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 $^{13}$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.

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 subma

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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).

Figure 2. A gas-hydrate phase diagram illustrating the temperature- pressure-dependent boundaries between the hydrate (shaded) and free methane gas and between ice and water. (After Kvenvolden, 1988.)
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 crystalizes 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 chemoautotrophic 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 1,700 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 >15% organic carbon, 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 seal-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 slope failure 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 (Håg, 1993).

Ketten 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 δ13C (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 δ13C (up to 2.5‰), implying that the entire water column may have experienced rapid δ13C 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 $^{13}C$) 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 peak warming that may have led to gas-hydrate dissociation.

In the latest Paleocene, bottom-water temperature increased rapidly (in $<10,000$ yr) by as much as 4 $^\circ$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 $^\circ$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 lysoclinal 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 (Stor-Regga) which have been ascribed to earth-quakes and gas-hydrate dissociation (Bugge et al., 1987; Jansen et al., 1987).

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 destabilization? 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 subaerially 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 concentrations >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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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 less 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 finding...

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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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REFERENCES CITED


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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 biostatigraphy and/or paleoceanography, and who have an interest in sequence stratigraphy analysis, particularly in conjunction with research into deep-sea sedimentology.

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, 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 Louisiana, 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 in 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.
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.

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 enstisols 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 topography of the once-lofty Appalachian-Caledonian chain, and isostatic compensation.

Postorogenic denudation: The period of stone wall construction, between about 20,000 and 8,000 yr. B.P., 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 topography of the once-lofty Appalachian-Caledonian chain, and isostatic compensation.

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WASHINGTON REPORT

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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 radon 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-
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.

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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 nontenured 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.

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

<table>
<thead>
<tr>
<th>Rank</th>
<th>Lecturer or instructor</th>
<th>Assist. prof.</th>
<th>Assoc. prof.</th>
<th>Prof.</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undergraduate</td>
<td>18.9</td>
<td>13.3</td>
<td>8.1</td>
<td>3.2</td>
<td>8.5</td>
</tr>
<tr>
<td>Graduate</td>
<td>12.6</td>
<td>11.8</td>
<td>6.3</td>
<td>0.8</td>
<td>4.6</td>
</tr>
<tr>
<td>All faculty</td>
<td>16.9</td>
<td>12.2</td>
<td>6.7</td>
<td>1.4</td>
<td>5.8</td>
</tr>
</tbody>
</table>

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.

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

<table>
<thead>
<tr>
<th>Rank</th>
<th>Nontenure</th>
<th>Assist. prof.</th>
<th>Assoc. prof.</th>
<th>Prof.</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>All faculty</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>1409</td>
<td>860</td>
<td>1292</td>
<td>3100</td>
<td>6661</td>
</tr>
<tr>
<td>Women</td>
<td>289</td>
<td>245</td>
<td>209</td>
<td>178</td>
<td>921</td>
</tr>
<tr>
<td>Total*</td>
<td>1706</td>
<td>1107</td>
<td>1503</td>
<td>3279</td>
<td>7595</td>
</tr>
<tr>
<td>% women</td>
<td>17</td>
<td>22</td>
<td>14</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>Ph. D.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>848</td>
<td>420</td>
<td>722</td>
<td>1957</td>
<td>3947</td>
</tr>
<tr>
<td>Women</td>
<td>121</td>
<td>111</td>
<td>123</td>
<td>133</td>
<td>458</td>
</tr>
<tr>
<td>Total</td>
<td>972</td>
<td>532</td>
<td>846</td>
<td>2061</td>
<td>4411</td>
</tr>
<tr>
<td>% women</td>
<td>12</td>
<td>21</td>
<td>14</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>M.A. or M.S.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>210</td>
<td>150</td>
<td>222</td>
<td>500</td>
<td>1082</td>
</tr>
<tr>
<td>Women</td>
<td>48</td>
<td>61</td>
<td>37</td>
<td>29</td>
<td>175</td>
</tr>
<tr>
<td>Total</td>
<td>261</td>
<td>211</td>
<td>259</td>
<td>529</td>
<td>1260</td>
</tr>
<tr>
<td>% women</td>
<td>18</td>
<td>29</td>
<td>14</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>B.A. or B.S.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>205</td>
<td>257</td>
<td>301</td>
<td>507</td>
<td>1270</td>
</tr>
<tr>
<td>Women</td>
<td>66</td>
<td>66</td>
<td>43</td>
<td>31</td>
<td>206</td>
</tr>
<tr>
<td>Total</td>
<td>273</td>
<td>324</td>
<td>345</td>
<td>538</td>
<td>1480</td>
</tr>
<tr>
<td>% women</td>
<td>24</td>
<td>20</td>
<td>12</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>A.A. or A.S.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>146</td>
<td>33</td>
<td>47</td>
<td>136</td>
<td>362</td>
</tr>
<tr>
<td>Women</td>
<td>54</td>
<td>7</td>
<td>6</td>
<td>15</td>
<td>82</td>
</tr>
<tr>
<td>Total</td>
<td>200</td>
<td>40</td>
<td>53</td>
<td>151</td>
<td>444</td>
</tr>
<tr>
<td>% women</td>
<td>27</td>
<td>18</td>
<td>11</td>
<td>10</td>
<td>18</td>
</tr>
</tbody>
</table>

*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 non tenure 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.

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.

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

<table>
<thead>
<tr>
<th>Rank</th>
<th>A.A. or A.S.</th>
<th>B.A. or B.S.</th>
<th>M.A. or M.S.</th>
<th>Ph.D.</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nontenure</td>
<td>45.0</td>
<td>18.4</td>
<td>20.7</td>
<td>22.0</td>
<td>22.5</td>
</tr>
<tr>
<td>Assistant professor</td>
<td>9.0</td>
<td>21.9</td>
<td>16.7</td>
<td>12.1</td>
<td>14.6</td>
</tr>
<tr>
<td>Associate professor</td>
<td>11.9</td>
<td>23.3</td>
<td>20.6</td>
<td>19.2</td>
<td>19.8</td>
</tr>
<tr>
<td>Professor</td>
<td>34.0</td>
<td>36.4</td>
<td>42.0</td>
<td>46.7</td>
<td>43.2</td>
</tr>
</tbody>
</table>

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


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 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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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 science continued on p. 15

REFERENCES CITED


Correction

In the 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 Hanover and Liege.”
 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, multi-continental 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 The Making of Geology: Earth Science in the Nineteenth Century: Changing Views of a Changing World (Cornell University, Cambridge University Press, 1998). Rappaport skillfully explores the changing view of fossils and their origin. Her sections on Diluvialism provides a 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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Johnstown, PA 15904
wbrice@pitt.edu

GSA Bookstore
NEWEST RELEASES
See October GSA Today

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 has 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.

INTEGRATED EARTH AND ENVIRONMENTAL EVOLUTION OF THE SOUTHWESTERN UNITED STATES

THE CLARENCE A. HALL, JR., VOLUME


The serious professional will appreciate the breadth of the book devoted to the integrated study of earth and environmental sciences of the southwestern United States. Topics span the geographic 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. Noted 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 book incorporates plate tectonics, climatic-ecological aspects and magnatism of the Southwest. A valuable resource for geologists and scientists who need the latest information concerning the southwestern United States.

SPE500, 500 pg., softcover, 7" x 10" format, ISBN 0-9665869-0-5, $89.95. Member price $72.00

ARCHITECTURE OF THE CENTRAL BROOKS RANGE FOLD AND THRUST BELT, ARCTIC ALASKA


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. The volume furnishes a comprehensive perspective of a fold-thrust belt and should prove useful in the study of other contractional belts around the world. SPE524, 350 p., ISBN 0-8137-2324-8, $70.00. Member price $55.00

ACCOMMODATION ZONES AND TRANSFER ZONES: THE REGIONAL SEGMENTATION OF THE BASIN AND RANGE PROVINCE

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

The heterogenous 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 within the Basin and Range province of western North America. Contributions range from analyses of individual structures to broad regional syntheses, including new a map of Basin and Range structures and tecton domains. Several papers discuss the implications of regional segmentation 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 is also proposed.

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In warfare, military geologists pursue five major categories of work: tactical and strategic terrain analysis, fortifications, 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 peace keeping, and the future of military geology.

REG001, 256 p., ISBN 0-8137-4113-0, $76.00. Member price $60.80

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GSA Today, November 1998
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 Kingtons, 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.

Lynnette Seigle 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

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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.

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

New Director of Publications

Electronic journals and speedier publication of journals and books are two of the challenges for GSA Publications Director Peggy 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.

“1 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.
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 petrology 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 half-moon of depleted lower crustal rocks. These geology next to the Insibric 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 through dislocation creep of 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 crust-scale shear zone system. Jamie Connolly considered the influence of rheology on compaction-driven fluid flow in oro-
scale is an important factor in controlling the segregation of partially molten systems. Although melt distribution at the grain growth began with a review of equilibrium melt distribution in rheology with mineral reactions and triggers for active crustal ites and ascent of granite. migmatites and igneous rocks, and to the geochemistry of diatex- results of research ranging from isotopic studies of rock suites the field and the experimental capsule. Other posters presented ovoids, to granulite facies metamorphism as viewed both from textures in which plagioclase forms a mantle around K-feldspar such as cordierite or the enigmatic rapakivi gneiss from particular minerals, whether a peritectic melting prod- ferentiation process. Thus, the content varied from what we can to present details of specific research on aspects of the crustal dif- fraction ages, to argue that the granites are older than the regional granulite-facies metamorphism, as previously postulated in this region, is brought into question. As an alternative, Bea postu- lated 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 del 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 abso- lute age of events and the distinction between growth and recy- cling of continental crust. Allen Glazner emphasized that mantle input to the crust is basaltic, which implies that a mafic-ultra- mafic 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 differenta- tion 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 differ- entiation process. Thus, the content varied from what we can glean from particular minerals, whether a peritectic melting prod- uct 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 research that would be central to discussions throughout the week, and experimental melts, to geochronology, to microfabrics in migmatites and igneous rocks, and to the geochemistry of diatex- ites and asente 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 intercon- nected but remains nearby 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 lev- els in the crust and the extent of crustal-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” propaga- tion), 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 deforma- tion; low rates of deformation lead to small variations in chem- istry (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 pre- serves only a small part of the melting history. Alfons Berger and Jean Louis Vigneresse discussed the rheology of migmatites, pat- tern in the lower crust, and partially crystallized systems, stressing that there are significant differences in behavior at any particular volume % liquid between partially molten and partially crystal- lized systems.

In starting the discussion, Ed Sawyer distinguished between melt-dominated and solid-dominated systems, and raised ques- tions 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 con- tentious, and both processes most likely occur in partially molten terranes. Several participants emphasized that leucocratic accumu- lations 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 crystaliza- Penrose Conference continued on p. 20
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 melt 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, 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 in 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 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 possible mixing paradox, the fact that the bulk composition of the continental crust is adiabatic, 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 Snowbird tectonic 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 granulate facies paragneiss septa within the mafic complex, and continuing deformation under left-lateral simple shear. Geochemical evidence in support of the model was pre-
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 isograd, 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, $\delta^{13}$C, $\delta^{15}$N, and $\delta^{17}$O 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-$\delta^{18}$O rocks.

Using the $\text{^{207}Pb}/\text{^{206}Pb}$ 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 interaction 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, 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

We are grateful for comments made to us by participants during and after the conference, and for a review by Phil Piccoli, but we take responsibility for any misperceptions or infelicities in this report.

We thank the Geological Society of America for sponsoring the conference and for providing funds to enable student participation, and the Petrology and Geochemistry Program of the National Science Foundation for provision of a grant to support travel by students.

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

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GSA TODAY, November 1998
The Pliocene-Pleistocene boundary should remain at 1.81 Ma

Maurice Aubry, Université Montpellier II, Montpellier, France
William A. Berggren, Woods Hole Oceanographic Institution, Woods Hole, MA 02543
John A. Van Couvering, American Museum of Natural History, New York, NY 10024
Domenico Rio, Università di Padova, Padova, Italy
Davide Castradori, ENI-Agip s.p.a., Milano, Italy

COMMENARY

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 correlatablity 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 "Subpenneen 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 expediency, 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-chronostratigraphic 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 chronostratigraphic boundary that represents a major shift in global air, ocean and land climate systems."

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 pernicious campaign to set aside principles in favor of attractive expediency will end in the course of this formal procedure.

REFERENCES CITED


Morrison, R., and Kukla, G., 1988, The Pliocene-Pleistocene (Tertiary-Quaternary) boundary should be placed at about 2.6 Ma, not at 1.8 Ma: GSA Today, v. 8, no. 8, p. 9.


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

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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.

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The application form and instructions are found in the Call for Papers for the 30th Lunar and Planetary 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@pli.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.

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, tapeing 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 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.

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NORTHEASTERN SECTION
March 22–24, 1999, Providence,
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Submit completed abstracts to:
Anne I. Veeger, Dept. of Geology,
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Kingston, RI 02881,
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C. Pius Weibel, Illinois State Geological
Survey, 615 E. Peabody Dr.,
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June 2–4, 1999, Berkeley, California.
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**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, IIE  
Geological Society of America  
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Boulder, CO 80301-9140

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

**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.
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Liangquan Li, Gerta Keller

999 Apatite fission-track thermochronology of the Sierras Pampeanas, central western Argentina: Implications for the mechanism of plateau uplift in the Andes
Timothy J. Coughlin, Paul B. O’Sullivan, Barry P. Kohn, Rodney J. Holcombe

1003 Strontium isotopic-paleotemperatual method as a high-resolution paleosalinity tool for lagoon environments
Eduard G. Reinhardt, Daniel Jean Stanley, R. Timothy Patterson

1007 High 3He/4He ratios in the Manus backarc basin: Implications for mantle mixing and the origin of plumes in the western Pacific Ocean
Colin G. Macpherson, David R. Hilton, John M. Sinton, Robert J. Poreda, Harmon Craig

1011 Mammalian community response to the latest Paleocene thermal maximum: An isotoponomic study in the northern Bighorn Basin, Wyoming
William C. Clyde, Philip D. Gingerich
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.


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


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


**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. Jocel.

**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@olita.colorado.edu, Dept. of Geological Sciences, University of Colorado, Boulder, CO 80309.

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**Systems Performance Analyst (Geostat)**

The U.S. Nuclear Regulatory Commission is currently seeking a Systems Performance Analyst (Geostat) to join our office in Rockville, MD. Responsibilities include evaluating, integrating, and applying geostatistical methods in system performance assessments of radioactive waste disposal facilities; applying the result of these assessments to the evaluation of evolving statutory requirements, environmental standards, environmental impacts, and regulatory criteria relevant to NRC’s waste management and decommissioning programs; and developing technical positions and reviewing plans for implementation of performance assessments.

**Requires:** 1 year experience at the next lower grade level in the occupational series listed above or other related series performing similar or like duties; knowledge of the theories, principles, and practices in the field of geostatistics as evidenced by a Bachelor’s degree in Engineering, Physical Science, Earth Science, Geology, or related major field of study or equivalent combination of education, training, and experience; and experience in the use of geostatistical techniques in the treatment of variability and uncertainty, and the estimation of risk.

Additional information and application materials should be obtained by calling the NRC Personnel Smartline at (800) 952-9678. Refer to Vacancy Announcement R9448007. Please send your resume or Federal application (OF-612), salary history and statement addressing rating factors, by November 20, 1998, to: U.S. Nuclear Regulatory Commission, Attn: Sandy Johnson (Dept. A-98150), Office of Human Resources, Mail Stop T2 D32, Washington, DC 20555-0001.

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**U.S. Nuclear Regulatory Commission**

An equal opportunity employer, M/F/D/V. U.S. citizenship required.
You are invited to participate in the 1999 GSA Annual Meeting in Denver, Colorado, 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 (JTTPC) 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 SYMPOISA

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 Symposa 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.

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 JTTPC 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 convenor (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. Small groups are encouraged to co-sponsor 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 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 online 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 is continued on p. 34.
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

Luncheon 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:

Annual Program Committee Chair
Sharon Mosher
Dept. of Geological Science
University of Texas at Austin
23rd & San Jacinto
Austin, TX 78712
(512) 471-4135 (office)
512-471-9425 (fax)
mosher@mail.utexas.edu

Technical Program Co-Chair
Craig H. Jones
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Campus Box 399
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Boulder, CO 80309-0399
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303-492-2606 (fax)
cjones@mantle.colorado.edu

Technical Program Co-Chair
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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. Volunteer 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.
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) 440-1472, fax 303-447-1133, or E-mail: acravo@geo society.org. Please include complete address, phone number, and E-mail address with all correspondence.

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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. Bachelor’s degree in Geography, Geology, or Environmental Studies. EMU is a comprehensive regional institution with 24,000 students. Faculty is AUP collective bargaining unit. Department Head position is a 12-month administrative appointment to be anticipated starting date July 1, 1999. Requirements include: earned doctorate in field taught in department; record of accomplishment in teaching, research and scholarly creativity; and ability to serve as primary mentor of graduate students.

Submit letter of interest with curriculum vitae and names and addresses of at least three referees to: Dr. James R. King, Search Committee Chair, Department of Geology, Eastern Michigan University, Ypsilanti, MI 48197.

ASSISTANT PROFESSOR GEOLOGY: UNIVERSITY OF RHODE ISLAND

The Department of Geology 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 Environment and Life Sciences, will complement our programs in the environmental sciences. We seek applicants whose primary interest is in the field of organic contaminant hydrogeology. A Ph.D. degree in hydrogeology, geochemistry, or an environmental science is required at the time of appointment. The following are also required: potential for developing an externally funded, nationally recognized research program in hydrogeology; an undergraduate degree (or equivalent) in geology; training and research experience in hydrogeology, organic chemistry, and contaminants transport; the ability to teach an upper-division course in environmental organic chemistry and a graduate-level course in soil/sediment 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.

Welcome to the St. John’s College Faculty and Staff Resource Guide.

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 and drinking water remediation. 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 both teaching and 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, Sacra mento, CA 95819-6343.

ASSISTANT PROFESSOR INDIANA 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 be committed to high-quality teaching. Applicants with teaching experience in the Ph.D. program to environmental sciences should complement our existing strengths in sedimentology and geomorphology. Applicants with research emphasis in hydrogeology are encouraged to apply. We are seeking candidates with research goals and a curriculum vitae including published applications, teaching goals and a curriculum vitae, and the names of at least three referees.

The initial appointment will begin August 1999. Interested candidates should apply to Chair, Search Committee, Department of Geology, Mail Code 4324, Southern Illinois University, Carbondale, IL 62901-4324, fax 618-453-7393; e-mail: jsbaub@geo.siu.edu. Applications will be accepted until December 7, 1999, or until the position is filled. Information about the Department and its programs can be found at: http://www.science.siu.edu/geology/index.html. Southern Illinois University is an Equal Opportunity, Affirmative Action Employer.

FACULTY POSITIONS

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 Professor position in paleontology. Both traditional and invertebrate paleontology competencies are encouraged. The appointment will begin in August 1999. We seek an outstanding researcher and teacher whose approach is liberal and whose teaching is dedicated to the liberal-quantitative and specia- men-based, and who will work with other faculty to

GSA TODAY, November 1998 35
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.

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.

**GeoTrip**

**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.

**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 Phil Deboo of Memphis, Tennessee.

**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.

**GeoHostels**

**Memories of the 1998 GeoVentures**

Photo by Lowell Bogart.

**Durango gang at Molas Pass. Photo by Sue Tanges.**

**Photo by Sheila Roberts.**
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 available 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
POSTDOCTORAL OPPORTUNITIES

The U.S. Geological Survey, Geologic Division, is conducting a national competition to find outstanding scientists, who have recently completed dissertation-level research, to fill 1-2 positions in various geologic disciplines. The objectives of the program are to provide graduate students with the experience and opportunity necessary to develop into professional geoscientists. Students who have completed their doctoral degree in a geoscience-related field and have a demonstrated commitment to a research program that falls within the Bureau's Geologic Division's long-term scientific strategy goals are encouraged to apply. Applications should include a letter of interest outlining your approach to teaching and research in an undergraduate setting, vitae, and three letters of recommendation. Applications are encouraged to and supportive of excellence in teaching and active research. In the general area of paleontology to be filled with an emphasis on ecosystem structure and function; interpreting the links between human health and geologic processes; and determining the geologic controls on ground water and 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 disposal. The postdoctoral scholar is expected to evolve its research program, attract external funding, and collaborate with students and other colleagues on campus.

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 depart-

WASHINGON AND LEE UNIVERSITY

POSTDOCTORAL OPPORTUNITIES

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 depart-

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UNIVERSITY OF FLORIDA

ASSISTANT PROFESSOR

The Department of Geology invites applications for a tenure-track position in the area of geology and sedimentology at the Assistant Professor level, to begin in the Fall semester of 1999; a Ph.D. is required. Primary teaching responsibilities include geologic processes, including de-
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 and in developing educational opportunities; (3) Experience in groundwater modeling; and (4) A commitment to developing a research program that includes undergraduates 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.

To apply, please send the following: (1) A detailed curriculum vitae; (2) A letter telling us about yourself and departmental endowment. To apply, please send the following: (1) A detailed curriculum vitae; (2) A letter telling us about yourself and departmental endowment. To apply, please send the following: (1) A detailed curriculum vitae; (2) A letter telling us about yourself and departmental endowment. To apply, please send the following: (1) A detailed curriculum vitae; (2) A letter telling us about yourself and departmental endowment.

HYDROGEOLOGIST, UNIVERSITY OF WYOMING
The Department of Geology and Geophyscics 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 and administrative duties. Applicants 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 those of the current faculty. Additional information on the Department can be obtained on our Web page (http://www.uwyo.edu/AES/geo/geo-1.htm).

Applications 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. Dreyer, Search Committee Chair, Department of Geology and Geophysics, University of Wyoming, Laramie, WY 82071-3006. Review of applications will begin on December 15, 1998 and 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 School of Continuing and Extended Education at SDSU seeks to fill a tenure-track faculty position in geological-sciences education at any level depending on the qualifications of the candidate. We are searching for someone with a doctorate in the geological sciences or geosciences 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/geosceduc.

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 qualified 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 sedimentary systems, shelf and slope sedimentation, 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 Institute. Preferred is 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 teaching 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, statement of research and teaching interests, a vita to Dr. Timothy J. Brabower, 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/.

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

ASSISTANT PROFESSOR
PETROLOGY AND EARTH RESOURCES
UNIVERSITY OF WASHINGTON
Tenure-track position in Igneous/Metamorphic Petrology and Earth Resources beginning in August 1999.

Teaching responsibilities include undergraduate courses as needed by the department, mineralogy/petrology, earth resources and economic mineral deposits. The individual will be expected to develop a vigorous undergraduate col-}

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