as we now see it, and that mass and entropy balances derived from modeling likely represent minimum estimates of basaltic magmatism. Ernie Rutter presented a synthetic seismic reflection profile through the Ivrea-Verbano zone–Serie dei Laghi crustal section. Interestingly, imaged features correspond closely to those seen on many present-day seismic profiles, and the broad features of the tectonic evolution would be correctly interpreted. On the other hand, important recumbent fold structures would be missed, and relations between intrusive bodies and their country rocks would be unclear. Diane Clemens-Knott presented conclusions from her exhaustive oxygen isotope study of the mafic complex. Covariations between $\delta^{18}O$, SiO_2, Mg#, K_2O, and Ba require variable amounts of crustal assimilation and/or isotopic exchange, fractional crystallization, and mixing. She expressed the view that the Permian granites may have been generated by interaction of the voluminous main gabbro magma with a crustal melt containing less Sr. Interestingly, geochemical comparison between the mafic complex and similar xenoliths collected worldwide suggests that the complex is a close representation of deep crust in which mantle-derived magmas interact with high-^{18}O rocks.

Using the $^{207}Pb/^{206}Pb$ evaporation technique on zircon, Fernando Bea argued for a decrease in the age of regional metamorphism with increasing pressure, in the interval 290–260 Ma, interpreted to reflect cooling and crystallization of the partially molten lower crust at granulite facies conditions. In discussion, the importance of separating individual events in complex terranes and the difficulty of dating precisely peak metamorphic conditions were emphasized.

The final conference discussion considered the dynamic conditions for melt generation, ascent, and emplacement. George Bergantz emphasized the importance of the interplay between the perturbations to initiate crustal melting and the tectonic setting, or "plumbing," in dictating the style of melt movement. Both are necessary conditions for crustal differentiation. The subsequent group discussion was directed at three themes. First, what are the rheological and geochemical responses of crustal growth processes and how are they expressed in the rock record? Second, how are perturbations of the steady state generated, what are the rates of such perturbations, and do rocks preserve evidence of the perturbations and record the rates? Third was the issue of the global rates of mass transfer in the crust-mantle system, expressed as the input rate of mantle materials and the style and rates of return of mafic or ultramafic materials to balance the crustal composition.

Part of the difficulty in generalizing the observations from the field trips and the oral and poster presentations is that any given set of outcrops usually provides a two-dimensional view of a three-dimensional or even four-dimensional problem. As a result, many participants offered their comments as questions to the group. These included: Do melt-producing perturbations arise from "tectonics as usual" or from special mantle events? What is the form and rate of return of mafic or ultramafic material to the mantle? Is it in the form of abrupt delamination or drips? How does one tell whether a leucosome was ever a melt or magma. Are there unequivocal criteria, or even useful generalizations for identification of reaction products, cumulates or residual melt? Can the middle or lower crust be partially molten and retain that melt for extended periods (millions of years)? How much time is required for a basaltic underplate to cool, possibly hydrate, and become a candidate for subsequent melting? What is the temperature at the Moho? Is there a general form for the constitutive equations of reacting, multiphase mixtures? If basaltic underplating (or interplating) is important, why are there so few examples of basaltic intrusions significantly melting their margins? Is the dominant means of enthalpy transfer for crustal melting perhaps the result of dense networks of basaltic dikes ahead of a growing volume of basaltic material in sill-like bodies? Is the lower crust generally depleted? If magma chambers grow by sill-like additions at the floor, then why are near-vertical contacts so common between magma bodies and within magmatic complexes? Is the true lower crust ever exposed, or does its density prevent its occurrence at Earth's surface, with the consequence that the lowest crust we see exposed is not the lowermost crust at all? How does the Ivrea-Verbano zone compare to other supposed lower crustal sections?

ACKNOWLEDGMENTS

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Lois Elms (Western Experience, Inc.) arranged the general logistics, and Kate Walker dealt with the local organization and field trip logistics. We thank the field trip leaders and their associates, without whom the spectacular geology of the region could not have been presented in such a stimulating way.

Finally, we thank the participants themselves, for they provided the energy and the excitement. ■

Penrose Conference Participants

Pierre Barbey	Jessica D'Andrea	Mark Harrison	Calvin Miller	Jim Quick	Gary Solar
Scott Barboza	Jon Davidson	Bruce Hobbs	Jonathan Miller	Kent Ratajeski	Martin Streck
Andrew Barth	Gareth Davis	Pentti Holtta	Robert Miller	Mary Reid	Alan Thompson
Fernando Bea	Sue DeBari	Leif Johansson	Isabelle Milord	Ernie Rutter	Simon Turner
Alfons Berger	Mónica de Luchi	Ben Johnson	Francis Monastero	Michel de Saint Blanquat	Jean-Louis Vigneresse
Paul Bons	Michael Dungan	Kurt Knesel	Alessandra Montanini	Mike Sandiford	Chris Wareham
Jean-Pierre Burg	Olav Eklund	Jana Kotkova	Pilar Montero	Sonia Sandroni	Jennifer Watkins
Luigi Burlini	Becky Flowers	Joern Kruhl	Takashi Nakajima	Ed Sawyer	Roberto Weinberg
Bernardo Cesare	John Foden	Rebecca Lange	Anne Nedelec	Urs Schaltegger	Bob Wiebe
Ma Changqian	Axell Gerdes	Didier Laporte	Narelle Neumann	Rolf Schmid	Mike Williams
John Clemens	Allen Glazner	Alan Levander	Alison Ord	Sheila Seaman	
Diane Clemens-Knott	Djordje Grujic	Fred McDowell	Gabriella Perisini	Silvano Sinigoi	
Bill Collins	Anita Grunder	Cathryn Manduca	Phil Piccoli	Kjell Skjerlie	
Jamie Connolly	Michel Guiraud	Julian Mecklenburgh	Roger Powell	R. K. Smith	

The Pliocene–Pleistocene boundary should remain at 1.81 Ma

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Morrison and Kukla (1998) have asserted that the Pliocene-Pleistocene boundary (PPB) should be relocated at a level linked to a shift in the pattern of oxygen isotope cycles at ~2.6 Ma, a level identified with the GSSP (Global Standard Stratotype Section and Point) at the base of the Gelasian Stage. In challenging the validity of the 1.81 Ma PPB at Vrica, Calabria, despite its worldwide acceptance since it was ratified by the International Union of Geological Sciences (IUGS) in 1985, Morrison and Kukla relied on two premises: (1) that the Vrica boundary is not associated with a major climatic change, and is thereby erroneous; and (2) that this boundary is virtually uncorrelatable, in comparison with the 2.6 Ma level.

These premises are readily refuted (see Van Couvering, 1997). Both the 2.6 and 1.8 Ma climate steps are significant, but neither is uniquely definitive in the history of Cenozoic climate deterioration. Global correlation of the Vrica level with regard to magnetostratigraphy, paleontology, and cyclostratigraphy is easily as good, overall, as that of the Gelasian GSSP (Rio et al., 1998).

For 30 years, rear-guard resistance to the consensus favoring a "young" boundary such as Vrica has come mainly from a few who work in continental paleontology and paleoecology, in whose data the 2.6 Ma mid-Pliocene climate step is strikingly evident and who see this as the beginning of the "Ice Age." But in this instance, the rear guard has found aid in quoting current International Commission on Stratigraphy (ICS) policy that the main criterion for GSSPs is "unambiguous recognition and ease of correlation in as many marine and non-marine terrains throughout the world as possible." This marks a shift in officially sanctioned standards since the mid-1980s, from principles that emphasize definition over correlation to principles that emphasize correlation over definition. Remane (1997, p. 4) noted that "If the level at 2.6 Ma, favoured by many Quaternary stratigraphers, would considerably improve the correlation potential of the [PP] boundary, then a change should be seriously envisaged, but only then."

Encouraged by this statement, Morrison and Kukla claimed correlatabilty as a compelling reason for lowering the boundary to meet their paleoclimatic preconception. They offered to respect earlier, Hedbergian guidelines by making the base of the Gelasian Stage the base of the Pleistocene Series. This hierarchical nicety is more than ICS requires; preconceived series GSSPs are now being ratified with supposedly inherent and essential stage boundaries carelessly redefined to fit, or dispensed with altogether.

If correlation is all, what arguments remain against lowering the PPB to the level of 2.6 Ma? For example, placing the PPB below strata that have always been assigned to the Pliocene would normally be enough for stratigraphers to reject the 2.6 Ma proposal on first principles. Indeed, the original "Subappenine marls of Asti," recognized by Lyell in the designation of the Pliocene Series and thus excluded from the Pleistocene *by definition,* are of Gelasian age. In the ICS view, however, this argument is no longer irrefutable. As Cowie (1986, p. 78) wrote,"… choices in international stratigraphy should violate historical priority as little as possible: this consideration can often be overridden by the higher priority of going for the best and making progress. Confusing historical precedents may need to be set aside by an authoritative international decision, even though this may violate some established usage." We are concerned that the enthusiasm of ICS for "authoritative international decisions" that do not adhere to Hedbergian principles will lead eventually to a standard chronostratigraphic scale of pure expedience, in which the familiar terms that have served for over a century would become hollow shells devoid of any intrinsic content. In effect, this is to return to pre-Lyellian stratigraphy.

The most compelling reason, however, that the PPB must not be lowered, even if the correlation at 2.6 Ma is clearly superior to that at 1.8 Ma (which is not the case), is that this would make non-stratigraphic criteria part of the boundary definition. This endangers the very nature of the chronostratigraphic framework. The concept of the series as a chronostratigraphic unit was proclaimed at the International Geological Congress in Bologna (1881). Its nature has remained unchanged, as an expression of the profound idea that the time correlation of rocks provides an intrinsic temporal framework for historical geology. The integrity of the series is based on its direct relationship to the rock record. Subjective interpretations, whatever their nature—climatic, tectonic, paleobiologic, oceanographic—should never become the means for defining a series, under the principle that the object of measurement cannot also be the tool of measurement. Morrison and Kukla believe that the PPB should be defined so as to "have significance in the glacial and climatic history," in order to be "a true climatostratigraphic boundary that represents a major shift in global air, ocean and land climate systems." In no instance, we believe, should a chronostratigraphic boundary be selected with such criteria as these.

In our view, the proposal for lowering the PPB is misconceived, and it also exposes a trend toward a destabilizing laxity in chronostratigraphy. Indeed, ICS should already have dismissed this same proposal when it was formally presented to the Subcommission on Quaternary Stratigraphy in Berlin in 1995. On the contrary, this proposal is being put to a postal ballot of the Neogene and Quaternary Subcommissions of ICS and, if a majority favors the change, to a vote of the full ICS. We can only hope that this perennial campaign to set aside principles in favor of attractive expediency will end in the course of this formal procedure.

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Van Couvering, J. A., editor, 1997, The Pleistocene boundary and the beginning of the Quaternary: Cambridge, UK, Cambridge University Press, 296 p. ■

SEG Offers Student Research Grants

Students of mineral resources throughout the world may apply for thesis research grants available in 1999 from the Society of Economic Geologists Foundation and the Society of Economic Geologists. This program is intended to provide partial support of master's and doctoral thesis research for graduate students. (1) doing studies with a substantial field component, (2) working on field projects in arctic, subarctic, or other challenging field areas, or (3) doing research in economic geology that focuses on new descriptive data on ore deposits, mining districts, and topical subjects.

Individual grants range from $500 to $3,000 and are intended to fund specific thesis research expenses. Application forms are available from the Chair, SEG Student Research Grants, 5808 South Rapp St., Suite 209, Littleton, CO 80120, USA, (303) 797-0332, fax 303-797-0417, socecongeol@csn.net, http://www.segweb.org.

Applications must be postmarked by *February 15, 1999;* awards will be announced by April 15, 1999.

Research Grants Administrator Retires

June Forstrom

GSA Research Grants Administrator June Forstrom retired May 29, 1998, after 25 years with the Society. She is one of the 1998 Distinguished Service awardees; she accepted the honor at the GSA Annual Meeting in Toronto.

Forstrom was recruited from the accounting department of a Boulder, Colorado, firm in February 1973. She began work in the GSA administrative department with Dorothy Palmer, administrative assistant to Executive Secretary (now termed Executive Director) Edwin Eckel.

"Dorothy Palmer was my mentor," Forstrom says. "She taught me everything about executive office protocol, discretion, and confidentiality." Forstrom put the lessons to use as Eckel's secretary, typing his letters ("that was before GSA acquired computers; we considered typewriters with correction ribbons a major improvement when we got them"), and working with most of the GSA committees.

Although interested primarily in math and accounting, Forstrom soon found herself happily immersed in tracking grant applications and working with the research grants committee as its members went through the process of selecting grant recipients. She also became a familiar face at Council meetings, taping the proceedings and taking notes.

Forstrom proposed the formation of the Staff Advisory Committee, which addressed staff concerns during the 1980s, until the Council instituted the Headquarters Advisory Committee.

In addition to her research grant duties, Forstrom was assistant to the communications director from 1984 through 1987. She also coordinated publication and mailing of the GSA section and division newsletters and ballots. She worked in the newsroom at the annual meeting from 1987 on, helping to schedule press conferences and speaker interviews, and she was there again this year, assisting on a contract basis.

Leah Carter has replaced Forstrom as GSA research grants coordinator.

Forstrom and her husband, Keith, a former teacher and now a Realtor, are accomplished ballroom dancers (specializing in jitterbug), enjoy camping, fishing, and river rafting, and plan to travel abroad. ■

Call for Papers

Planetary Geoscience Student Paper Award

The Award

Planetary geologist Stephen E. Dwornik established this award in 1991 to provide encouragement, motivation, and recognition to outstanding future scientists. Two awards are given annually, one for the best oral presentation, the other for the best poster presentation, each winner receiving a citation and $500. The program is administered through the Planetary Geology Division of the Geological Society of America. The GSA Foundation manages the award fund. For further details, see http://www.planetary.brown.edu.

Criteria

The Dwornik Student Paper Award applies to papers presented at the annual Lunar and Planetary Science Conference held each March in Houston. Student applicants must be (1) the senior author of the abstract (the paper may be presented orally or in a poster session); (2) a U.S. citizen; and (3) enrolled in a college or university, at any level of their education, in the field of planetary geosciences. Papers will be judged on the quality of the scientific contributions, including methods and results; clarity of material presented; and methods of delivery, oral or display.

To Apply

The application form and instructions are found in the Call for Papers for the 30th Lunar and Planetary Science Conference, to be held March 15–19, 1999, in Houston, Texas. For further information, contact Program Services Division, Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058-1113, (281) 486-2158, simmons@lpi.jsc.nasa.gov. Only one abstract per student will be considered.

Deadline

Mailed abstracts are due January 8, 1999; electronic submissions are due at 6:00 p.m. (CST) January 15, 1999. ■

Geologic Time Scales
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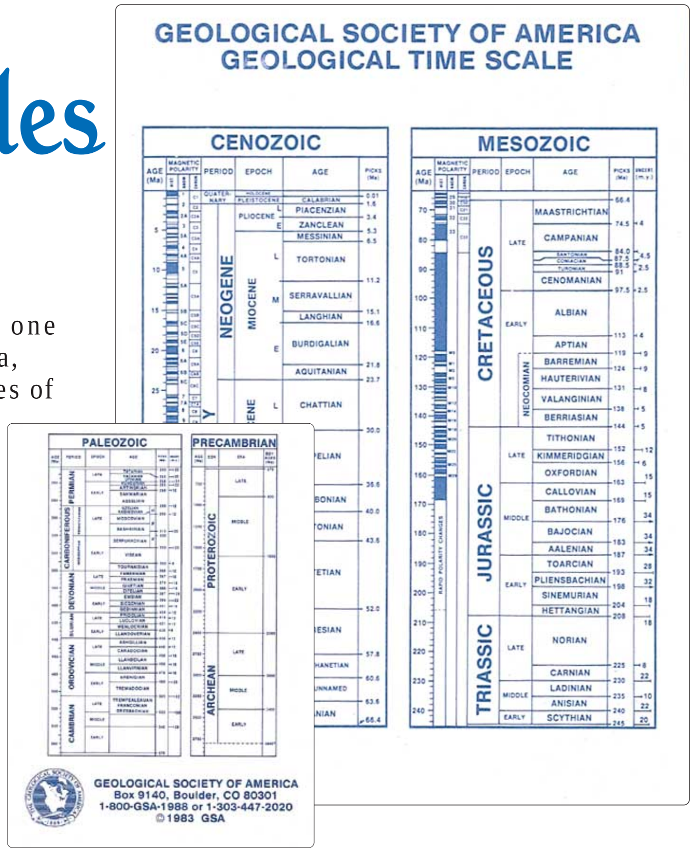
A. R. Palmer, 1998

Three versions of this popular time scale are available. Each one contains current chronostratigraphic and numerical age data, magnetic reversal stratigraphy, and estimates of uncertainties of assigned Paleozoic and Mesozoic numerical age. Data sheet accompanies each version.



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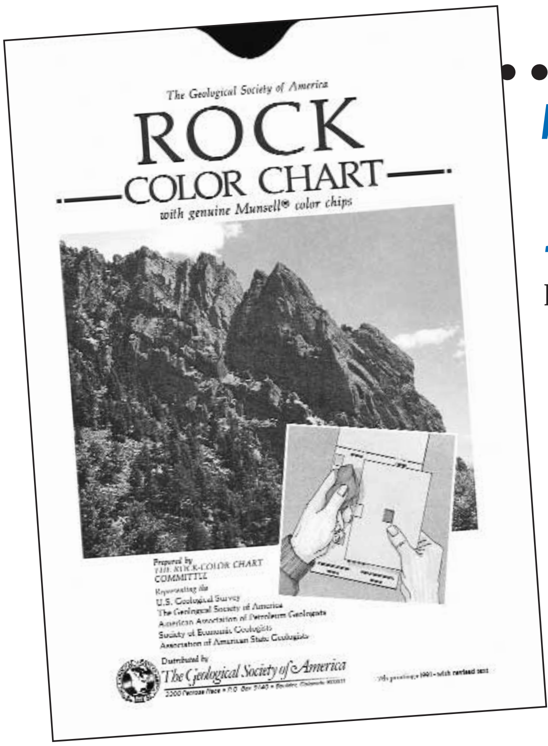

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GSA SECTION MEETINGS 1999

SOUTH-CENTRAL SECTION

March 15–16, 1999, Lubbock, Texas. Submit completed abstracts to: James Barrick, Dept. of Geosciences, Texas Tech, Lubbock, TX 79409-1053, (806) 742-3107, ghjeb@ttu.edu.
Abstract deadline: December 15, 1998.

NORTHEASTERN SECTION

March 22–24, 1999, Providence, Rhode Island. Submit completed abstracts to: Anne I. Veeger, Dept. of Geology, University of Rhode Island, Green Hall, Kingston, RI 02881, (401) 874-2187, veeger@uriacc.uri.edu.
Abstract deadline: December 8, 1998.

SOUTHEASTERN SECTION

March 25–26, 1999, Athens, Georgia. Submit completed abstracts to: Michael F. Roden, Dept. of Geology, University of Georgia, Athens, GA 30602-2501, (706) 542-2416, mroden@uga.cc.uga.edu.
Abstract deadline: December 14, 1998.

ROCKY MOUNTAIN SECTION

April 8–10, 1999, Pocatello, Idaho. Submit completed abstracts to: Paul Link, Dept. of Geology, Idaho State University, 785 South 8th Ave., Pocatello, ID 83209-8072, (208) 236-3846, linkpaul@isu.edu.
Abstract deadline: December 29, 1998.

NORTH-CENTRAL SECTION

April 22–23, 1999, Champaign-Urbana, Illinois. Submit completed abstracts to: C. Pius Weibel, Illinois State Geological Survey, 615 E. Peabody Dr., Champaign, IL 61820-6964, (217) 333-5108, weibel@isgs.uiuc.edu.
Abstract deadline: January 11, 1999.

CORDILLERAN SECTION

June 2–4, 1999, Berkeley, California. Submit completed abstracts to: George Brimhall, Dept. of Geology & Geophysics, University of California, Berkeley, CA 94720-4767, (510) 642-5868, brimhall@socrates.berkeley.edu.
Abstract deadline: February 19, 1999.

CALL FOR APPLICATIONS AND NOMINATIONS FOR

Geology Co-Editor

GSA is soliciting applications and nominations for the position of co-editor of *Geology*, to serve a three-year term, beginning in January 2000, as one of a two-editor team. Desirable characteristics for the successful candidate include:

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

GSA provides the editor with a small stipend as well as expenses for secretarial assistance, mail, and telephone.

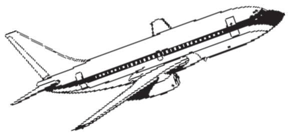
If you wish to be considered, please submit a curriculum vitae and a brief letter describing why you should be chosen. If you wish to nominate another, submit a letter of nomination and the individual's written permission and c.v. Send nominations and applications to Peggy S. Lehr, Director of Publications, Geological Society of America, P.O. Box 9140, Boulder, CO 80301, *by April 14, 1999*.

GSA Student Associate Member TRAVEL GRANTS

The GSA Foundation has awarded $4,000 grants to each of the six GSA sections. The money, when combined with equal funds from the sections, is used to assist GSA undergraduate Student Associates, as well as graduate Student Members, traveling to GSA meetings. For information and deadlines, contact your section secretary.

Cordilleran—Bruce Blackerby,
(209) 278-2955, bruceb@zimmer.csufresno.edu

Rocky Mountain—Kenneth Kolm,
(303) 273-3932, kkolm@mines.edu



North-Central—Robert Diffendal, Jr.,
(402) 472-7546, rfd@unlinfo.unl.edu

Northeastern—Kenneth Weaver,
(410) 554-5532, kweaver438@aol.com

South-Central—Rena Bonem,
(254) 710-6806, Rena_Bonem@baylor.edu

Southeastern—Harold Stowell,
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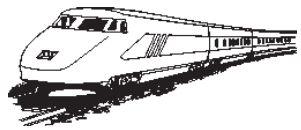

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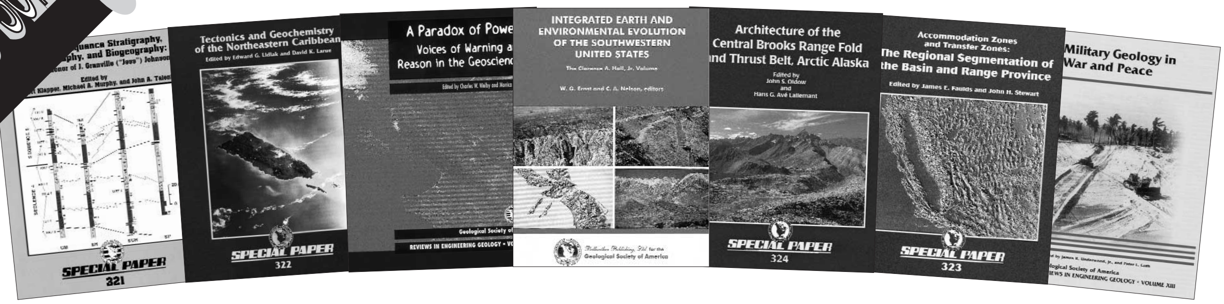

Integrated Earth and Environmental Evolution of the Southwestern U.S.

co-edited by G. Ernst and C. A. Nelson, 1998
Available exclusively through GSA

The Geological Society of America is proud to introduce a new publication, Integrated Earth and Environmental Evolution of the Southwestern United States, co-published with Bellwether Publishing, Ltd., devoted to the integrated study of earth and environmental sciences of the southwestern United States. The serious professional will appreciate the breadth of the book. Volume topics span the geological spectrum from Archean evolution of the crust-mantle system, to Neogene paleogeography and extensional faulting of the southwestern continental margin, and from petrotectonic evolution of the Sierra Nevada, the central Klamaths and the Basin and Range, to a Devonian bolide impact in the Great Basin, as well as the Cenozoic–Holocene climate development throughout the region. Notable geologists E. M. Moores, C. A. Nelson, B. C. Burchfiel, T. Atwater, and W. G. Ernst are among the more than 45 authors who have contributed significant findings to the volume. Liberally illustrated, this new 500 page, softcover volume incorporates plate tectonics, climatic-ecological aspects of the Southwest, and magmatism of the area. Integrated Earth and Environmental Evolution of the Southwestern United States is a valuable resource for geologists and scientists who need the latest information concerning the southwestern United States.

IBS001, 500 pg., softcover, 7" x 10" format, ISBN 0-9665869-0-5, $89.95, Member price $71.96

A Paradox of Power: Voices of Warning and Reason in the Geosciences

edited by C. W. Welby and M. E. Gowan, 1998

The 13 papers in this volume illustrate issues and opportunities confronting geologists as they bring their knowledge and understanding to bear in matters related to public health and welfare. Public decisions and decision-making processes in the face of geologic complexity and uncertainty are the subject of the first group of papers. In the second group, several "voice of warning" papers illustrate the use of geologic knowledge and research to warn the public of health hazards derived from geologic materials and processes. A third group of papers, in the "voice of reason" section, describes use of geologic knowledge to help lower the costs of mitigation and avoidance of geologic hazards. Finally, ethical and philosophical questions confronting geoscientists are discussed and issues of "truth" as related to the legal process and questions about the adequacy of information in making decisions about long-term radioactive waste disposal are discussed.

REG012, 185 p., ISBN 0-8137-4112-2, $64.00, Member price $51.20

Military Geology in War and Peace

edited by J. R. Underwood, Jr., P. L. Guth, 1998

In warfare, military geologists pursue five main categories of work: tactical and strategic terrain analysis, fortifications and tunneling, resource acquisition, defense installations, and field construction and logistics. In peace, they train for wartime operations and may be involved in peace-keeping and nation-building exercises. The classic dilemma for military geology has been whether support can best be provided by civilian technical-matter experts or by uniformed soldiers who routinely work with the combat units. In addition to the introductory paper this volume includes 24 papers, covering selected aspects of the history of military geology from the early 19th century through the recent Persian Gulf war, military education and operations, terrain analysis, engineering geology in the military, use of military geology in diplomacy and peacekeeping, and the future of military geology.

REG013, 256 p., ISBN 0-8137-4113-0, $76.00, Member price $60.80

Paleozoic Sequence Stratigraphy, Biostratigraphy, and Biogeography; Studies in Honor of J. Granville ("Jess") Johnson

edited by G. Klapper, M. A. Murphy, J. A. Talent, 1997

The late J. Granville ("Jess") Johnson made major contributions in geology and paleontology, specifically to the areas of Middle Paleozoic biostratigraphy, taxonomy, and biogeography of brachiopods and conodonts, sedimentary tectonics, and sequence stratigraphy. This volume is a collection of 20 papers dedicated as a tribute by Jess's colleagues and former students. Five of the papers are on sequence stratigraphy and related topics (ranging from the Ordovician through the Devonian); six are on biostratigraphy (graphic correlation, Devonian and Carboniferous conodonts and fish); five more are on Silurian and Devonian biogeography and paleogeography; and three are on the paleobiology of Silurian and Devonian corals. The volume introduction contains a memorial tribute and biographical statement written by Jess Johnson's close friend and colleague John A. Talent.

SPE321, 386 p., indexed, ISBN 0-8137-2321-3, $108.00, Member price $86.40

Tectonics and Geochemistry of the Northeastern Caribbean

edited by E. G. Lidiak and D. K. Larue, 1998

This up-to-date account of the geology of the northeastern Caribbean plate boundary region is the first general summation of this region since the publication of the DNAG series volume (H) on the Caribbean region (1990). The primary focus of this Special Paper is on the tectonics and geochemistry of the plate boundary, with emphasis on the island of Puerto Rico, the Puerto Rico trench, and adjacent areas. Following an introductory chapter on tectonic setting and stratigraphic correlations of the volcanic strata in Puerto Rico, five papers deal with geochemical aspects of these and related igneous rocks. A second group of three papers explores the tectonics and stratigraphy of Tertiary and younger rocks along the north coast of Puerto Rico and in the adjacent Puerto Rico trench. This volume is an excellent companion to GSA Special Papers 262 and 295; all three concern the circum-Caribbean plate margins.

SPE322, 222 p., indexed, ISBN 0-8137-2322-1, $68.00, Member price $54.40

Accommodation Zones and Transfer Zones: The Regional Segmentation of the Basin and Range Province

edited by J. E. Faulds and J. H. Stewart, 1998

The heterogeneous distribution of strain produces regional segmentation of extended terranes and a variety of fault-related structures known as accommodation zones and transfer zones. Interest in such structures has increased rapidly in recent years, owing to the recognition that segment boundaries may act as barriers to earthquake rupture, commonly host large hydrocarbon accumulations, and are critical for understanding the three-dimensional geometry of extensional orogens. This volume focuses on the geometry, kinematic development, and origin of regional segmentation structures within the Basin and Range province of western North America. Contributions range from analysis of individual structures to broad regional syntheses, including a new map of Basin and Range structures and tilt domains. Several papers discuss the implications of regional segmentation structures in assessing seismic hazards, hydrocarbon and mineral resources, and ground-water supplies. On the basis of characteristic geometries in the Basin and Range and other extended terranes, a new classification for regional segmentation structures is also proposed.

SPE323, 257 p., 1 color plate, ISBN 0–8137–2323–X, $60.00, Member price $48.00

Architecture of the Central Brooks Range Fold and Thrust Belt, Arctic Alaska

edited by J. S. Oldow, H. G. Avé Lallemant, 1998

The 17 papers in this volume present the results of a decade of geological and geophysical research centered largely along a north-south transect through the central Brooks Range of Arctic Alaska. Investigations and results center on a comprehensive description of the rocks and their tectonic evolution from the foreland to the hinterland of the orogen; the geometry and kinematics of contractional and extensional structures, regional and local stratigraphic relations, thermochronology, and the deep crustal structure of the Brooks Range and parts of the North Slope; and detailed descriptions of the major lithotectonic assemblages composing the orogenic belt. This volume offers a unique perspective of a fold-thrust belt and should prove useful in the study of other contractional belts around the world.

SPE324, 268 p., ISBN 0-8137-2324-8, $70.00, Member price $56.00

Depositional Environments, Lithostratigraphy, and Biostratigraphy of the White River and Arikaree Groups (Late Eocene to Early Miocene, North America)

edited by D. O. Terry, Jr., H. E. La Garry, R. M. Hunt, Jr., 1998

The Paleogene-Neogene transition in nonmarine rocks of the North American midcontinent lies within the White River and Arikaree Groups of late Eocene to early Miocene age. This volume presents current lithostratigraphic revision and magnetostratigraphy of these fine-grained volcaniclastic sediments, known for over a century for their abundant fossil mammals. Interbedded tuffs, paleomagnetic zonation and mammalian faunas in the White River and Arikaree rocks provide a revised correlation to other important areas of similar age within North America at a critical time in Earth history—the dawn of the Neogene.

SPE325, 224 p., ISBN 0-8137-2325-6, $69.00, Member price $55.20

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GSA 1999–2000

CONGRESSIONAL SCIENCE FELLOWSHIP

The Geological Society of America is accepting applications for the 1999–2000 Congressional Science Fellowship. The Fellow selected will spend a year, or optionally 16 months, in the office of an individual member of Congress, a congressional committee, or a congressional support agency for the purpose of contributing scientific and technical expertise to public policy issues and gaining firsthand experience with the legislative process. The American Association for the Advancement of Science conducts an orientation program to assist the Fellow in seeking a congressional staff position.

CRITERIA

The program is open to highly qualified Ph.D. earth scientists. Candidates are expected to show exceptional competence in some area of the earth sciences, have a broad professional background, be cognizant of matters outside their area of expertise, and to demonstrate a strong interest and some experience in applying scientific knowledge toward the solution of societal problems.

AWARD

The 1999–2000 GSA Congressional Science Fellow will receive a one-year stipend of $42,000, or $56,000 for 16 months. The Fellow will also receive limited allowances for health insurance, relocation, and travel. The fellowship is funded by GSA and the U.S. Geological Survey.

(The fellowship is available only to U.S. citizens, and employees of the USGS are ineligible to apply for this fellowship. For information about other programs, contact the AAAS, or the Geological Society of America.)

TO APPLY

Procedures for application and detailed requirements are available in the geology departments of most colleges and universities in the United States or upon request from:

Cathleen May
Director, IEE
Geological Society of America
P.O. Box 9140
Boulder, CO 80301-9140

Deadline for receipt of all application materials is February 1, 1999

CALL FOR

GSA Today Correspondent for Student Matters

GSA seeks a Member or Fellow willing to coordinate and be responsible for a regular (monthly) contribution for *GSA Today* dealing with matters of interest to undergraduate and graduate student members of the Society. GSA headquarters will provide administrative support for the correspondent. The one-year renewable appointment begins in March 1999.

Please send a statement of interest and a short vita to:

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Environmental & Engineering Geoscience Contents

Volume IV, Number 2, Summer 1998

About People

GSA Fellow David M. Abbott, Jr., Denver, Colorado, is the recipient of the American Institute of Professional Geologists (AIPG) Martin Van Couvering Memorial Award. Fellows William C. Gussow, Ottawa, Ontario, and John D. Haun, Evergreen, Colorado, are recipients of the AIPG Honorary Membership Award. The AIPG Ben H. Parker Memorial Medal for 1998 goes to GSA Fellow Peter R. Rose, Austin, Texas.

November *BULLETIN* and *GEOLOGY* Contents

The Geological Society of America
BULLETIN
Volume 110, Number 11, November 1998

GEOLOGY

VOLUME 26
NO. 11
P. 961–1056
NOVEMBER 1998

Denver '99

1999 Annual Meeting Field Trips

The 1999 GSA Annual Meeting field trip program takes advantage of Denver's location, at the junction of the High Plains and the Rocky Mountains in Colorado, to unveil a wide variety of destinations and topics. Within an interdisciplinary context, reflecting the theme "Crossing Divides," these trips will familiarize participants with the geology at various areas of focus, introduce new information and research methodologies, and stimulate thoughtful discussion. The Denver meeting site is renowned for field trip opportunities; we encourage meeting attendees to take advantage of a diverse collection of trips including focus on structural geology, stratigraphy, sedimentology, Quaternary, hydro-environmental, and industry-related topics. Some shorter (half-day) trips, quite popular in past years, will be available to local points of geologic interest. As always, travel plans that include Saturday-night stay-over flights can substantially offset field trip costs. Most trips will begin and end in Denver. The following list is tentative. Further details will be given in the April issue of *GSA Today*.

PREMEETING TRIPS

Coal Mining in the 21st Century. Michael Brownfield, Ronald Affolter, Edward Johnson, Charles Barker.

Cretaceous Hydrocarbon Plays—Southern Colorado. Paul R. Krutak.

Geological Reconnaissance of Dinosaur Ridge and Vicinity. Norb Cygan, Betty Rall, "T" Caneer, Bob Raynolds.

Geology of the Heart Mountain Detachment and Related Structures, Northeast Absaroka Range, Wyoming. David Malone, Tom Hauge.

K/T Boundary in the Raton Basin, New Mexico and Colorado. Charles L. (Chuck) Pillmore, Douglas Nichols.

Laramide to Recent Structural Development of the Northern Colorado Front Range. Eric A. Erslev, Karl Kellogg.

Sedimentology and Stratigraphy of Cambrian and Ordovician Inner Detrital Belt Facies of Western Colorado. Paul Myrow, John F. Taylor, James F. Miller, Raymond L. Ethington, Robert L. Ripperdan.

200,000 Years of Climate Change Recorded in Eolian Sediments of the High Plains of Eastern Colorado and Western Nebraska. Dan Muhs, James Swinehart, David Loope.

HALF-DAY TRIP—
Concurrent with the meeting

Geology Tour of Denver Buildings and Monuments. Jack Murphy.

POSTMEETING TRIPS

Geological Reconnaissance of Dinosaur Ridge and Vicinity. Norb Cygan, Betty Rall, "T" Caneer, Bob Raynolds.

Geology and Paleontology of the Gold Belt Back Country Byway, South-Central Colorado. Herb Meyer, Thomas W. (Woody) Henry, Dan Grenard, Emmett Evanoff.

Phosphoria Rock Complex of West-Central Wyoming: An Integrated Sequence Stratigraphic and Paleoceanographic Model. Eric E. Hiatt, Philip W. Choquette, David A. Budd.

Laramide Minor Faulting and Tectonics of the Northeastern Front Range of Colorado. Eric A. Erslev, Steven M. Holdaway.

Late Cenozoic Geology of the Southern Panhandle of Nebraska—Relationship to Occurrence of Water and Other Natural Resources. Robert F. Diffendal, Jr., James Cannia, David Oldham, R. M. Joeckel.

Soil-Geomorphic Relationships Near Rocky Flats, Boulder, and Golden, Colorado Area, with a Stop at the Pre-Fountain Formation of Wahlstrom (1948). Peter Birkeland.

For further information, contact 1999 Field Trip Co-Chairs Alan Lester, lestera@spot.colorado.edu, and Bruce Trudgill, bruce@lolita.colorado.edu, Dept. of Geological Sciences, University of Colorado, Boulder, CO 80309. ■

Technical Program Invitation and Proposal Guidelines for the 1999 GSA Annual Meeting

You are invited to participate in the 1999 GSA Annual Meeting in Denver, Colrado, where new programming initiatives will be inaugurated. As GSA enters the next millennium, we ask your help in increasing the vitality and quality of the annual meeting through these programming changes. We hope to make the GSA Annual Meeting become *the* meeting to attend for all its members. The theme for the 1999 Denver meeting is, appropriately, "Crossing Divides," as outlined below. A brief description of the possible ways of participating in the new program and instructions for proposing Pardee Keynote Symposia and topical sessions follow.

"CROSSING DIVIDES"—Theme of the 1999 Denver Annual Meeting

Craig H. Jones and G. Lang Farmer are the Technical Program Co-Chairs.

Denver, Colorado, will serve as host to the 1999 GSA Annual Meeting. The proximity of the meeting both in space to the main drainage divide of the continent and in time to the end of the 20th century inspires our theme of "crossing divides." In this context, it is appropriate to celebrate at the 1999 GSA Annual Meeting the cross-disciplinary nature of the geological sciences. As a result, we wish to encourage a scientific program that "crosses divides" between the various chemical, biological, and physical disciplines of our science. Even the structure of the meeting program represents a major divide crossing: the 1999 meeting is the first to fully use the new format that combines keynote, topical, hot-topic, and general sessions. We encourage proposals for topical and Pardee Keynote sessions that will mix disciplines, discuss significant changes in the field of geology, or otherwise cross intellectual divides. A main goal is to generate sessions that expose both presenters and audience to the benefits of multidisciplinary approaches to the study of specific geological problems. Such sessions might focus on the divides themselves or on topics of common concern where communication has been intermittent. Our hope is that this program will instill in attendees a broadened sense of the contributions geological sciences can make as a discipline and the degree to which an individual's research is linked to many other specialties.

PROGRAM OPPORTUNITIES

The 1999 GSA Annual Meeting program structure offers new opportunities for effective and dynamic programming and increases programming flexibility by allowing a mixture of invited and volunteered papers and different session formats. Joint Technical Program Committee (JTPC) representatives also have a larger role in programming decisions. Because the changes to the program and procedures are major, we ask that you carefully read the descriptions of the various programming options and procedures before submitting a proposal.

Prominent among the programming changes are major revisions to rules that govern which session organizers may issue formal invitations to presenters, and how many invitations they may issue. Please pay particular attention to the statements below regarding invited presentations in Pardee Keynote Symposia and in topical sessions. Bear in mind that an important benefit of receiving a formal invitation is that an invited presenter is permitted to be a speaker for an additional volunteered presentation at the meeting. Please remind your colleagues that if an author submits more than one *volunteered* abstract with the same person as *speaker*, all abstracts listing that speaker may be rejected. This limitation does not apply for those who are invited speakers for topical sessions or Pardee Keynote Symposia.

PARDEE KEYNOTE SYMPOSIA

The Pardee Keynote Symposia are made possible by a grant from the Joseph T. Pardee Memorial Fund.

These sessions are *special events* that should be of broad interest to the geoscience community. Topics appropriate for these keynote symposia should be on the leading edge in a scientific discipline or area of public policy, address broad fundamental problems, be interdisciplinary, or focus on global problems. The primary criterion for selection is excellence. Selection is on a competitive basis; *only four to eight* half-day, nonconcurrent (one per half-day; minimum of one per day) sessions will be offered. All speakers will be invited. We are striving for a good mix of Pardee Keynote Symposia that will be of interest to the GSA and associated society membership. GSA Council has approved funding up to $2000 per Pardee Keynote Symposium to help the conveners bring in the very best speakers. Conveners will need to indicate in advance how the funds will be used and to provide an accounting of actual expenditures.

Session scheduling commitment will be made no later than April 30 so that speakers may be invited for a specific date and time.

Proposals. Proposals must justify why the session should have keynote stature, have a well-formed plan, discuss the format of the session, and include a tentative list of appropriate, effective speakers. Individuals, GSA Divisions, and associated societies may submit proposals. *Deadline:* January 6, 1999, midnight. *Sorry, but NO proposals will be accepted after that date. Web submission is required.*

Review. These proposals will be reviewed by a seven-member panel of JTPC representatives who broadly cover the major geoscience disciplines. Affiliations with a GSA Division, associated society, or other group will not be a factor considered during the review process. Proposals not chosen as Pardee Keynote Symposia will automatically be considered for topical sessions, unless the convener indicates otherwise.

Scheduling. Conveners may indicate preferred times for the proposed symposia; however, only one per half-day, *including Thursday morning and afternoon*, will be allowed. In scheduling the Pardee Keynote Symposia, we will consider what is best for the entire program and which order will provide the most effective meeting. We will consider preferences based on other programmatic issues. In submitting a Pardee Keynote proposal, the convener (and any affiliated group) agrees that any half-day, Monday through Thursday, is acceptable. *If a specific time slot is desired, submit a proposal for a topical session instead.*

TOPICAL SESSIONS

These sessions should have a topical focus and a mix of invited and volunteered papers. The sessions are designed to promote the exchange of timely or state-of-the-art information with respect to a central topic and to allow scheduling of interdisciplinary talks that bear on a specific topic. Organizers (advocates) may invite specific papers to ensure a successful and excellent session. A maximum of four invited speakers is automatically allowed, but an advocate may request more invitations with a justification for the larger number. Volunteered abstracts will be automatically solicited in *GSA Today* for all approved topical sessions. Individuals, GSA divisions, and associated societies may propose and organize one or more topical sessions.

Length. Generally a half-day session (4 hours, 12–16 papers) is required for a topical session to be viable. Quarter-day sessions (2 hours, 8 papers) will be considered for smaller GSA divisions and associated societies. Smaller groups are encouraged to cosponsor sessions with other disciplines, invite (or encourage) speakers in complementary disciplines or from outside GSA, or develop creative programming, using the available flexibility.

Proposals. Proposals must include (1) a brief description of the session for publication (limited to 50 words); (2) the rationale for the session, the number of proposed invited speakers (names of prospective invited speakers may be included), and a justification for the number of invited speakers if more than four are proposed; (3) the program format or relationship to other potential sessions (see below). Three scientific discipline categories should be selected; the JTPC representatives for these categories will serve as reviewers of the proposal if more than four invited speakers are proposed. The first category selected by the advocate will determine which JTPC representative is responsible for the session and which category should be checked on the abstract form. The division, associated society or other organization affiliated with the session, if any, should be indicated, but a sponsor is not necessary.

Deadline: January 6, 1999, midnight. *Sorry, but NO proposals will be accepted after that date. Web submission is requested.*

Review. These proposals will be reviewed by the Technical Program Chairs (TPCs). Proposals with more than four invited speakers will be reviewed by two JTPC representatives; the 1999 Technical Program Chair and the Annual Program Committee will make the final decision. Thus, it is essential that proposals be submitted by January 6, 1999.

Organization. After acceptance, the advocates should formally invite speakers who will ensure a dynamic session and are encouraged to solicit additional volunteered contributions. In addition, the Call for Papers in *GSA Today* and other GSA mailings will request volunteered abstracts for both the topical and general sessions. *GSA Today* will publish the topical session title, a brief description, the advocates' names and addresses, the format if different from the usual, and the discipline category to be checked (all derived from the proposal). Speakers will not be asked to identify whether they are contributing an invited or volunteered abstract. The advocate is responsible for sending the list of invited speakers to the Abstracts Coordinator and the appropriate JTPC representative after the abstract deadline. This is a critical step because a person may be speaker on only ONE volunteered abstract. Thus, it is important to make sure the speaker and GSA know which papers are invited (as opposed to solicited, volunteered papers).

Abstracts that specify a topical session will be reviewed by the advocate and JTPC representative. The advocate will arrange them into a tentative order of presentation and will work with the JTPC representative if there are too many or too few abstracts. The JTPC representative will alert the advocate to potential additional abstracts from the volunteered discipline general session abstract pool. The JTPC representative will be notified by the TPC how many abstracts may be invited (based on proposal approval) and by the advocate as to which ones are actually invited. The JTPC representative will check that the number of invited talks matches the number in the proposal and transmit this information to the TPC.

Please note: Proposals for Pardee Keynote Symposia MUST be submitted using the 1999 electronic form, and topical session proposals should be submitted on the Web, if at all possible. *Electronic submission is greatly preferred!* The form will be available on-line by November 1 (www.geosociety.org/meetings/99). The paper copy will be also available from GSA headquarters by contacting us by phone (303) 447-2020 or e-mail: meetings@geosociety.org.

SESSION FORMAT

Flexible and creative programming is encouraged for both the Pardee Keynote Symposia and topical sessions. A topical poster and/or oral session related to a

Technical Program *continued on p. 34*

Technical Program and Hot Topics Chairs: Call for Nominations

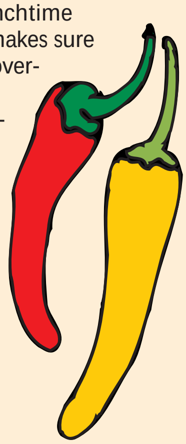
The Technical Program Chair for GSA Annual Meetings, starting in 2001, and the Hot Topics Chair, starting in 1999, will no longer be tied to the meeting site location. This change will give more people the opportunity to organize the Annual Meeting Technical Program or the Hot Topics lunchtime forums.

The Technical Program Chair (TPC) has the final responsibility over the entire technical program, including the review and acceptance of keynote and topical session proposals (January–February) and the scheduling of all sessions for the GSA Annual Meeting (July–early August) in coordination with the Joint Technical Program (JTPC) representatives. This chairmanship also includes active participation over a three-year commitment in the Annual Program Committee, which meets twice a year (usually March and August). GSA reimburses the chair for all travel expenses, including full expenses for attending the prior year's and current year's annual meeting.

The Technical Program Chair must have a broad perspective on the geological sciences and be efficient, organized, fair-minded, flexible, and committed to organizing a dynamic meeting. Some experience with technical program scheduling would be helpful, especially membership on the GSA Joint Technical Program Committee (JTPC) within the past 5 years, but is not required. In addition, the TPC must be able to work regularly and interactively on the Web and Internet,and must be a GSA member.

The Hot Topics Chair organizes four spirited lunchtime debates during the GSA Annual Meeting and makes sure that the titles of the debates reflect their controversial and lively nature. Responsibilities include locating, organizing, and securing debate organizers who will identify topics and speakers.

If you know of someone who would be an effective Technical Program or Hot Topics Chair, or are interested yourself, please contact the GSA Meetings Department for a nomination form: (303) 447-2020, ext. 186, snace@geosociety.org. Nominations are due January 31, 1999.



Technical Program *continued from p. 33*

keynote symposium or a combination of a topical oral followed by a poster session is encouraged. Such combinations should be outlined in the proposals. In general, each session should have a different primary advocate or convener.

Organizers are encouraged to have one (or more) of the invited speakers present an overview of the topic at the beginning of the session that would be of interest and understandable to fellow scientists who are not in the specialty field. This type of overview presentation would be so designated in the program and should be given by well-regarded effective speakers.

Different or new formats are allowed, but they must be stated in the proposal along with the technical-support needs. Formats that promote discussion are encouraged. Discussion periods using remote microphones or with microphones set up in the audience, discussion sessions by a panel of speakers, or forums with invited discussion leaders are possibilities. Another possibility is informal (no abstract) poster displays on chairs in technical session rooms with a period of time set aside for the audience to discuss the posters with the authors. (Note: Poster boards not provided by GSA.) Proposals may request different time limits for papers or discussion sessions, as appropriate. Organizers should remember, however, that the normal time limit for talks is 15 minutes, and keeping to a schedule similar to that of the rest of the meeting is desirable, to allow for synchronized movement between sessions.

A limited number of papers without abstracts could be given in special cases such as for speakers on public policy, etc. On-line sessions may be possible, depending on the available technology.

GENERAL SESSIONS

Oral and poster general sessions with all volunteered papers, which represent the majority of the program, remain the same. The number of abstracts received determines the number of these in each discipline. The rejection rate for recent annual meetings has been less than 5%, and for 1997 and 1998, it was less than 1%. The goal of the TPC and JTPC representatives is to provide presenters the best possible opportunity for communicating new scientific information rather than to dictate what can or will be presented. Poster sessions have been expanded to allow more papers to be presented. Poster sessions will not be scheduled concurrently with oral sessions in the same discipline, to allow for well-attended, dynamic sessions.

HOT TOPICS

Lunchtime Hot Topics forums will be continued (one each day, Monday–Thursday), with more discussion and audience participation. If you are interested in organizing one of these sessions or in being chair of a Hot Topics session, contact Technical Program Co-Chairs Craig Jones and Lang Farmer. These sessions are to be different from technical sessions. The majority of the one-hour time is to be allocated to discussion, with audience participation, and not to talks by "experts." A debate format is recommended, and panels are discouraged. Each session must have a moderator. Titles should be catchy and provocative.

We look forward to working with you. If you have any questions or concerns regarding these program initiatives, please call or e-mail:

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512-471-9425 (fax)
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303-492-2606 (fax)
farmer@terra.colorado.edu

The 1999 GSA Annual Meeting will be held October 25–28 in Denver, Colorado. Although exact times have not been finalized for the meeting, we anticipate them to be similar to past meetings: Sunday through Thursday, 8:00 a.m.–12 noon, 1:30–5:30 p.m. Volunteered presentations take place only during the official meeting days, Monday through Thursday. Topical sessions, therefore, will not be scheduled on Sunday, nor will there be poster sessions on Sunday. Informal programming on Sunday is always welcome; however, the JTPC will arrange the technical program keeping in mind suggestions from societies, divisions, conveners, and advocates. While trying to accommodate the needs of many diverse groups, the TPCs make the final scheduling decisions. Quality of the technical program as a whole takes precedence over all other considerations.

1999 Schedule

January 6: Proposals due. *Firm deadline.*
March 1: Paper copy of 1999 abstract forms will be available from Nancy Carlson at GSA, (303) 447-8850, ext. 161; e-mail: ncarlson@geosociety.org. Conveners and advocates will automatically be mailed a set of forms in March.
May 1: Electronic abstract form will be on GSA home page for active submission—http:/www.geosociety.org.
July 12: Abstracts deadline. Paper copy original and 5 copies due at GSA. Electronic copies accepted until 12 midnight. Authors should submit all abstracts directly to GSA.
August 6: Schedule finalized.
September 1: Accepted abstracts submitted electronically will appear on Web after September 1. All speakers and titles appear on Web with links to those abstracts submitted electronically. ■

CLASSIFIED ADVERTISING

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

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

Situations Wanted

GEOSCIENTIST, 20 years cost-effective experience, ground water, petroleum, environmental and natural resource projects, US and Abroad, Respond (318) 981-4678.

Positions Open

DEPARTMENT HEAD
EASTERN MICHIGAN UNIVERSITY

Eastern Michigan University invites applications for Head of the Department of Geography and Geology. Department has 17 full-time faculty and 15-20 adjuncts, about 250 undergraduate majors and 100 master's students, offers bachelor's degrees in Earth Science; Geography; Geology; Travel and Tourism; and Urban and Regional Planning; and master's degrees in Geography and Historic Preservation. EMU is a comprehensive regional institution with 24,000 students. Faculty is AAUP collective bargaining unit. Department Head position is a 12-month administrative appointment, anticipated starting date July 1, 1999. Requirements include: earned doctorate in field taught in department; record of accomplishment in teaching, research and scholarly/creative activity meriting appointment as full professor; demonstrated commitment to promoting and encouraging excellence in undergraduate and graduate instruction, scholarly research, and faculty, staff and student development; evidence of superior leadership and administrative abilities; strong interpersonal skills and commitment to shared governance. Submit letter of interest with statement summarizing administrative philosophy, evidence of teaching and administrative ability, curriculum vitae, sample of scholarly work, and list of references who can be contacted after screening has occurred. Review of applications will begin in early January and continue until position is filled. For additional information about the department and university visit www.emich.edu/public/geo/welcome.html. Apply to Chair, Search Committee, Position APAA9903, 202 Bowen, Eastern Michigan University, Ypsilanti, MI 48197. We encourage applications from women and members of minority groups. AA/EOE.

SEDIMENTARY SYSTEMS & STRUCTURAL GEOLOGY
WITTENBERG UNIVERSITY

Applications are invited for a one-year Visiting Assistant Professor or Visiting Instructor appointment, Ph.D. or ABD, beginning August, 1999,with possibility of renewal for a second and third year. The successful candidate will teach introductory geology and, on an alternate year pattern, a majors' course in structural geology and another course about some aspect of sedimentary systems/processes, broadly defined. Existing departmental expertise includes paleontology, stratigraphy, process geomorphology, igneous & metamorphic petrology, mineralogy, environmental geology, and economic geology. Possible contributions to interdisciplinary programs in environmental and field studies are supplemental considerations in this search. Preference will be given to applicants with a demonstrated aptitude for teaching undergraduates.

Wittenberg is a small, private, residential, undergraduate institution firmly committed to the liberal arts. Interested applicants are encouraged to visit our Web site (www.wittenberg.edu). Wittenberg is an affirmative action/equal opportunity employer. Review of applications will begin January 15, 1999, and continue until the position is filled.

Candidates should send a curriculum vitae, a brief statement of teaching interests and philosophy, and list of 3 references (with phone numbers or e-mail addresses) to: Dr. Kenneth W. Bladh, Professor and Chair, Geology Department, Wittenberg University, P.O. Box 720, Springfield, OH 45501-0720; kbladh@mail.wittenberg.edu; (937) 327-7334.

ASSISTANT PROFESSOR GEOLOGY
UNIVERSITY OF RHODE ISLAND

The Geology Department at the University of Rhode Island invites applications for a new tenure-track faculty position beginning in the Fall of 1999. This position, within the newly formed College of the Environment and Life Sciences, reflects the commitment to expanding its programs in the environmental sciences. We seek applicants whose primary interest is in the field of organic contaminant hydrogeology. A Ph.D. in hydrology, geology, or within the environmental sciences is required at the time of appointment. The following are also required: potential for developing an externally funded and nationally recognized research program in hydrogeology; an undergraduate degree (or equivalent) in geology; training and research experience in hydrogeology, organic chemistry, and contaminant transport; the ability to teach an upper-division course in environmental organic chemistry and a graduate-level course in solute/contaminant transport; a strong commitment to quality instruction. The following are preferred: post-doctorate experience; a record of peer-reviewed publications and research funding; teaching experience. For information about the Department of Geology, refer to our Web site: http://www.uri.edu/cels/gel. Interested candidates should submit a curriculum vitae, transcripts, a statement of research and teaching interests and the names of four referees by 10/30/98 or until position is filled to: Anne Veeger, Search Committee Chair (Log # 021336). University of Rhode Island, P.O. Box G, Kingston, RI 02881. The University of Rhode Island is an AA/EEO employer and is committed to increasing the diversity of its faculty, staff, and students. Persons from under-represented groups are encouraged to apply.

SOUTHERN ILLINOIS UNIVERSITY, CARBONDALE

The Department of Geology invites applications for a tenure-track position in paleobiology at the assistant professor level, starting August 16, 1999. Applicants must hold a Ph.D. or show that they will complete all degree requirements by August 16, 1999. If the successful candidate has not completed all requirements for the Ph.D. degree by August 16, 1999, he/she will be appointed for one year as instructor at a reduced salary. The successful candidate must have demonstrated teaching ability and the existence of, or potential for developing, an externally funded research program of high quality. Areas of research emphasis may include but are not limited to paleobiology, biostratigraphy, and global change. Teaching duties will include invertebrate paleontology and paleoecology, introductory undergraduate geology courses, and upper level and graduate courses in the emphasis area. Applicants should submit a curriculum vitae, a statement of teaching and research interests, and the names and addresses of at least three referees to: Dr. James R. Staub, Search Committee Chair, Department of Geology, Mail Code 4324, Southern Illinois University, Carbondale, IL 62901-4324; fax 618-453-7393; e-mail: jstaub@ geo. siu.edu. Applications will be accepted until December 7, 1998 or until the position is filled. Information about the Department and its programs can be found at: http://www.science.siu.edu/gelogy/index.html. Southern Illinois University is an Equal Opportunity, Affirmative Action Employer.

FACULTY POSITIONS
STRUCTURAL GEOLOGY AND GEOPHYSICS
STATE UNIVERSITY OF NEW YORK AT BUFFALO

The Department of Geology invites applications for two tenure-track faculty positions, structural geology and geophysics, starting in September 1999 at the Assistant Professor level. The successful candidates will demonstrate a potential for research and teaching, which will both complement and integrate with our existing programs in volcanology and environmental geology. Existing research includes studies of active volcanoes, analysis of neotectonics, characterization of fractured rock systems, remediation of ground water, and applications of basin analysis. The geology home page gives more details of our departmental research and teaching program (http://wings. buffalo.edu/academic/department/geology/). Teaching duties for both positions will involve undergraduate and graduate level courses in their respective specialties. The salary and the initial University contribution to the candidates/research equipment will be very attractive. Successful candidates must have the Ph.D. degree as of the date of appointment. Apply with a statement of teaching and research goals and a curriculum vitae, including published research, grant support, and names of at least three references to: Chair, Search Committee, Department of Geology, State University of New York at Buffalo, 876 Natural Sciences Complex, Buffalo, NY 14260-3050. We will begin evaluating applicants on December 20, 1998.

The State University of New York is an Equal Opportunity/Affirmative Action Employer and encourages applications from women and minorities.

HYDROGEOLOGIST
CSU, SACRAMENTO

The Geology Department at California State University, Sacramento, seeks to fill one tenure-track position in Hydrogeology at the Assistant or Associate Professor level. Expertise is sought in one or more of the following fields: groundwater modeling, contaminant transport, aqueous geochemistry, vadose zone interactions, watershed management, environmental restoration, surface water hydrology and engineering geology. Review of applications will begin February 1, 1999; position open until filled.

Candidates must be committed to strong undergraduate teaching. The Department shares a building with the USGS Water Resources Division and has one of the largest on-campus well fields in the nation, offering ample opportunities for collaborative research. A Master's program is under development.

A detailed description of the position may be found at: http://www.asnet.csus.edu/geol.

Submit resume, letter of application and three letters of reference to Dr. Susan Clark Slaymaker, Geology Department, California State University, 6000 J Street, Sacramento, CA 95819-6043.

ASSISTANT PROFESSOR
INDIANA UNIVERSITY–PURDUE UNIVERSITY
AT INDIANAPOLIS (IUPUI)

Applications are solicited for a tenure-track, assistant professor position in mineralogy or hydrogeology. A Ph.D. in geology or a related field is required. We seek an individual who will develop an externally funded research program and is committed to high-quality teaching. Applicants with research specialty in mineralogy applied to environmental issues should complement our existing strengths in sedimentology and geomorphology. Applicants with research specialty in hydrogeology should complement our existing strengths in hydrogeochemistry, geomorphology, and coastal/wetland sedimentology.

Indianapolis is the twelfth largest city in the United States. The city uniquely combines the cultural amenities of urban life with the residential qualities of smaller communities. IUPUI is the third largest university in Indiana, with about 28,000 students. The Geology Department is part of the School of Science, and offers B.S., B.A., and M.S. degrees in geology. There are currently 9 full-time and 7 adjunct faculty, with about 60 undergraduate and 15 graduate majors.

The initial appointment will begin August 1999. Interested candidates should send a resume, statements of research and teaching interests, and the names of at least three referees. Deadline for receipt of applications: January 15, 1999. Applications and correspondence should be addressed to: Dr. Andrew Barth, Chair, Search and Screen Committee, Department of Geology, Indiana University–Purdue University at Indianapolis, 723 W. Michigan Street, Indianapolis, IN 46202-5132. E-mail address: nfribley@iupui.edu. Web site: www.geology.iupui.edu.

IUPUI is an equal-opportunity, affirmative-action employer.

ASSISTANT PROFESSOR IN PALEONTOLOGY

The Department of Geology at the University of Iowa invites applications for a full-time tenure-track Assistant Professorship with a speciality in micropaleontology or invertebrate paleontology. The appointment will begin in August 1999. We seek an outstanding researcher and teacher whose approach is both quantitative and specimen-based, and who will work with other faculty to

Classifieds *continued on p. 38*

Memories of the 1998 GeoVentures

The 1998 GSA GeoVentures Program offered three programs unrelated to the annual or section meetings. The total of 94 participants, ranging in age from 29 to 80, represented a vast range of interests and backgrounds.

This educational program serves professionals who enjoy geology and the company of other geologists in a field setting. GeoVentures are a special benefit created for members, but are open to guests and friends also. GeoVentures is the overall name for adult educational and adventure experiences of two kinds: GeoHostels and GeoTrips. Both are known for superior scientific leadership. Fees for both are low to moderate (relative to the destination, length, time of year, and number of participants). GeoHostels are usually five-day, campus-based programs. GeoTrips are anywhere from one to three weeks in length, and the itinerary covers a wide variety of destinations.

GeoTrip

Photo by Lowell Bogart.

From the Birth of a Continent to Glen Canyon Dam: A Grand Canyon Voyage

27 participants, April 10–18, 1998

Leaders: Brad Ilg, Cerro Alto Geological Consultants, Inc., Glorieta, New Mexico; Jeff Bennett, Northern Arizona University, Flagstaff; Mike Timmons and Joel Pederson, University of New Mexico, Albuquerque.

"They (the leaders) were all great and are rewriting the geologic history of the Grand Canyon! All in all, it was a splendid trip and I'm very glad I went," wrote Lowell Bogart, Port Townsend, Washington.

Note: If you see the same folks in the different "gang" photos, it's because our GeoTrips and GeoHostels have developed a core of faithful followers. We thank them for their continued support, and we invite other members and friends to join the fun. We're always looking for new gang members.

GeoHostels

Durango gang at Molas Pass. Photo by Sue Tanges.

Geology of the Southwestern San Juan Mountains

27 participants, June 27–July 2, 1998

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

"The leaders, Greg Holden and Ken Kolm, were outstanding," wrote Phili Deboo of Memphis, Tennessee.

Photo by Sheila Roberts.

Geology of the Grand Teton–Yellowstone Country

37 participants, July 18–23, 1998

Leaders: Robert Thomas and Sheila Roberts, Western Montana College, Dillon, Montana.

"You could not find better leaders if you tried. They (Rob and Sheila) are the best!" wrote Irene and Al Boland, Rock Hill, South Carolina.

Crossing Divides

1999 Denver, Colorado

GSA Annual Meeting and Exposition

October 25–28
Colorado Convention Center

General Co-Chairs

Mary J. Kraus
(303) 492-7251, fax 303-492-2606, kraus@spot.colorado.edu
David Budd
(303) 492-3988, fax 303-492-2606, budd@spot.colorado.edu
Both at Dept. of Geosciences, Campus Box 250, University of Colorado, Boulder, CO 80309-0250

Technical Program Chairs

Craig Jones
(303) 492-6994, fax 303-492-2606, cjones@mantle.colorado.edu
G. Lang Farmer
(303) 492-6534, fax 303-492-2606, farmer@terra.colorado.edu
Both at Dept. of Geosciences, Campus Box 399, University of Colorado, Boulder, CO 80309-0399

Due date for Pardee Keynote Symposia and topical Session proposals: January 6, 1999
Electronic Proposal Form Available November 1, 1998.

Call for Field Trip Proposals

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

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

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

Call for Short Course Proposals

Due December 1, 1998

The GSA Committee on Continuing Education invites those interested in proposing a GSA-sponsored or cosponsored course or workshop to contact GSA headquarters for proposal guidelines. Courses may be conducted in conjunction with all GSA annual or section meetings. We are particularly interested in receiving proposals for the 1999 Denver Annual Meeting or the 2000 Reno Annual Meeting.

Proposals must be received by December 1, 1998. Selection of courses for 1999 will be made by February 1, 1999. For those planning ahead, we will also consider courses for 2000 at that time.

For proposal guidelines or information, contact:
Edna Collis, Continuing Education Coordinator, GSA headquarters, 1-800-472-1988, ext. 134, ecollis@geosociety.org

Denver Mini-Calendar

1998

November 1 — Electronic Symposia/Topical Session Proposal Form available on the GSA Web site
December 1 — Short Course Proposals due to GSA

1999

January 6 — Symposia and Topical Proposals due to Technical Program Chairs
April 1 — Call for Papers published and distributed
May 1 — Electronic Abstract Submittal Form avaialble on the GSA Web site
June 1 — Registration and housing information printed in June *GSA Today*
July 12 — Abstracts Deadline
September 17 — Preregistration and Housing Deadline

Future GSA Meetings

2000 Reno, Nevada
November 13–16

2001 Boston, Massachusetts
November 5–8

2002 Denver, Colorado
October 28–31

2003 Seattle, Washington
November 2–5

For information on any GSA Meeting call the GSA Meetings Department
1-800-472-1988 or • (303) 447-2020, ext. 113
fax 303-447-0648 • meetings@geosociety.org

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

improve our strong graduate program in paleontology and sedimentary geology. In addition to developing an active, externally funded program of research, the successful candidate will be expected to teach three courses per academic year. These will include: (1) an upper-level undergraduate/graduate course in biostratigraphy, micropaleontology or invertebrate paleontology, (2) team-participation in Evolution and History of Life, a general education course, and (3) a graduate seminar in paleontology. He/she will also be expected to contribute both to our Paleontology Repository as well as to new departmental initiatives in the environmental sciences and climate change. Applicants should have a Ph.D. or be in the final stages of completing the degree. Women and minorities are especially encouraged to apply. Applicants should send a complete resume (including a bibliography and statement of teaching and research interests) and have at least three letters of recommendation sent to: Dr. Holmes Semken, Search Committee Chair, Department of Geology, University of Iowa, Iowa City, IA 52242-1379 (phone: (319) 335-1818; fax: 319-335-1821). The closing date for applicant applications is December 1, 1998, and screening of candidates will begin immediately thereafter and continue until the position is filled. The University of Iowa is an Affirmative Action-Equal Opportunity Employer.

WASHINGTON AND LEE UNIVERSITY
STRUCTURAL GEOLOGY,
GEOPHYSICS, AND TECTONICS

The Department of Geology at W&L seeks a new colleague for a tenure-track position at the Assistant Professor (beginning) level at the start of the 1999-2000 academic year. With a nationally competitive student body, four faculty members, a technician, and secretary, we occupy spacious and well-equipped quarters in a new $23 million science center. The department receives generous independent funding, is a member of the Keck Geology Consortium, and is advantageously situated in the Shenandoah Valley adjacent to the Blue Ridge and Allegheny Mountains.

We seek a broadly trained geologist with research and teaching experience in structural geology, geophysics, and/or tectonics. Course offerings will include introductory geology, structural geology, field methods, and geophysics. The successful applicant will be expected to maintain an active research program, attract external funding, and collaborate with students and other colleagues on campus.

Candidates should submit a letter of application outlining their approach to teaching and research in an undergraduate liberal arts setting, vitae, graduate academic transcripts, and 3 or 4 letters of recommendation that specifically address their potential as a teacher/scholar. All application materials must arrive by December 15, 1998. Highest ranked candidates will be invited to campus beginning in January 1999. Send applications to: Structure-Geophysics Position, Department of Geology, Washington and Lee University, Lexington, VA 24450. W&L is an equal opportunity educator and employer.

MINERALOGY/PETROLOGY
DENISON UNIVERSITY

The Department of Geology and Geography invites applications for a tenure-track appointment at the Assistant Professor level, to begin in the Fall semester of 1999; a Ph.D. is required. Primary teaching responsibilities include mineralogy, petrology, and introductory physical geology. Other subjects which would complement our program include economic geology and geochemistry. Our department stresses a balance of classroom, field, and laboratory experiences for our majors, and we seek a colleague who will contribute to and collaborate with us on all these components of undergraduate geoscience education. Denison is a selective liberal arts college strongly committed to and supportive of excellence in teaching and active faculty research which involves undergraduate students.

Candidates should submit a letter of application, including a discussion of their approach to teaching and research in a liberal arts setting, along with a vitae, academic transcripts and the names, addresses, e-mail and phone numbers of three or four references – to Tod A. Frolking, Chair, Department of Geology and Geography, Denison University, Granville, OH 43023; (740) 587-6217; frolking@denison.edu. Application materials must arrive by December 1, 1998, for full consideration, interviews will be held on campus in late January. Early applications are strongly encouraged. Denison is an affirmative action/equal opportunity employer.

POSTDOCTORAL OPPORTUNITIES

The U.S. Geological Survey, Geologic Division, is conducting a national competition to find outstanding scientists, who have recently completed doctorate-level research, to fill 1-2 year contractural positions as guest Research Associates. The objective of the program is to provide guest Research Associates of unusual promise and ability a formal opportunity to conduct research in an area of their choice that falls within the realm of the Geologic Divison's long-term scientific strategy goals as follows:

Conducting geologic hazard assessments for mitigation planning; providing short-term prediction of geologic disasters and rapidly characterizing their effects; advancing the understanding of the Nation's mineral and energy resources in a global, geologic, economic, and environmental context; anticipating the environmental impacts of climate variability; establishing the geologic framework for ecosystem structure and function; interpreting the links between human health and geologic processes; and determining the geologic controls on ground water resources and hazardous waste isolation.

Approximately five (5) Research Associate opportunities are available. The principal duty stations will be Reston, VA, Denver, CO, or Menlo Park, CA, depending on the candidate's chosen research area. Limited opportunities, however, may be available at other field locations. Compensation will be in fixed weekly stipends for the geographic area in which they work. Approximate stipend amounts are as follows: Reston, VA, $820.00; Denver, CO, $855.00; and Menlo Park, CA, $886.00 Awardees are offered a services contract initially for 12 months. However, a 1-year extension may be granted at the discretion of the USGS should funds be available.

For more information about the program and the application materials required, complete details are provided in the Postdoctoral Research Associateship Program Announcement which is available on the web at http://geology.usgs.gov/postdoc/ or you may call (703) 648-6630 to request a copy.

The U.S. Geological Survey is an equal opportunity employer. Qualified applicants will receive consideration without regard to race, creed, color, age, sex, national origin, political preference, labor-organization affiliation or non-affiliation, marital status, or non-disqualifying handicap.

WASHINGTON STATE UNIVERSITY
NOTICE OF VACANCY
TWO FULL-TIME TENURE TRACK POSITIONS

The Department of Geology, Washington State University, seeks to fill two full-time, tenure-track faculty positions at the Assistant Professor level. The successful candidates must have an earned doctorate, will demonstrate commitment to excellence in research and teaching, and the ability to generate external research funding. Both will be expected to teach undergraduate and graduate courses in their areas of specialty, and to take a significant role in teaching and administering our popular introductory course. We encourage applications from scientists working with both ancient and modern systems.

Position 1 will be filled with a candidate with expertise in the general area of carbonate sedimentology/stratigraphy. Applicants should have expertise in one or more of the following areas: diagenesis, paleoclimatology, paleontology, paleoecology, and global change. The successful candidate will be responsible for undergraduate paleontology and historical geology instruction, and will participate in teaching of undergraduate and graduate sed-strat courses.

Position 2 will be filled by a candidate with expertise in the general area of geochronology. Applicants should be proficient in modern isotopic dating and analytical methods, preferably ICP-MS and/or laser ablation techniques. The successful candidate will be expected to participate in securing funding for equipment acquisitions. Teaching responsibilities, in addition to physical geology, will include courses in application of geochronologic methods to geological processes.

With these appointments, we seek to build on existing strengths in clastic sedimentology, paleoclimatology, cosmogenic dating, igneous petrology, volcanology, low-T geochemistry, analytical geochemistry, economic geology, hydrogeology, and structural geology. Strong curricular and research ties exist with the Department of Geology and Geological Engineering at the neighboring University of Idaho, and at Washington State University branch campuses at Vancouver and Tri-Cities.

The Department currently has 13 FTE and several adjunct faculty. Existing facilities in the Geoanalytical Laboratory include a newly upgraded electron microprobe, automated XRF and XRD, quadrupole ICP-MS, and an automated gas source mass spectrometer for stable isotope analysis. Additional facilities include a FTIR spectrometer, CL and epifluorescence scopes, a gas-flow fluid inclusion stage, and gas chromatographs for organic work. Local and regional geology and geography offer diverse research opportunities in the northern Rocky Mountains, the Columbia River Plateau, the northern Basin and Range, and the active volcanoes of the Cascade Range.

Applications for the carbonate sedimentology/stratigraphy position should be addressed to David Gaylord, Chair, Carbonate Sedimentology/Stratigraphy Search Committee, OR for the geochronology position to John Wolff, Chair, Geochronology Search Committee, Department of Geology, Washington State University, Pullman, WA 99164, U.S.A.

Applications should include a full curriculum vitae, a statement of teaching and research philosophy, and the names, addresses, and e-mail addresses of 4 referees, and must be received by January 1, 1999.

Washington State University employs only U.S. citizens and lawfully authorized non-U.S. citizens. All new employees must show employment eligibility verifications as required by the U.S. Immigration and Naturalization Service. Washington State University is an equal opportunity/affirmative action educator and employer. Members of ethnic minorities, women, Vietnam era or disabled veterans, persons of disability and/or persons the ages of 40 and over are encouraged to apply.

UNIVERSITY OF FLORIDA
ASSISTANT PROFESSOR

The Department of Geology invites applications for a tenure-track assistant professor position in the general area of sedimentary geology to begin with or during the 1999-2000 academic year. Preference will be given to quantitative, process-oriented scientists who will develop strong and innovative research programs, and exhibit a strong commitment to teaching undergraduate and graduate students. We are particularly interested in scientists whose research investigates fundamental earth processes in a quantitative way. Possible specialties include sedimentology; sedimentary geochemistry, including biogeochemistry; environmental geology; seismic stratigraphy; basin evolution, etc. In addition, consideration will be given to those whose research complements existing research strengths of the department, e.g., paleoclimatology/paleoceanography, crustal evolution/chemical geodynamics, paleomagnetism/ tectonophysics, isotope geology, and environmental geology. More information on the department is available at http://web.geology.ufl.edu.

Qualified candidates should send a letter of interest, including a statement of research and teaching goals, a curriculum vitae, and the names and addresses of three references by January 15, 1999, to: Dr. Paul Mueller (mueller@geology.ufl.edu), Department of Geology, Box 112120, University of Florida, Gainesville, FL 32611, (352) 392-2231; fax 352-392-9294.

The University of Florida is an equal opportunity employer; qualified women and minorities are especially encouraged to apply.

SENIOR SCIENTIST
DELAWARE GEOLOGICAL SURVEY

The Delaware Geological Survey (DGS) at the University of Delaware is seeking qualified candidates for a Geologist/Senior Scientist. The DGS is the lead agency for investigating the geology, water, mineral, and other earth resources in the state, and for dissemination of such information. Responsibilities include developing, managing, and conducting complex research on the stratigraphy of the mid-Atlantic Coastal Plain and Outer Continental Shelf, classifying and correlating stratigraphic units, developing research proposals, and publishing results of research. Requires interest and ability to interact with state, local, and federal agencies, industry, and the general public. Experience with use of computers for graphics and data reduction to support research efforts highly desirable.

Requires a Ph.D. in geology with a minimum of 7 years or a M.S. in geology with 10 years of directly related experience using geophysical log interpretation, micropaleontology, biostratigraphy, paleoenvironmental interpretation, sequence stratigraphy and seismic stratigraphy in stratigraphic investigations. To apply send a letter of interest, resume, and the names and addresses, including e-mail, of 3 references to: SS Search Committee, Delaware Geological Survey, DGS building, University of Delaware, Newark, DE 19716 by December 1, 1998. The University of Delaware is an Equal Opportunity Employer which encourages applications from Minority Group Members and Women.

HYDROGEOLOGIST

The Department of Geological Sciences, California State University, Fullerton, invites applications for a tenure-track position at the Assistant Professor level, starting August 1999. Applicants should have the following credentials and capabilities: (1) A Ph.D. in geology or hydrogeology; (2) A primary interest in teaching and achieving excellence in teaching; (3) A field-based orientation with experience in groundwater modeling, and (4) A commitment to developing a research program that includes undergraduate and graduate students.

Teaching responsibilities will include: physical geology, hydrogeology, field hydrology, graduate courses in the new faculty member's area of expertise, and participation in our summer hydrology field camp at Mammoth Lakes, California. Expertise in G.I.S., exploration geophysics, and/or contaminant hydrogeology/hydrogeochemistry is a plus. Before applying, see the full text of this announcement at http://geology.fullerton.edu/geology/.

To apply, please send the following: (1) A detailed curriculum vitae; (2) A letter telling us about yourself and detailing how you meet the qualifications outlined above; (3) A statement about teaching that includes a discussion of relevant course work and/or experience in preparation for teaching, a list of courses you would feel comfortable teaching, and a statement of your teaching philosophy; (4) A statement of your future research plans and goals; and (5) The names, addresses, phone numbers, and e-mail addresses of at least three references familiar with your teaching and research potential.

Send application to: Dr. Brady Rhodes, Chair, Search Committee, Department of Geological Sciences, California State University, P.O. Box 6850, Fullerton, California 92834-6850. Applications will be accepted until January 15, 1999.

California State University, Fullerton is an Affirmative Action/Equal Opportunity Employer. All personnel policies conform with the requirements of Executive Order 11246, the Americans with Disabilities Act (ADA) of 1990, Title IX of the Higher Education Amendments of 1972 and other federal regulations regarding nondiscrimination.

CHAIR
DEPARTMENT OF GEOLOGY & GEOPHYSICS
LOUISIANA STATE UNIVERSITY

The Faculty of the Department of Geology & Geophysics seek an outstanding research-oriented geologist to serve as departmental Chair. This search is undertaken in response to renewed interest within the University to move the Department to the highest level among Carnegie I research universities. We seek candidates with proven records of scholarship and external research funding who can provide leadership for the planning and administration of undergraduate and graduate instruction and for development of departmental research programs. Preference will be given to candidates with international recognition, clear perspectives on the future of the earth sciences, and scientific interests that will strengthen departmental programs in basin analysis, depositional systems, fluids in the crust, tectonics of the lithosphere, and earth history. In addition, the Chair will be expected to have the experience and/or the research interests needed to strengthen ties between the Department and the oil and gas industry. The Chair will also oversee development of alumni relations and manage a significant and growing departmental endowment.

This tenured appointment will be at the level of Full Professor beginning in August 1999 or sooner. Salary and start-up funding will be commensurate with the record of scholarly activity, commitment to continued research productivity, and previous administrative responsibilities.

All applications received by December 15, 1998, will receive full consideration, but the search will continue until the position is filled. We welcome letters of nomination for potential candidates. Letters of application, including a curriculum vitae, a statement of research and teaching activities, a description of administrative positions and philosophy, and the names of five potential references should be sent to: Dr. Roy K. Dokka, Chair, Search Committee, A. G Gueymard Professor of Geology & Geophysics, Department of Geology & Geophysics, Ref: Log #325, Louisiana State University, Baton Rouge, LA 70803.

LSU is an Equal Opportunity/Equal Access Employer.

ASSISTANT PROFESSOR
PETROLOGY AND EARTH RESOURCES
UNIVERSITY OF WISCONSIN, EAU CLAIRE

Tenure-track position in Igneous/Metamorphic Petrology and Earth Resources beginning in August 1999.

Teaching responsibilities include introductory courses as needed by the department, mineralogy/petrology, earth resources and economic mineral deposits. The individual will be expected to develop a vigorous undergraduate collaborative research program. Screening of applications will begin on January 20, 1999; however, screening will continue until position is filled.

The University of Wisconsin is an equal opportunity/affirmative action employer. Minority and female applicants are particularly encouraged to apply. For a complete position description contact the department at (715) 836-3732 or visit the department web site at http://www.uwec.edu/academic/geology.

HYDROGEOLOGIST, UNIVERSITY OF WYOMING

The Department of Geology and Geophysics at the University of Wyoming invites applications for a tenure-track position at the assistant professor level starting August 1999. Teaching responsibilities will include undergraduate and graduate courses in hydrogeology, advising undergraduate and graduate students, and participating in the general teaching mission of the department. The successful applicant must show promise of establishing an active research program with the potential for external funding. Preference will be given to applicants with research areas that complement existing departmental strengths. Additional information on the Department can be obtained on our Web page (http://www.uwyo.edu/A&S/geol/geolog~1.htm).

Applicants must have a Ph.D. at the time of appointment. To apply, send a curriculum vitae, a statement of research and teaching interests, graduate transcripts, and the names and addresses of three references to: James I. Drever, Search Committee Chair, Department of Geology and Geophysics, University of Wyoming, Laramie, WY 82071-3006. Review of applications will begin on December 15 and the search will continue until the position is filled. The University of Wyoming is an affirmative action/equal opportunity employer.

SAN DIEGO STATE UNIVERSITY
GEOLOGICAL SCIENCES EDUCATION

The Department of Geological Sciences in association with the Center for Research in Mathematics and Science Education at SDSU seeks to fill a tenure-track faculty position in geological-sciences education at any level depending on the applicant's qualifications. We are searching for someone with a doctorate in the geological sciences or geological-sciences education with an established research program, or a clearly defined plan to develop one, that investigates learning in the geological sciences. Applications must be received by Jan. 5, 1999. Details available at http://www.geology.sdsu.edu/geoscieduc/.

E-mail inquiries to dkimbrough@geology.sdsu.edu. SDSU is an Equal Opportunity Title IX Employer and does not discriminate against persons on the basis of race, religion, national origin, sexual orientation, gender, marital status, age, or disability.

UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL
CONTINENTAL MARGIN GEOLOGIST

The Department of Geology at the University of North Carolina at Chapel Hill seeks a tenure-track Assistant Professor in the field of Continental Margin Geology beginning July 1999. The successful candidate will conduct research on the evolution of continental margins. Areas of interest include (but are not limited to): coastal and estuarine geology, shelf and slope sedimentaiton, sequence stratigraphy and basin analysis. We seek a versatile scientist whose research has a strong impact on environmental problems such as coastal development, water supply, and natural resources. In addition, we are particularly interested in individuals who will interface with existing departmental research programs and develop cross-disciplinary ties with other units on campus including the Departments of Marine Sciences and Geography and the new Carolina Environmental Program, and the Institute of Marine Sciences in Morehead City, NC.

Applicants must hold a Ph.D. at the time of appointment and postdoctoral and teaching experience is highly desirable. The successful candidate will be expected to establish a vigorous, externally funded research program and to demonstrate excellence in undergraduate and graduate education and interest in the use of information technology in teaching.

Applicants must submit a letter of application, names, addresses, e-mail and phone numbers of four references, statements of teaching and research interests, and their vitae to Timothy J. Bralower, Chair, Department of Geology, University of North Carolina, Chapel HIll, NC 27599-3315. Applications must be received by December 15, 1998. For more information on the department and the university please visit our web page at http://geosci.unc.edu/web/.

The University of North Carolina at Chapel Hill is an equal opportunity/affirmative action employer. Women and minorities are encouraged to apply.

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Opportunities for Students

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California Institute of Technology. Postdoctoral Fellowships in Geological and Planetary Sciences. The California Institute of Technology announces two fellowships in earth and planetary sciences: The O.K. Earl Postdoctoral Fellowship, and the Texaco Postdoctoral Fellowship.

These awards are from funds endowed by Orrin K. Earl, Jr. and by the Texaco Philanthropic Foundation. Each fellowship carries an annual stipend of $36,000 and offers a research expense fund of $1,000 per year and one-way travel to Pasadena. The duration of each appointment will normally be for two years, contingent upon good progress in the first year, and beginning with the 1999-2000 academic year. Fellows are eligible to participate in Caltech's health and dental program.

These fellowships have been established to support the research of scientists typically within two years after receipt of the Ph.D. The intent of the program is to identify and support innovative and creative work in the earth and planetary sciences, with particular emphasis on interdisciplinary work. Applicants with training in physics, chemistry, biology, or computer sciences are urged to apply. The Caltech faculty is currently active in geobiology, geochemistry, geology, geophysics, petrology, seismology, and atmospheric and planetary sciences. It is expected that each fellowship holder will be hosted by a division professor (designated by the division chairman) who will contribute to the fellowship support both financially and by providing intellectual guidance.

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

Completed applications with references should arrive at Caltech by Monday, December 18, 1998.

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

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

Graduate Research Assistantships in reservoir characterization are available in the Department of Geological Sciences at Clemson University. Research opportunities for motivated students include outcrop stratigraphic studies in western United States, reservoir geology, and 3D computer modeling and visualization. Contact: Dr. James Castle, Department of Geological Sciences, Box 341908, Clemson University, Clemson, SC 29634-1908, phone (864) 656-5015, or e-mail: jcastle@clemson.edu.

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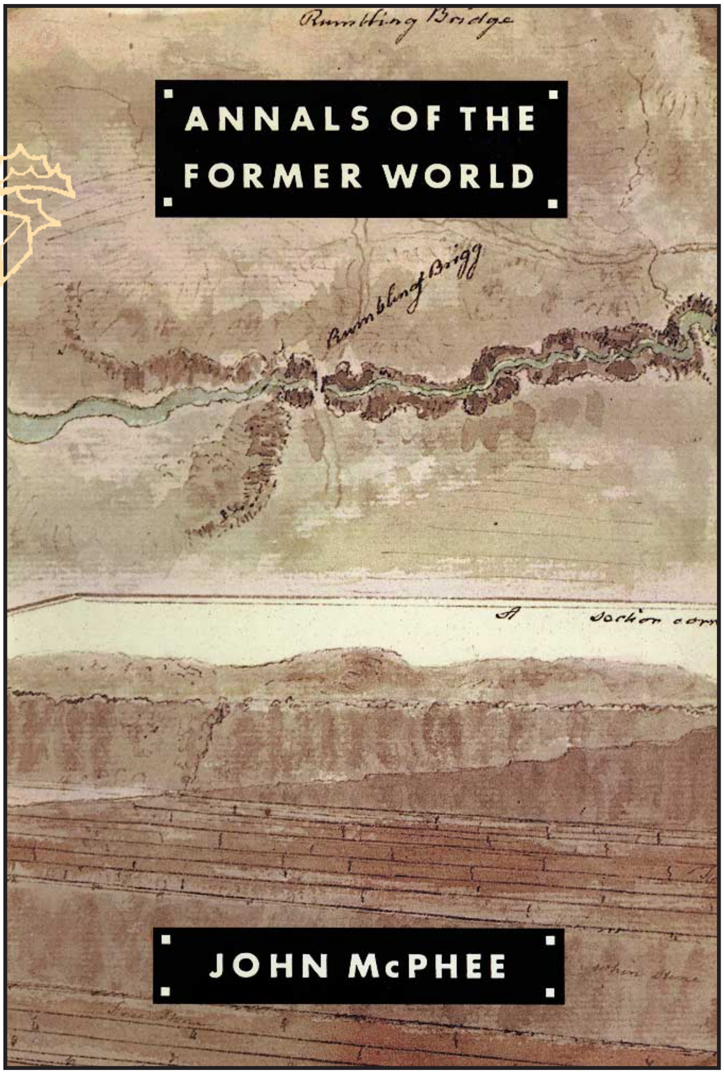

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