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GSA TODAY

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INSIDE

Vibrational Spectroscopy of Minerals at Pressure: Application to the Mantle

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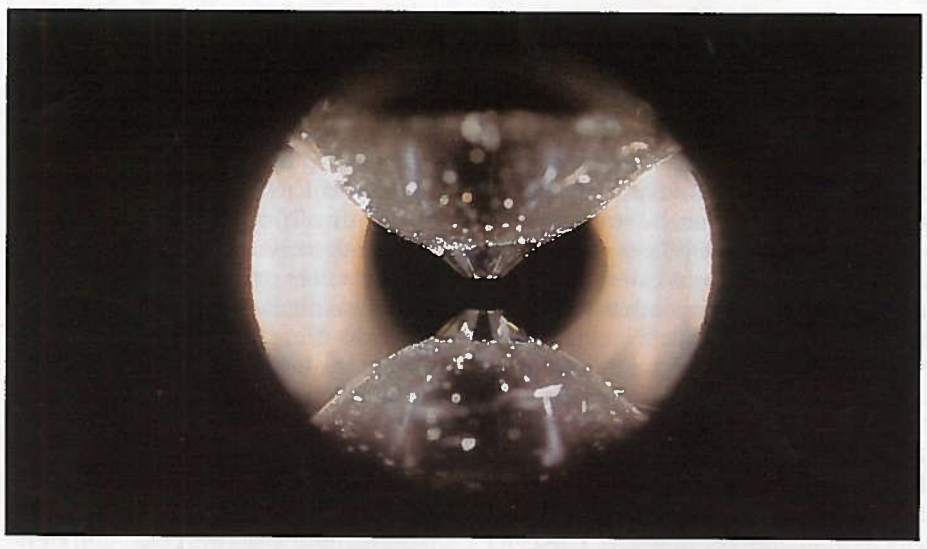

Figure 1. Opposing diamonds in a Mao-Bell piston-cylinder diamond anvil cell. Diameter of the tips is 0.6 mm.

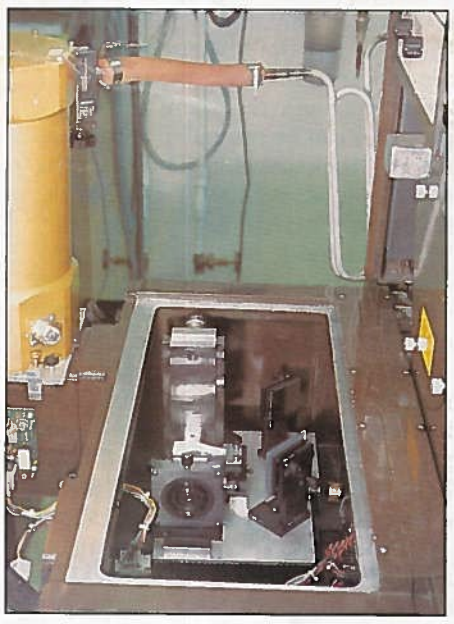

Figure 2. Experimental configuration used in IR studies at pressure. The evacuable sample compartment of our state-of-the-art Fourier Transform Infrared spectrometer (Bomem Model DA 3.02) contains a diamond anvil cell (lower middle). The mirrors are used to enhance light transmission. The gold-coated cylinder is a liquid-helium dewar containing three ultra-sensitive detectors for study of fundamental bands from 7 to 5000 μm in minerals and glasses.

Figure 3. A pair of type I diamonds used for far-IR studies. Largest diameter is 3 mm. Diameter of the tip is 0.6 mm.

Figure 4. Fayalite maintained at 320 kbar in a Mao-Bell diamond anvil cell. Sample thickness is about 5 μm. Light streaks to the right are reflections from the diamond facets.

Editor's Note:

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

ABSTRACT

Vibrational spectroscopy is a powerful tool to investigate the composition and thermal state of Earth's interior, as well as to study the basic properties of materials. Infrared (IR) data can be collected as a function of pressure (up to 100 GPa) from microsamples in a diamond anvil cell. Correct interpretation of these high-pressure spectra requires complete characterization of the sample at ambient conditions. Such data provide information on bonding and structure of materials, and allow calculation of thermodynamic and elastic properties, as functions of pressure and temperature, which are needed to establish the mantle geotherm. Current research involves measurement of IR spectra of phases in the MgO-FeO-SiO_2 system and their analogues as a function of pressure. Future endeavors will concern modification of the experiments to attain high temperatures during compression.

INTRODUCTION

A fundamental problem in geophysics concerns deduction of the composition and thermal character of Earth's interior from seismic data and from laboratory measurements of mineral properties. A major obstacle is the experimental difficulty of performing laboratory studies at appropriately high pressures *(P)* and temperatures *(T)* simultaneously. Determinations of the mantle's composition can be approached through accurate measurement of volume *(V)*, thermal expansivity, compressibility, and higher T and P derivatives, given a reasonable approximation for the equation of state $V(P,T)$. However, progress in establishing the geotherm is severely impeded by (1) the impossibility of directly measuring thermodynamic properties such as heat capacity and entropy through calorimetry at pressure, and (2) the limited temperature range at which the thermodynamic properties of synthetic high-pressure phases are determined at 1 atm due to small sample sizes and metastability at low pressure.

A new approach involves prediction of heat capacity and entropy at pressure from vibrational spectroscopy (Hofmeister et al., 1989; Chopelas, 1990a, 1990b) by use of a modified version of the model developed by Kieffer (1979) which is based on statistical thermodynamics. Here, I briefly describe this model, the theory of vibrations, and infrared (IR) and Raman spectroscopic methods. Current studies involve use of diamond anvil cells (Fig. 1) to collect high-pressure IR data from phases likely to occur in the mantle (e.g., olivine and its spinel polymorphs; and pyroxene and its ilmenite, garnet, and perovskite polymorphs). Detailed studies at 1 atm of such phases and chemically or structurally related minerals are being done not only to provide reference data needed for high-pressure studies, but also to characterize these materials (e.g., Hofmeister et al., 1990a, 1990b). Work at the University of California, Davis is coordinated with calorimetric experiments at high temperatures by P. Richet (Institut de Physique du Globe) and with Raman spectroscopic studies by A. Chopelas (Max Planck Institute) in order to refine the thermodynamic model so that it is sufficiently accurate (±1%) to be useful under mantle conditions. This report focuses on spectroscopic study of garnet at 1 atm and olivine at pressure, and applications of the results.

RELATION OF VIBRATIONS TO STRUCTURE, BONDING, AND THERMODYNAMIC PROPERTIES

All atoms oscillate about their equilibrium positions, except at the unattainable 0 K. Strictly speaking, this phenomenon can only be correctly described by quantum mechanics in terms of transition probabilities and selection rules, which is beyond the scope of this report. Instead, I use a classical analogy.

A vibrating material is crudely analogous to a set of balls (atoms) of different weight interconnected with springs (bonds) varying in length and stiffness. Any and all vibrations can be described as a combination of a limited

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number of components. The simplest possible vibrations are known as fundamentals or modes, each of which is related to the motion of an individual ion or group of atoms. A particular motion can be characterized by the amount of energy needed to drive it, which is typically described in terms of frequency (or wavelength) in accord with the cyclic nature of oscillations. The classical analogue suggests that the frequency of a given mode should depend strongly on the masses, bond lengths, and bond strengths of the ions that are involved. This analogy appears to be valid in that various frequency regions are characteristic of certain species. For example, light mass and tight bonding inside of SiO_4 tetrahedra make its bending and stretching motions occur at short IR wavelengths of 7 to 25 μm, whereas heavy mass and loose bonding inside of FeO_6 octahedra yield stretching modes at long wavelengths of 50 to 200 μm (e.g., McMillan and Hofmeister, 1988). Because a fundamental primarily involves nearest neighbor interactions, its existence requires that similar structural units occur throughout the material but does *not* require a regular array of atoms, in constrast to X-ray diffraction. Therefore, vibrational data on glasses can be used to infer coordination and polymerization.

For crystalline solids, the number of fundamental modes is determined by, and diagnostic of, its space group, because the atoms must move in directions consistent with the symmetry (e.g., Farmer, 1974). For example, MgO has six modes, spinel has 42, and olivine has 83, whereas garnet has 240. Thus, spectroscopic data are useful in studying phase transformations. The combination of the number of modes, which is controlled by the crystal structure, and the frequency, which is controlled by chemical composition, makes vibrational spectroscopy useful in mineral identification.

The activation of vibrations by heat intimately connects spectroscopic data with thermodynamic properties. In fact, atomic vibrations contain virtually all of the thermal energy of the solid; only a small amount is electronic or magnetic. Kieffer's (1979) model assumes that thermal excitation of a mode increases exponentially with temperature. The internal energy E of the mineral is then calculated according to statistical thermodynamics from the sum of the thermally weighted energies of all of the different fundamental vibrational modes and converted to integral form. (See Reif, 1965, for details.) Functions like heat capacity C_V or entropy S are then derived from E by classical thermodynamics, for example, $C_V = (\partial E/\partial T)_V$. As a result,

$$C_V = k\int_0^\infty \frac{e^{h\upsilon/kT}}{(e^{h\upsilon/kT}-1)^2}\left(\frac{h\upsilon}{kT}\right)^2 g(\upsilon)\,d\upsilon, \quad (1)$$

where h is Planck's constant, k is Boltzmann's constant, υ is the frequency, and $g(\upsilon)$ is the distribution of modes over frequency. Only two input values are required to determine C_V or S: temperature and $g(\upsilon)$. The distribution of modes $g(\upsilon)$ is assembled from spectroscopic data as follows. Three modes originate from translations of the lattice and can be obtained from sound velocities or elastic deformation of a mineral. (Elastic properties for a wide variety of compounds were compiled by Sumino and Anderson, 1984.) A parabolic function is used for their contribution to $g(\upsilon)$: this is a Debye model (see Kieffer, 1979, for further discussion). Otherwise, $g(\upsilon)$ consists of delta functions (spikes) or a box-shaped function placed at optically active frequencies derived from IR and Raman spectroscopies. These models were derived by Albert Einstein and by Susan Kieffer. The symmetry of the mineral is used to arrive at the proper number of modes—i.e., to account for the fact that a given vibrational frequency may represent more than one atomic motion (Hofmeister, 1987).

Elastic properties also can be calculated from vibrational frequencies by using the fact that both of these properties can be described in terms of the interatomic potentials ϕ_i of a solid. By arranging the two equations (υ_i as a function of ϕ_i and compressibility as a function of ϕ_i) and to eliminate the potentials, Brout (1959) showed that bulk modulus—i.e., the inverse of compressibility—for the rock-salt structure is

$$K_T = -\left[\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T\right]^{-1} = \frac{\mu}{18r_0}\sum_i \upsilon_i^2, \quad (2)$$

where μ is the reduced mass and r_0 is the bond length. Similar formulas have been derived for the structures in which high-pressure phases crystallize, and the derivation was extended to relate the pressure dependence of K_T to the pressure dependence of the vibrational frequencies for these substances (A. M. Hofmeister, in prep.). Thus, the compressibility of a solid and its pressure derivatives can be calculated easily from only ionic masses, bond lengths, and vibrational frequencies as a function of pressure. These data are needed to determine the mantle's composition. Such relations provide a simple way to correlate macroscopic elastic properties with microscopic spectroscopic parameters, without use of complicated computer routines such as those needed to calculate interatomic potentials.

EXPERIMENTAL TECHNIQUES

All minerals have IR modes. These modes are excited by direct absorption of long-wavelength light ($\lambda > 1$ μm), if the energy of the incident light matches that of the vibration, and if the magnitude or direction of the dipole moment between the atoms is changed during their vibration. Absorption peaks are observed at various frequencies, each with a width and height that are characteristic of the particular motion and types of atoms involved. Peaks can equally well be measured by reflection of IR light because of similar interactions with atoms near the surface.

A closely related method is Raman spectroscopy, which involves stimulation of vibrations during scattering of short-wavelength light, usually blue light emitted from a laser. The existence of Raman peaks is tied to momentum conservation, and requires a change in the shape of the ionic group (i.e., its polarizibility) during the vibration (McMillan and Hofmeister, 1988, and references therein). The difference in energy between the peaks in the scattered light and the incident light give the Raman frequencies. The Raman effect is obviously based on quantum mechanics, because the connection with momentum requires that both the light and the vibrations be treated as particles (photons and phonons). Most, but not all, structures possess Raman peaks. The Raman peaks usually result from atomic motions differing from those associated with IR peaks; thus, these two techniques offer complementary information (e.g., Farmer, 1974; Karr, 1975). One advantage of the IR technique is that peak intensities are absolute and provide quantitative information on optical properties such as the dielectric functions; an advantage of Raman scattering is that spectra can be acquired from samples as small as 1 μm.

IR spectroscopy in the past has revolved around qualitative absorption measurements from powder dispersed in a matrix like KBr that is transparent over a wide wavelength range. Quantitative results require reflection measurements from a single crystal, with polarized light if the structure is not cubic. Common occurrence of weak and overlapping modes in many structures requires additional absorption measurements on crystals thinned to 1 μm or less. Recent technological advances, such as Fourier Transform Infrared (FTIR) spectrometers, have made quantitative study of complicated minerals feasible. Commercially available IR microscopes and state-of-the-art detectors (Fig. 2) provide for collection of data until the diffraction limit is reached when the wavelength of incident light equals the sample's diameter. IR peaks usually occur at wavelengths λ shorter than 100 μm, which is sufficiently small to permit complete study of many synthetic high-pressure phases. These advances permit data to be collected at the longest IR wavelengths (the far-IR), which involve cations other than Si and thus reveal microscopic behavior connected with solid solutions in minerals.

The high sensitivity of modern instruments also allows collection of IR data from samples compressed in a diamond anvil cell. Numerous types exist (Hazen and Finger, 1982; Jephcoat et al., 1987), but all operate under the same principles: diamonds (Fig. 3) are strong and transparent to most electromagnetic radiation, and high pressures can be generated with small forces if the contact area between the two diamonds is small (Fig. 1). At UC Davis, the piston-cylinder design of H-K. Mao and P. Bell (Fig. 2) is used. For this type of diamond anvil cell, pressures of IR studies are limited by diffraction. For example, the difficult far-IR measurements are possible at mantle pressures of up to 100 GPa, because attaining this pressure requires small (~100 μm) samples that diffract light with $\lambda > 100$ μm. Figure 4 shows a fayalite crystal used in such a study.

Pressure is calibrated by means of a ruby fluorescence spectrometer (Mao et al., 1986), which takes advantage of the fact that compression moves electronic orbitals closer together. Thus, for ruby, compression alters the transition energies between d electron levels of Cr^{3+} impurity ions and thus changes the color. This systematic increase in frequency of emitted light with pressure has been calibrated through comparison with shock-wave experiments.

CHARACTERIZATION OF GARNETS AT AMBIENT CONDITIONS

Complete single-crystal IR reflectance and Raman spectra have been obtained for five natural end-member garnets (Hofmeister and Chopelas, 1991a), in order to characterize vibrations of this structure and to develop an accurate thermodynamic model for this ubiquitous mineral family. (IR measurements for geologically relevant binary and ternary solid solutions involving the dodecahedral site are part of a Ph.D. thesis by Timothy

Fagan.) Applying the thermodynamic model developed for the end members (see below) to these results will enable accurate calculation of mixing properties, and hence improvement in garnet geobarometers and geothermometers.

Thermodynamic properties of the end members pyrope and grossular have been calculated from their complete vibrational spectra using our modification of Kieffer's (1979) model. The calculations (Hofmeister and Chopelas, 1991b) reproduce experimental heat capacity and entropy at 1 atm for pyrope within 0.5% from ~100 to 1300 K. We show that the calorimetrically determined entropy for grossular at 300 K is 5% low, probably due to hydrous impurities. This result solves the decade-long controversy over why entropy measured for grossular at 300 K was higher than that for pyrope, in contrast to expectations. Correct values for entropy are needed for calculation of phase equilibria involving grossular (e.g., Koziol and Newton, 1988). The excellent agreement of our results with calorimetric measurements on pyrope of Tequi et al. (1991) and their extrapolations to higher temperatures suggests that spectroscopically based calculations based on single-crystal data are reliable at geologically relevant temperatures, and thus can be used to calculate phase boundaries. Calculations based on powder data are not sufficiently accurate for these applications.

IR SPECTROSCOPY OF OLIVINE AT MANTLE PRESSURES

The response of far- and mid-IR bands to pressures of up to 42.5 GPa for ferro-magnesian olivines (Fig. 5; Hofmeister et al., 1989) are typical of low-pressure silicate phases. Mid-IR bands associated with Si-O bonds shift linearly with pressure (not shown), whereas far-IR band shifts associated with Mg (or Fe) gradually become smaller as pressure increases (Fig. 5). The different slopes can be used to validate assignments of peaks to atomic motions, and hence to improve upon our thermodynamic calculations. These differences between Si-O and Mg-O vibrations are due to the fact that the more loosely bonded octahedra are more compressible than the tetrahedra with very strong bonds. These data are important because the second derivative of frequency with respect to pressure is related to the second pressure derivative of the bulk modulus. K is difficult to measure directly but is needed to compare laboratory measurements to seismic data. Near 10 GPa, the IR and Raman peaks of olivine change in intensity and number, as well as position, indicating that a phase transformation occurs (Hofmeister et al., 1989; Chopelas, 1990a).

Changes in peak positions with pressure measurably affect the thermodynamic properties, which are calculated by incorporating the pressure shifts into the 1 atm model of olivine by Hofmeister (1987). The calculated results match extrapolation of calorimetrically determined C_v from 1 atm to C_v at pressures, within the uncertainty of the equation of state used for extrapolation. At 200 kbar, the heat capacity at 298 K drops to 94% of its 1 bar value, whereas that at 1200 K decreases by only 0.5%. Thus, at mantle conditions, the thermodynamic parameter most affected by temperature is volume. Accurate measurements of

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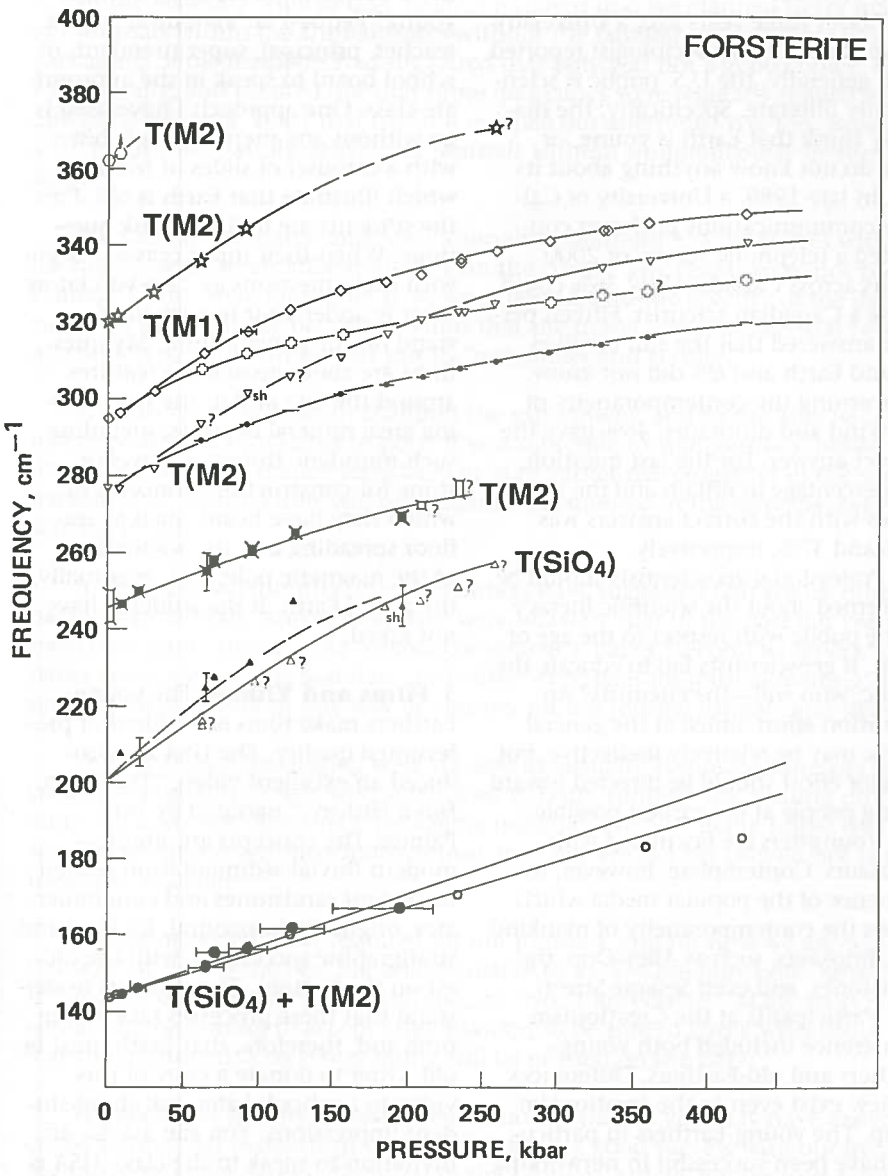

Figure 5. Pressure dependence of the far-IR peaks of forsterite, from Hofmeister et al. (1989). Symbols denote individual peaks, which may represent more than one mode. $T(SiO_4)$ indicates that the peak involves a translation of the SiO_4 tetrahedron. T(M1) or T(M2) indicate translations of the Mg ion in either the M1 or M2 sites. Intensities of most of these peaks decreased during compression such that many peaks could not be tracked above 20 GPa.

Computer Legislation in the U.S. Senate Subcommittee on Technology and the Law

Craig M. Schiffries
GSA Congressional Science Fellow

The U.S. Senate Judiciary Committee established the Subcommittee on Technology and the Law to ensure that American law keeps pace with changes in technology. Many of the subcommittee's activities are designed to promote the technological leadership, international competitiveness, and economic growth of the United States.

I am serving on the staff of the Subcommittee on Technology and the Law during my tenure as the GSA Congressional Science Fellow. Many of my legislative responsibilities are concerned with computer technology. In this column, I discuss some of the computer legislation that will be introduced this spring by Senator Leahy (D–Vermont), chairman of the Subcommittee on Technology and the Law.

Computer Viruses

Innovations in computer technology create new opportunities for improving productivity and increasing the flow of information, but they also create new vulnerability and new opportunities for abuse. It is important to update our laws to stay abreast of rapid changes in computer technology and in techniques of computer-system abuse.

The deliberate abuse of computer systems to cause damage and disruption has already posed significant burdens on numerous computer users. For example, thousands of scientists had their research interrupted when Robert Morris introduced a computer "worm" on the INTERNET computer network in November 1988. The program quickly replicated itself, clogged the network, and halted research throughout the country.

Last year, the Senate unanimously passed a bill to clarify and strengthen the criminal laws against the intentional transmission of destructive computer viruses and related forms of computer-system abuse. The House of Representatives did not consider the bill before the Congress adjourned. I am working with Senator Leahy to reintroduce the bill in the current Congress.

In crafting this legislation, we have sought to balance punishment of destructive conduct with the need to encourage legitimate experimentation and the free flow of information. There are important differences among computer incidents, and the legislation would establish a structure for treating such incidents—whether they are malicious, reckless or accidental—with appropriately balanced legal sanctions. The bill has been drafted and revised on the basis of careful review of issues raised in the subcommittee's hearings. It has a great deal of popular support from both the scientific and legal communities, and it should move quickly through the legislative process.

Semiconductor Chips

Semiconductor chips lie at the heart of the worldwide computer revolution. These marvels of modern technology have propelled dozens of new industries toward the 21st century. Research and innovation are essential to the life and health of the American semiconductor industry. But research and innovation in the design of semiconductor chips were threatened by "chip piracy"—the unauthorized copying and distribution of semiconductor chips. Neither patents nor copyrights provided adequate protection against piracy of computer chips.

The U.S. Congress passed the Semiconductor Chip Protection Act (SCPA) of 1984 to combat the piracy that was plaguing innovation in the design of computer chips. The SCPA established a new form of intellectual property protection particularly suited to the needs and special characteristics of semiconductor chips.

The United States became the first nation to enact a law specifically to protect the design of semiconductor chips. The law was drafted so that it would become the worldwide standard, and it included incentives for other countries to enact equivalent protection. To encourage foreign nations to adopt laws protecting U.S. chips, the SCPA authorized the Secretary of Commerce to issue temporary protection to countries that are "making good faith efforts and reasonable progress ..." toward reciprocal protection for U.S. chips.

The reciprocal approach—we will protect your country's work so long as you make speedy progress toward laws protecting ours—has been very effective. Nineteen countries have been granted temporary protection, and most of these countries have enacted legislation that is substantially similar to the SCPA.

The authority of the Secretary of Commerce to issue temporary protection expires in July. I am working with the Subcommittee on Technology and the Law on legislation that would extend the authority of the secretary to issue temporary protection to countries that are making adequate progress toward laws protecting U.S. chips.

The semiconductor industry is vital to the economic welfare and national security of the United States. The Semiconductor Chip Protection Act has helped stimulate research and preserve jobs by reducing the international piracy that was plaguing the semiconductor industry. ■

Note: *Craig Schiffries is the GSA Congressional Science Fellow for 1990–1991. He is serving on the staff of the Subcommittee on Technology and the Law, of the Senate Judiciary Committee. He can be reached at (202) 224-3406. The one-year fellowship is funded by the GSA and by the U.S. Geological Survey, which supports 47% of the program with a $21,000 grant.*

GSA FORUM

Bruce F. Molnia

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

ISSUE: The Age of Earth—Science and Religious Views

Is the geoscience community effectively educating the public about the age and history of the Earth?

PERSPECTIVE 1:

Reflections on the Age of Earth

Ellis Yochelson, National Museum of Natural History, Washington, D.C.

Obviously a misunderstanding regarding the age of Earth based on a literal interpretation of the Bible is of concern to earth scientists. Most geologists agree that Earth is old and are concerned that this view is misinterpreted in some quarters.

From my limited teaching experience, I can confirm that most adults do not carry the notion of an ancient Earth as part of their intellectual baggage. However, almost all are open-minded, and those that are not keep silent in a classroom setting. An effective teaching device is a pile of books dropped one at a time to show the law of superposition and the notion that time separates the layers; if done properly, at least the noise keeps students awake.

Some years ago, a couple of sincere young men knocked on my door. They brought up the subject of the age of Earth and when I asked for a figure, they told me 27,000 years. I insisted that if one thought as a geologist, the answer was far too short, but if one interpreted the Bible literally, this was much too long. I then started a lecture on Bishop Ussher. They could not wait to leave and they have not come back. It never hurts to turn an argument around, and perhaps the best detailed source to consult on alternative explanations and how to refute them is *Science and Earth History—the Evolution/Creation Controversy* by A. N. Strahler.

A Navy helicopter pilot on duty in the Ellsworth Mountains, West Antarctica, in 1979–1989, was a member of the Creation Research Society (CRS). One night, he showed a filmstrip prepared by CRS of thrust faults, which demonstrated that the law of superposition is wrong and, therefore, the concept of an ancient Earth fails. A dozen geologists disagreed. This discussion was on the highest and most polite plane, for we were ever mindful of the difficulties of walking home if the helicopter did not arrive. Neither side was convinced. For true believers on any issue, debate does not change anything. If effort is to be expended on education, it is better to speak with the young or with those who have no clearly formed opinion.

PERSPECTIVE 2:

The Age of Earth—Reaching the Christian Community.

Davis A. Young, Calvin College, Grand Rapids, Michigan

As geologists who universally acknowledge that physical evidence for Earth's extreme antiquity is overwhelming, we are distressed by the lack of public awareness of the planet's vast history and are decidedly baffled by the overt resistance of the flood-geology school to an old Earth. Our predicament is not new. As belief in a young Earth and a geologically significant global flood has always been found among Christians (and adherents of other faiths), Christian geologists have long struggled to educate church members about geology. In the 19th century, devout Christian geologists like Benjamin Silliman, Edward Hitchcock, James Dwight Dana, Arnold Guyot, Alexander Winchell, Hugh Miller, and J. William Dawson either vigorously challenged the pseudo-geology of people like Granville Penn and George Fairholme or else labored to demonstrate to fellow believers the compatibility of their Christian faith with acceptance of an old Earth.

More than a century later, members of the newly founded Affiliation of Christian Geologists are combating young-Earth, flood-geology conceptions by meeting with theologians and church leaders, speaking at churches, seminaries, and Christian colleges, and writing for the Christian community. The fact that young-Earth views are still common suggests that geologists will always be tormented by unscientific ideas entertained by a public that perversely delights in rejecting the authority of experts. Nonetheless, we must persist in the enterprise of geological education. How can we improve our chances of success?

My own talks at churches and Christian colleges include slides of mudcracks, fossil soils, uncomformities, glacial deposits, eolian dunes, igneous intrusion, and metamorphic rocks so that people can see the evidence for Earth's long, dynamic history. Physical evidence alone, however, is insufficient. World view is all-important! If a person's world view does not allow for an old Earth, no amount of physical evidence will persuade, no matter how persuaded we geologists may be. So I always try to show my audience that physical evidence is compatible with Christian convictions about God and the Bible.

Geology is practiced by people holding a diverse array of world views —atheism, Buddhism, pantheism, mysticism, Islam, Judaism, Christianity, and so on. GSA wants to educate a public holding a similar spectrum of world views—a daunting task indeed! I submit that geologists will not be very successful in convincing some Christians of an old age for Earth unless these individuals are persuaded of the consistency of an old Earth with their Christian world view. This means that an old Earth must not be perceived as being inconsistent with the Bible or the belief that God has brought the world into existence and providentially guided its development. To demonstrate that consistency to a skeptical Christian requires tact, patience, and some understanding of Christian theology and biblical studies. Thus, geologists who have no attachment to the Bible or divine providence will do well to refrain from rash assertions that Genesis contains only myths, that the Bible is factually in error about the world's origins, or that Earth history is incompatible with God's governance. Some geologists hold such views passionately but to assert them may prove counterproductive, for if a Christian is presented with a choice between God or an old planet, one may safely predict that God will win out. If we are truly concerned about advancing our science, we will be careful to recognize the limitations of geology and its inability to provide answers to the ultimate questions of life.

PERSPECTIVE 3:

Educating About the Old Age of Earth: An Action Plan

C. Gordon Winder, University of Western Ontario, London, Ontario, Canada

Modern geological research, begun almost two centuries ago, has established that Earth is old. In August 1990, the International Creationism Conference was held at Duquesne University, Pittsburgh, PA. The conference theme was The Age of Earth. Papers were presented by many scientists with graduate degrees, including one with a Ph.D. in geology from Harvard. That the conference was held at a university conveys authenticity about the conference theme to the general public. I question whether a paper with the title "Pick Your Own Age for the Earth" is really science.

About three years ago, a University of Northern Illinois sociologist reported that, generally, the U.S. public is scientifically illiterate. Specifically, the majority think that Earth is young, or they do not know anything about its age. In late 1989, a University of Calgary communications professor conducted a telephone survey of 2000 adults across Canada. Only 36% could name a Canadian scientist. Fifteen percent answered that the sun revolves around Earth and 6% did not know. Concerning the contemporaneity of mankind and dinosaurs, 46% gave the correct answer. For the last question, the percentage in Britain and the United States with the correct answers was 46% and 37%, respectively.

Professional geoscientists should be concerned about the scientific literacy of the public with respect to the age of Earth. If geoscientists fail to educate the public, who will—the chemists? An education effort aimed at the general public may be relatively ineffective, but a major effort should be directed toward young people at the earliest possible age. Youngsters are fascinated with dinosaurs. Contemplate, however, the influence of the popular media which shows the contemporaneity of mankind and dinosaurs, such as Alley-Oop, the Flintstones, and even Sesame Street!

Participants at the Creationism Conference included both young-Earthers and old-Earthers. Differences of view exist even in the creationism camp. The young-Earthers in particular, have been successful in networking their ideas to the public through the fundamentalist churches, Christian schools, radio broadcasts, brochures, pamphlets, and tracts. Many tracts are distributed free or sold at nominal cost. Young-Earthers have been effectively communicating and paying special attention to youngsters, particularly with respect to views about the age of Earth.

I suggest that geoscientists use the same techniques.

1. **The Debate Format.** Geoscientists should argue only the simple basic premise, "RESOLVED, that directly observable geologic data indicate that Earth is old." This statement can be effectively defended. The factual observable data are: thick fossiliferous sedimentary sections, including drill holes measuring thousands of meters; sedimentary sections with sills; thick evaporite sections with thousands of calcite and evaporite couplets, as in the Permian Castile Formation of West Texas; reefs, as in the Middle Devonian of Alberta and the Silurian of Michigan, both surrounded by evaporites; and such slow processes as diagenesis. It is logical to argue that a 4000-m-thick section of sandstone and shale with several levels of upright tree trunks took a long time to deposit. Could this have happened in the 371 days of the Biblical flood? The young-Earther will attempt to divert attention away from the basic premise that Earth is old by raising questions about the validity of radiometric dating and the reliability of index fossils. Such diverting tactics should be cited to the audience. One undesirable aspect of the debate format is that the young-Earther is provided with a platform.

2. **School Instruction.** In a political jurisdiction which has a geological survey publishing geologic maps and reports, the school curriculum should specify that Earth is old. Does the teacher follow the prescribed curriculum or is the subject of the age of the Earth presented in such a way that the student can decide that Earth is young? Request an invitation from a teacher, principal, superintendent, or school board to speak in the appropriate class. One approach I have used is go without any prepared topic but with a carousel of slides of features which illustrate that Earth is old. First, the students are invited to ask questions. When their input ceases, I begin with such questions as, "Do you know what is under your feet when you stand on the playground?" My questions are about geoscience features around the city and in the surrounding area; mineral deposits, including such mundane things as gravel or stone for construction; concepts of which they have heard, such as seafloor spreading and the wanderings of the magnetic pole; and, eventually, the age of Earth, if the students have not asked.

3. **Films and Videos.** The young-Earthers make films and videos of professional quality. The GSA has produced an excellent video, "The Earth *Has* a History," narrated by Pete Palmer. The concepts are simple—modern fluvial sedimentation related to ancient sandstones and conglomerates, originally horizontal; folding; and stratigraphic succession, with the oldest on the bottom. The students understand that these processes take a long time and, therefore, that Earth must be old. Offer to donate a copy of this video to a school. Later, ask about student impressions. You can ask for an invitation to speak to the class. GSA is cooperating with the U.S. Geological Survey on preparation of a series of CD-ROM discs, the JEdI series, containing graphic earth science data and pro-

grams suitable for use on PCs in secondary schools.

4. **Publications.** The books produced by the young-Earthers are attractive and inexpensive. The titles are intriguing and provocative, the binding is rugged, the language is simple, the print is large and clear, and the illustrations are numerous and colorful. The message is obvious—Earth is young. The most effective publications produced by the young-Earthers are brochures, pamphlets, and tracts. The few pages are hand size and fit readily into a pocket, possibly with a single fold. The message is simple, the language is understandable to a youngster who can read, and the required attention span is short. A comic-book format may include a crusading character. The titles are catchy: "The Mystery of the Buried Redwood" or "The Missing Rocks of the Grand Canyon." A single copy may be a dime or less, with a substantial discount for bulk purchases. Geoscientists should produce similar books, brochures, even "tracts," with the message that Earth is old. A "tract" should have only one topic. Examples of observable geologic evidence appropriate to establish that Earth is old include thick stratigraphic sections exposed in mountains and canyons, uncomformities, single and multiple intrusions, and cyclic sequences such as varves. The pamphlets can be distributed during visits to schools, with the cooperation of a teacher. Such pamphlets can even be distributed in Sunday schools by geoscientists who are church members, with the approval of the minister.

5. **Radio, Television, and Newspapers.** The age of Earth is a somewhat restricted topic, but all opportunities to make the point on radio and TV that Earth is old should be acted upon. An article or letter in a local newspaper arguing a young age for Earth can evoke letters to the editor. My practice has been to contact any letter writer with an invitation to visit a local outcrop. None have yet accepted! I have been consulted by a local science reporter about building stones and glacial geology. The reporter is most cooperative about including statements on the age of the stone and the long, complex glacial history.

In summary, the majority of the public apparently is unaware that Earth is old. The directly observable geologic evidence is persuasive of an Earth with great age. Geoscientists should act on every opportunity to inform the public about the age of Earth, but a special effort should be directed toward students through the schools, especially at the elementary level. This effort will also draw attention to the field of geoscience, a discipline which is generally absent from the minds of the public.■

Journals to Mail in Poly Again

Jim Clark, GSA Production Manager

In the February issue of *GSA Today*, I reported that we planned to try mailing our journals within the United States without the familiar polyethylene (poly) packaging. Some members had suggested that poly was not a good choice, environmentally, and pointed out that some magazines were regularly mailed without any packaging, a fact that had not escaped our attention. We, too, wondered if we might successfully deliver our journals without simultaneously delivering poly.

We mailed our March and April journals to domestic U.S. addresses without packaging, with labels affixed directly on the covers. The results were not good. Damage claims were far higher than we expected, and the severity of the damage surprised us. It quickly became obvious that the newer automated Postal Service machinery is, as one subscriber put it, "not kinder and gentler."

We had no choice but to abandon the experiment, and so the May issues will once again be packaged in poly. If you subscribe to *both* journals, please note that they were mailed separately in May, rather than together in the same package. Rest assured they will once again be combined in the same package, starting in June.

In the past two months several members have suggested that we try other packaging methods. Apparently, they were unaware that in the past ten years we have tried paper sleeves (like *National Geographic*), paper "second wrappers," paper envelopes, corrugated flats, and "Jiffy"-type bags for journal mailing, all proving unsuccessful in one way or another for our journal formats and sizes.

Only with poly packaging were we able to virtually eliminate damage claims, combine journals to those who subscribed to both, simplify the mailing process, and keep costs low. Some new packaging materials are now being tested that seem to be more environmentally sound, but they are not yet proven nor commercially available.

Packaging is definitely required for our journals, and for now we are convinced that poly is the best material available to us. We use pure poly, rated by the Society of the Plastics Industry, Inc., as "No. 4 Recyclable." Many recycling centers are beginning to accept rated plastics, so be sure to check with yours. Starting in June, this recycling rating will be printed on the poly.

We apologize for any inconvenience and frustration you may have experienced during this two-month trial. We are having good success with our increasing use of recycled papers, discussed in the February article, but we were wrong on the packaging issue. ■

GSA Officer and Councilor Nominees for 1992

Council announces the following officer and councilor candidates. Voting members will receive biographical information on all candidates with the ballot to be mailed in August.

For Councilor (1992–1993) and President (1992)
E-an Zen; College Park, Maryland
For Councilor and Vice-President (1992)
Robert D. Hatcher, Jr.; Knoxville, Tennessee
For Councilor and Treasurer (1992)
Robert L. Fuchs; Denver, Colorado
For Councilor (1992–1994)—Position 1
Karen L. Prestegaard; College Park, Maryland
Leigh H. Royden; Cambridge, Massachusetts
For Councilor (1992–1994)—Position 2
Hugh C. Morris; Vancouver, British Columbia
Fernando Ortega-Gutierrez; Mexico City, Mexico
For Councilor (1992–1994)—Position 3
Genevieve Atwood; Salt Lake City, Utah
James Helwig; Dallas, Texas
For Councilor (1992–1994)—Position 4
Robert H. Dott, Jr.; Madison, Wisconsin
Clement F. Shearer; Northfield, Minnesota

Call for Nominations 1991 John C. Frye Environmental Geology Award

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

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

In addition, nominated papers must:

- Establish an environmental problem or need.
- Provide substantive information on the basic geology or geologic process pertinent to the problem.
- Relate the geology to the problem or need.
- Suggest solutions or provide appropriate land use recommendations based on the geology.
- Present the information in a manner that is understandable and directly usable by geologists and addresses the environmental need or resolves the problem. It is highly desirable that the paper be directly applicable by informed laypersons (e.g., planners, engineers).

Basis for selection:

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

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

About People

GSA Member **Nicholas Beskid** has been appointed director of the Applied Research and Development Program Coordination Office of Argonne National Laboratory, Argonne, Illinois.

GSA Fellow **Paul B. DuMontelle**, Urbana, Illinois, has been appointed principal scientist and branch chief of Environmental Geology and Geochemistry at the Illinois State Geological Survey.

GSA Fellow **Richard E. Gray**, GAI Consultants, Inc., Monroeville, Pennsylvania, has been selected as a 1991 recipient of the American Society for Testing and Materials Award of Merit.

GSA Fellow **Norman Herz**, University of Georgia, Athens, has been elected a Corresponding Member of the Brazilian Academy of Sciences.

GSA Fellow **Betty M. Miller**, U.S. Geological Survey, Reston, Virginia, has received the 1991 J. J. Arps Award from the Society of Petroleum Engineers.

SEPM recently elected new officers, who include GSA Fellow **Gail M. Ashley**, Rutgers University, New Brunswick, New Jersey, who took over the duties of president of SEPM; Member **Harry E. Cook**, U.S. Geological Survey, Menlo Park, California, who was named president-elect; Member **Gregory H. Blake**, UNOCAL, Ventura, California, who was elected paleontology councilor; Fellow **Stephan A. Graham**, Stanford University, Stanford, California, who was named sedimentology councilor; Fellow **Michael E. Field**, U.S. Geological Survey, Menlo Park, California, who was elected secretary-treasurer; and Member **Lisa M. Pratt**, Indiana University, Bloomington, who was named councilor for research activities.

SEPM appointed two new editors: GSA Fellow **David J. Bottjer**, University of Southern California, Los Angeles, who was named editor of *PALAIOS*; and Member **Barbara H. Lidz**, U.S. Geological Survey, St. Petersburg, Florida, who was named editor of Special Publications.

SEPM awards went to GSA Fellow **John Imbrie**, Brown University, Providence, Rhode Island, who received the William H. Twenhofel Medal; Fellows **H. Edward Clifton**, U.S. Geological Survey, Menlo Park, California, and **John C. Harms**, Harms & Bradley Inc., Littleton, Colorado, who were awarded honoray membership; Fellow **Elazar Uchupi**, Wood Hole Oceanography Institute, Massachusetts, who received the Francis P. Shepard Medal; and Fellow **Erle G. Kauffman**, University of Colorado, Boulder, who received the Raymond C. Moore Medal. ■

Spectroscopy *continued from p. 119*

thermal expansivity are sorely needed to interpret seismic profiles and to establish the geotherm. Chopelas (1990a) has used spectroscopic data in conjunction with adiabatic compression measurements (Boehler, 1982) to constrain dependence of forsterite's thermal expansivity on pressure.

APPLICATIONS TO THE MANTLE AND CURRENT PROJECTS

Entropy and Phase Transformations. Measurements of entropy for very high pressure phases is impossible because these phases are produced only in minute quantities and commonly revert at high temperature and 1 atm. Accurate calculation of entropy can be provided by spectroscopy, as shown by our garnet studies. Using the resulting entropy in a Clausius-Clapeyron equation

$$\frac{\partial P}{\partial T} = \frac{\Delta S}{\Delta V} \qquad (3)$$

gives slopes for reactions involving $MgSiO_3$ ilmenite that match those of experimentally determined phase boundaries (Hofmeister and Ito, 1991). A number of other phases have reaction boundaries that are poorly constrained (e.g., transformations involving stishovite, and β- or γ-Mg_2SiO_4; Fei et al., 1990). Ongoing spectral measurements of these phases should provide independent knowledge of reaction slopes from equation 3 for phase tranformations important to mantle petrology.

Phase transformations can also be observed directly in spectra as a function of pressure, because the number of bands depends on the space group of a mineral. Spectroscopic determination of the α- to γ-Mg_2SiO_4 transformation at room temperature and 10 GPa (Chopelas, 1990a; Hofmeister et al., 1989) falls on the same trend as the phase boundary established near 1000 K through phase equilibria experiments, suggesting that IR and Raman studies can provide important constraints on phase stabilities. Currently, a Ph.D. thesis by Ren Lu involves measurement of $\upsilon(P)$ for $MgSiO_3$ perovskite and analogues. An intriguing question to which this study should provide an answer is whether a cubic structure of one of the distorted orthorhombic or tetragonal polymorphs is stable in the mantle.

Equations of state. Laboratory studies of minerals cannot be related to seismic data without adequate knowledge of the relevant equations of state, $V(P,T)$ (e.g., Birch, 1952). Dependence of thermal expansivity on pressure has been determined for MgO and Mg_2SiO_4 through spectroscopy (Chopelas, 1990a, 1990b). Comparison with a variety of other compounds indicates that the relation is generally applicable to crystal structures found in the mantle (Anderson et al., 1990).

Available equations of state for $V(P)$ differ by an order of magnitude in their prediction of the second pressure derivative of the compressibility. The relations of vibrational frequencies to elastic properties (Hofmeister, in prep.) can be used to provide the first and second pressure derivatives of K_T and to distinguish which of the various formulations are appropriate. Ongoing IR measurements of solid-solution garnets can also be used to calculate elastic properties in an attempt to understand why compressibility depends linearly on composition for some garnet series, while for others it does not (e.g., Bass, 1986). Derivation of systematic relations is important because pressure derivatives of elastic properties are lacking for many minerals.

Calculation of the geotherm requires data on heat capacity as a function of pressure because the adiabatic temperature gradient is given by

$$\left(\frac{\delta T}{\delta P}\right)_S = \frac{\alpha T V K_T}{K_S C_V}, \qquad (4)$$

where the bulk modulus K is defined in equation 2 and α is the thermal expansivity. Brown and Shankland (1981) generated a temperature profile from seismic data that is in accord with recent values for core temperatures of Boehler et al. (1990). Geotherms calculated for forsterite based on spectroscopic data at pressure agree reasonably well with the seismic profile (current study). However, for a laboratory-based geotherm to be meaningful requires a large data base of vibrational spectra at pressure. Currently, work at UC Davis focuses on pyroxene, spinel, and perovskite phases.

LIMITATIONS OF THE TECHNIQUE AND FUTURE DIRECTIONS

Single-crystal study at ambient conditions has reached the theoretical limit involving diffraction of light from small samples. Improvement in quality of IR data for synthetic high-pressure phases therefore rests on synthesis of untwinned crystals larger than 100 μm. Pressure studies have a similar intrinsic limitation (light is scattered by a hole smaller than the wavelength).

One area worthy of pursuit is study of spectra at elevated temperatures and, ultimately, elevated temperatures and pressures simultaneously. In the near future, such advances are more likely for Raman than IR studies because the latter has wider band widths, which become even broader as temperature increases.

Another limitation is the accuracy of the thermodynamic model. Incorporation of additional terms may improve Kieffer's (1979) model. Refining the model requires increased accuracy of calorimetric measurements of C_V, and complete vibrational data on a large variety of compounds. The gain for mantle studies is a more reliable prediction of heat capacity and entropy. This is especially important for very high pressure phases that are metastable. Accordingly, the main focus of our research group, now and in the future, is assembly of a spectroscopic data base, at ambient conditions, and as a function of pressure and temperature, of rock-forming minerals and mantle phases.

ACKNOWLEDGMENTS

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WASHINGTON REPORT

Bruce F. Molnia

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

Strength in Numbers

January's Washington Report described the Committee on Earth and Environmental Science (CEES) U.S. Global Change Research Program (GCRP), the first very successful, multiagency program spawned by the White House Office of Science and Technology Policy's (OSTP) Federal Coordinating Council for Science, Engineering, and Technology (FCCSET). One of the key ingredients for the successful selling of the GCRP has been a small (~14.5 cm × ~23 cm finished size), very slick booklet, "Our Changing Planet," now in its third iteration. Successive versions of this booklet have been produced to capitalize on the look and the recognition factor of the previous version. The primary target for these booklets is the Congress of the United States. Enough copies are produced each year—as many as 20,000—to ensure that almost everyone in the budget process will have an opportunity to see the GCRP booklet.

Before release of the FY 1991 version, a decision was made to change the cover photograph from an Apollo 10 view of Earth to an Apollo 16 version of that view. The images were so similar, however, that the only change required in the caption was the spacecraft number. In Washington, you don't want to tamper with a winner.

By last year, the word was out: (1) Programs sell better when described with a nicely packaged booklet, and (2) the more agencies involved as cooperators, the better the chances of success! In January 1990, the Interagency Arctic Research Policy Committee produced the first of the look-alike booklets, "Arctic Oceans Research," which proposed a strategy for a series of six new integrated, interagency Arctic Ocean research projects. "Arctic Oceans Research" continued the cover photograph tradition of "Our Changing Planet," by using a Nimbus-7–generated view of Earth.

This year, the first look-alike booklet to appear is "Grand Challenges: High Performance Computing and Communications." This breaks new ground in the booklet wars by presenting a glossary of acronyms and terms not usually in the vocabulary of your typical member of Congress, and by replacing that ubiquitous cover photograph of Earth with an array of eight images representing ongoing scientific projects in scientific disciplines described in the report, networked to a map of the U.S. These eight color photographs are used in the text to accompany a series of technology case studies.

The glossary of this booklet defines a "grand challenge" as a fundamental problem in science and engineering, with broad economic and scientific impact, whose solution could be advanced by applying high-performance computing techniques and resources. The glossary defines high performance as encompassing "advanced computing, communications, and information technologies, including scientific workstations, supercomputer systems, high speed networks, special purpose and experimental systems, the new generation of large scale parallel systems, and applications and systems software with all components well integrated and linked over a high speed national network."

"Grand Challenges," which describes the components of an FY 1992 $638.3 million program in high-performance computing and communications, is the product of the 22-member High Performance Computing and Communications Working Group of the FCCSET Committee on Physical, Mathematical, and Engineering Sciences. Among the members of the Working Group are five representatives from the Department of Energy (DOE), five from the National Science Foundation (NSF), three from the National Space and Aeronautics Administration (NASA), and three from the Department of Defense (DOD). Not one of the other six Working Group members is a representative from the Department of Interior (DOI), the host department for most earth science–oriented agencies. DOI is also conspicuously absent from any of the programs described in the report.

In his transmittal letter to the members of the Congress, Presidential Science Advisor D. Allan Bromley states that the "goal of the Federal High Performance Computing and Communications Program (HPCCP) is to accelerate significantly the commercial availability and utilization of the next generation of high performance computers and networks. Recent advances offer the potential for a thousand-fold improvement in useful computing capability and a hundred-fold improvement in available computer communications capability by 1996. These advances will come through improvements in hardware and software. This increased capability will greatly expand the availability of these resources for research and education." Bromley continues, "It is my personal view, moreover, that the successful implementation of this program will lay the foundation for changes in education at all levels."

"Grand Challenges" refers to the success of the early 1980s, when a new computing technology of scalable parallel-processing computers emerged. The booklet states that "by the mid-1990s, this innovative approach to high performance computing systems promises to achieve sustained performance improvements of a thousand-fold compared to current systems."

Goals. "Grand Challenges" lists the following as goals of the HPCCP: (1) extend U.S. technological leadership in high-performance computing and computer communications; (2) provide wide dissemination and application of the technologies both to speed the pace of innovation and to serve the national economy, national security, education, and the global environment; and (3) spur gains in U.S. productivity and industrial competitiveness by making high-performance computing and networking technologies an integral part of the design and production process. These goals will be realized by achieving computational performance of one trillion operations per second (10^{12} ops, or teraops) on a wide range of important applications; development of associated system software, tools, and improved algorithms for a wide variety of problems; a national research network capable of one billion bits per second (10^9 bits or gigabits); sufficient production of Ph.D. earners and other trained professionals per year in computational science and engineering to enable effective use and application of these new technologies.

Programs. The HPCCP consists of four integrated components. (1) *High-performance computing systems*, encompassing the development of the underlying technology required for scalable parallel-computing systems capable of sustaining trillions of operations per second on large problems. (2) *Advanced software technology and algorithms*, encompassing the development of genetic software technology and algorithms for grand challenge applications to realize the performance potential of high-performance computing systems in a networked environment. (3) *National research and education*, encompassing the development of a national high speed network to provide distributed computing capability to research and educational institutions and to further advanced research on very high-speed networks and applications. (4) *Basic research and human resources*, providing support for individual investigators and for multidisciplinary long-term research drawn from diverse disciplines, including computer science, computer engineering, and computational science and engineering. This component also contains provisions to initiate activities to significantly increase the pool of trained personnel and to provide support for efforts leading to accelerated technology transfer.

Budget. Proposed FY 1992 expenditures (in millions of dollars) are: for component 1—$156.8; for 2—$265.1; for 3—$91.9; and for 4—$124.5. Proposed budgets for participating departments (in millions of dollars) are: DOD—$232.2; NSF—$213; DOE—$93.0; NASA—$72.4; Health and Human Services—$17.1; Department of Commerce—$5.4; and Environmental Protection Agency—$5.2. The proposed $638.3 million budget for FY 1992 represents a $148.9 million or 30% increase over the FY 1991 enacted level of funding. ■

ANNOUNCEMENT

Travel Grant Program
29th IGC in Kyoto, Japan—1992

The Geological Society of America is accepting applications for the 29th International Geological Congress (IGC) Travel Grant Program.

This program was established as a final act of the Organizing Committee for the U.S.-hosted 28th IGC held in Washington D.C., in July 1989. Surplus funds available at the conclusion of the 28th IGC were transferred to the GSA Foundation with the stipulation that income from the fund be used to support the attendance of young geoscientists to future IGCs, until such time as the United States again hosts an IGC. Travel grants will consist of economy airfare to Japan and prepayment of the registration fee.

To be eligible, an applicant must be a resident or citizen of the Untied States (includes students); must have a birth date after August 31, 1952; and must have submitted an abstract for inclusion in the program of the 29th IGC.

Official application forms are available from the Grants Coordinator, GSA Headquarters, 3300 Penrose Place, P.O. Box 9140, Boulder, CO 80301. Along with the form, applicants must include a copy of the abstract that was submitted to the 29th IGC. Applications must be supported by two letters from current or recent supervisors. Students may use faculty members. **Qualifying applications and letters of support must be postmarked no later than *October 31, 1991*.** Applicants will be notified of results early in 1992.

GSA Divisions and Sections—1991

DIVISIONS

GSA's eleven specialty divisions provide a focus for members interested in a particular discipline. The divisions hold annual business meetings in conjunction with the Society's annual meeting, and each division publishes a newsletter periodically. Division membership totals are as of December 31, 1990.

Archaeological Geology Members: 495
Officers: Julie K. Stein, chairman; E. Arthur Bettis III, first vice-chairman; Bonnie A. Blackwell, second vice-chairman; C. Reid Ferring, secretary-treasurer; Robert M. Thorson, past chairman.
Newsletter editor: Vance T. Holliday.

Coal Geology Members: 350
Officers: Robert B. Finkelman, chairman; Timothy A. Cross, first vice-chairman; Robert A. Gastaldo, second vice-chairman; Cortland F. Eble, secretary; James C. Cobb, past chairman.
Newsletter editor: Cortland F. Eble.

Engineering Geology Members: 1173
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GSA has six regional North American sections, generally including GSA members who live within the geographical limits of each section. (Members who live in one section but have a professional interest in another section can become members of the section of interest.) Each section holds annual technical and business meetings. The number of voting members shown for each section is as of December 31, 1990.

Cordilleran Voting members: 3858
Geographic area: Alaska, Arizona south of lat 35°N, California, Hawaii, Nevada, Oregon, Washington, British Columbia, Yukon, Northwest Territories.
Officers: Patrick L. Abbott, chairman; Richard A. Schweickert, vice-chairman; Bruce A. Blackerby, secretary; Martin L. Stout, past chairman.

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North-Central Voting members: 1238
Geographic area: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Nebraska, Ohio, Wisconsin, Manitoba, Ontario west of 89th meridian.
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Officers: Timothy M. Chowns, chairman; Paul D. Fullagar, vice-chairman; Michael J. Neilson, secretary-treasurer; Vernon J. Henry, past chairman; Juergen Reinhardt, past vice-chairman. ■

Geological Society of America Foundation

GSA Foundation

Annual Report 1990

DALLAS
OCTOBER, 1990

Geological Society
of America Foundation
P.O. Box 9140, Boulder, CO 80301

CHAIRMAN'S MESSAGE

1990 was a good year for the GSA Foundation. Donors increased slightly, from 1200 in 1989 to 1209, but contribution income was up 16% to $550,000 while the Foundation fund balance increased four-fold, as explained in the President's Message. In 1991 we expect even greater support for student aid and other GSA programs, in part because the growth of the Foundation's endowment allows us to disburse more money from investment income. In addition, the Foundation's development efforts can bear fruit in indirect ways. A cooperative effort of GSA and the Foundation begun in 1989 has resulted in a three-year, $300,000 grant from the National Science Foundation that will allow GSA to increase the student research grant program by 50% beginning in 1991.

One of our most important priorities in 1991 is the development of new approaches to funding "the application of geology to the wise use of the Earth." Take a moment to read the Foundation Mission Statement, included with this Annual Report, which has been broadened to include this appendage, a particularly appropriate step for the decade of the nineties. Wise use of the Earth is becoming a pervasive concept in GSA. For example, the focus of the 1991 Annual Meeting in San Diego will be on Global and Environmental Geology.

The increased emphasis on the environmental consequences of land use and resource exploration and exploitation is reflected in the name of GSA's new program directed toward the wise use of the Earth, the "Institute for Environmental Education," and in the proposed name changes of AEG to the "Association of Engineering, Environmental and Ground Water Geologists" and the EGD of GSA to the "Environmental and Engineering Geology Division."

The Institute for Environmental Education (IEE) and Science Awareness through Geoscience Education (SAGE) programs are two most important new initiatives. At the heart of the proposed IEE program is the concept of apprenticeship, to provide student training concurrent with filling an industry need. Training in industry has received special attention by the Commission on Skills of the American workforce, who indicate that the only long-term escape from the doldrums of the recession is increased productivity through upgraded skills. It has been widely recommended that all U.S. companies spend at least 1% of their payrolls on education and training. This remains an unachieved goal in this country, while by comparison West German companies are required to spend 3.5% and Swedish companies 2.5%.

The SAGE program will focus on pre-college educational levels and public geoscience education. Two principal goals are to encourage more students to enter the profession, as well as to enhance public understanding and appreciation of geoscience. For example, we must see that more geoscience topics receive the same media attention as *Time* Magazine gave "The Antarctic Connection" in the issue of April 8, 1991.

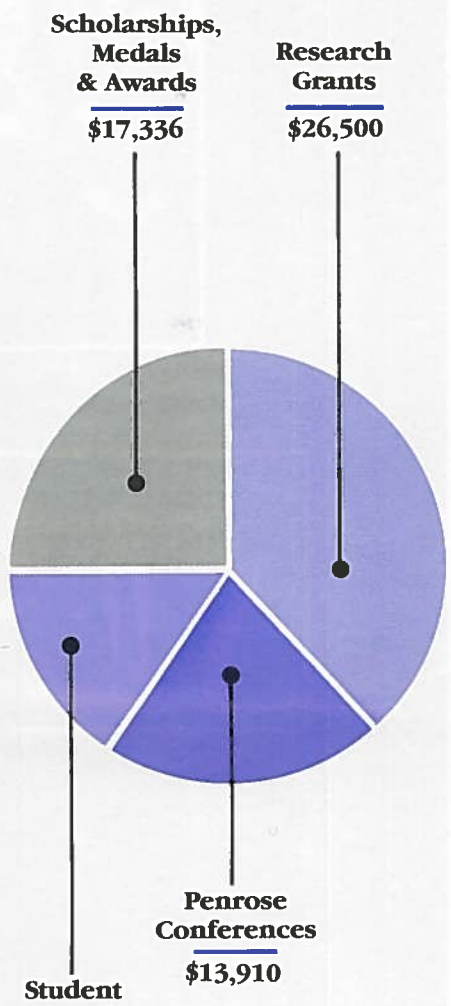
IEE and SAGE are worthwhile targets for individual member financial support, as well as donations from companies, institutions, and individuals not GSA members. Both have high priority in Foundation fund-raising activities. These initiatives further demonstrate the resiliency and innovation within this 103-year-old Society.

We all thank Bob Fuchs and Mike Wahl for their continued leadership roles with the Foundation and GSA. Fred Donath, Executive Director of IEE, Steve Stow and Dave Stephenson, SAGE prime movers, and Ed Geary, Coordinator of SAGE, are to be commended for their work in establishing and nourishing these important programs.

The Board of Trustees met three times in Dallas within the past year, first in June, 1990, then the GSA Annual Meeting in October, and finally in April 1991 at the AAPG Annual Meeting. Phil LaMoreaux has been Chairman of the Board for the past few years and we thank him for his dedicated efforts on behalf of the GSA Foundation. Trustee Philip Oxley is a sterling addition to the Board. He filled the vacancy created in 1990 by the resignation of Roy Huffington, who became U.S. Ambassador to Austria. The Board is actively identifying potential major donors, opening doors for the Foundation, and contributing to the major causes. We must always remember to thank the membership-at-large who in the past have faithfully stood by GSA programs, in terms of both time and money. We look forward to a most successful GSA fund-raising campaign in 1991.

F. Beach Leighton
Chairman

FUND DISBURSEMENTS 1990



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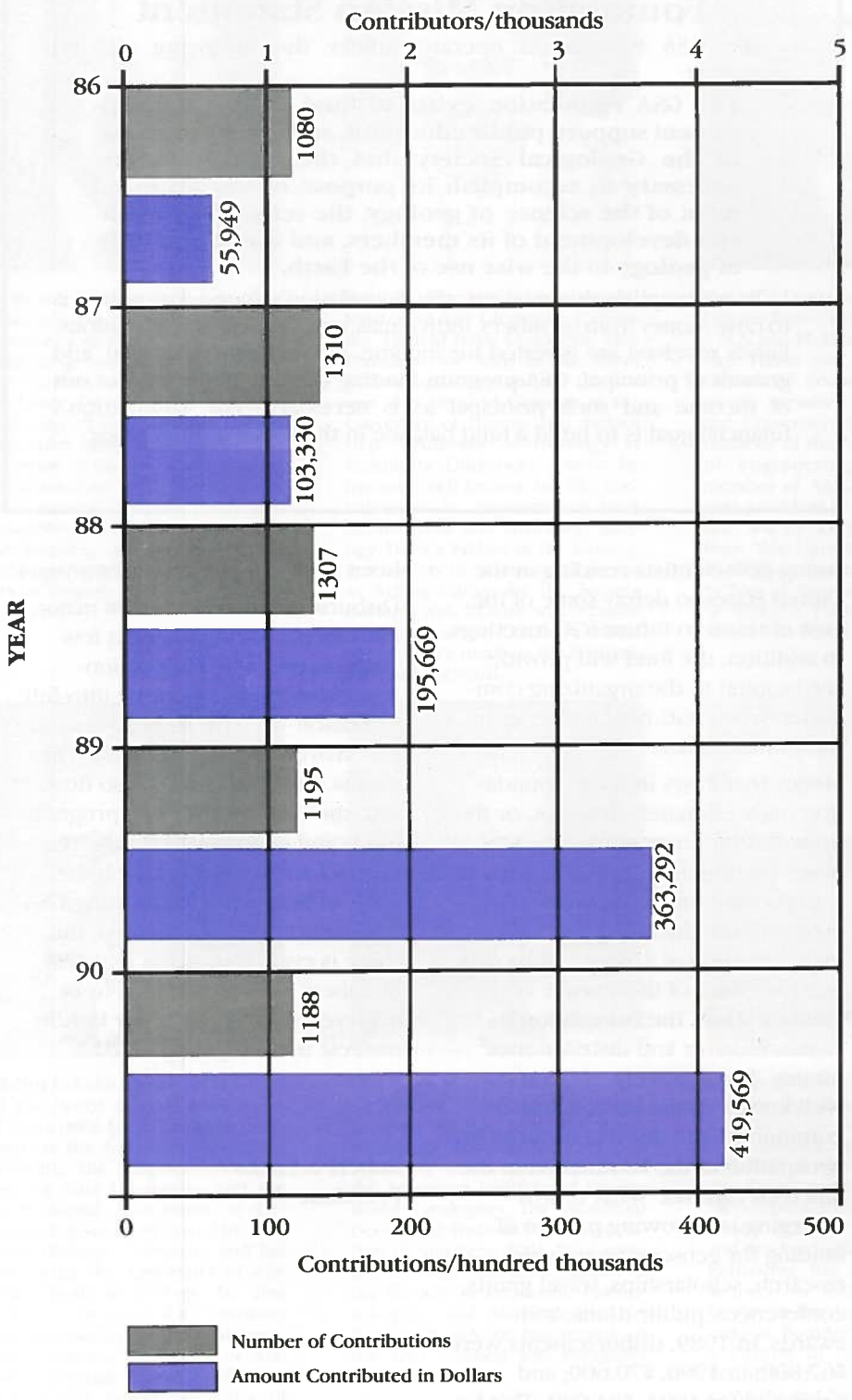

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2. Donna Russell, Robert Fuchs
3. Robert Fuchs, Philip LaMoreaux and Peter Flawn

4. Philip Oxley, Philip LaMoreaux
5. William Heroy, McLain Forman, Charles Mankin and Fred Donath

At GSA's annual meeting Foundation Trustees meet to elect officers, appoint new Trustees, review the progress of the Foundation, and plan for the future. Foundation officers and some GSA staff also attend the meeting, thus providing a forum for the coordination of GSA programs and Foundation financing activities.

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GSAF PRESIDENT'S MESSAGE

When I wrote this message last year, the Foundation's fund balance had slipped to less than $300,000. I spoke then about an ongoing organization in transition, from one dominated by the Herculean multi-million dollar task of publishing the Decade of North American Geology to one that was embarking on a new role for the future — supporting a variety of very popular GSA programs while experiencing rapid growth in numbers of contributors and dollars contributed. What has happened in the intervening year? A great deal.

The consternation about that fund balance disappeared in a blaze of increased assets. Part of the disappearance relates to what can be simply called a bookkeeping change. Not just some sleight-of-hand number juggling and mirror flashing, but the legitimate recordation of a very important asset — the DNAG inventory of books and other published materials.

In looking at the balance sheets of both the Foundation and GSA, it was readily apparent that as books from the publisher began to build up as inventory in the GSA warehouse during the past three years, accounting policy that pertained during the early, formative years of the project was no longer appropriate. The costs of intangibles such as salaries and travel which were expensed in the early days of the project, had given way to tangible hard copy in the form of hundreds of Decade volumes. If for no other reason than valuation in the event of catastrophic loss, good business judgment demanded that the value of this asset be reflected on the balance sheet. The Foundation's Board and GSA Council both agreed to a restatement of the financials of the two organizations, the result of which has been to increase the assets of the Foundation by $807,900, the year-end carrying value of this inventory.

But an accounting change by itself does not make for a stellar fiscal year. The audited financial report of the Foundation for 1990, included in this annual report, indicates important increases in assets and net worth. Assets increased 21.8%, an amount of $400,000. Because of the accounting change discussed above and this assset growth, the Foundation's fund balance, or net worth so to speak, jumped nearly fivefold to $1,352,200.

The largest single gift was the receipt of $328,000 from the 28th International Geological Congress, the surplus generated by that organization at its meeting in Washington, D.C., in July 1989. As its last official act in winding up affairs, the 28th IGC Bureau designatd the GSA Foundation as the recipient for this money, the income from which will be used for travel grants to young geoscientists residing in the United States to defray some of the cost of travel to future IGC meetings. In addition, the fund will provide seed capital to the organizing committee when IGC next convenes in the United States.

Money that flows into the Foundation must ultimately flow out, or the organization serves no useful purpose. The mission of the Foundation is to provide financial support for programs conducted by the Geological Society of America in its role as a promoter of the science of geology. Thus, the Foundation is both a receiver and distributor of money. The financing of DNAG is well known in the earth science community, and this was the principal occupation of the Foundation in the nineteen eighties. What is now emerging is a growing pattern of funding for geoscience activities — research, scholarships, travel grants, conferences, publications, and awards. In 1989, disbursements were $67,800; in 1990, $70,600; and projected for 1991, $94,000. This has been a 40% increase over two years.

Disbursements will grow in major increments during the next few years, as two new Foundation-supported programs come into full operation — SAGE and the Institute for Environmental Education. This means that money must also flow into the Foundation, both program funds and endowment funds. The task before us is very large if the goals of both new and existing GSA programs are to be achieved. But there is every indication that GSA members want these goals to be achieved. That is the major hurdle; the rest is merely hard work.

Robert L. Fuchs
President

Foundation Mission Statement

The GSA Foundation operates under the following mission statement:

The GSA Foundation exists to fund those research, student support, public education, and other programs of the Geological Society that the Society deems necessary to accomplish its purpose of the advancement of the science of geology, the scientific growth and development of its members, and the application of geology to the wise use of the Earth.

To accomplish this mission, the Foundation's long-term policy is to raise money from members, individuals, companies, and institutions. Funds received are invested for income, preservation of capital, and growth of principal. GSA program funding requirements are met out of income and such principal as is necessary. The Foundation's financial goal is to build a fund balance in the $5-10 million range.

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28th International Geological Congress

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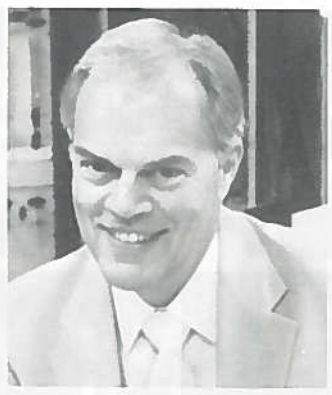
F. Beach Leighton is currently Chairman Emeritus of Leighton & Associates, an engineering geology consulting firm located in southern California. Before retirement in 1988, Dr. Leighton was the chairman of the board and chief executive officer and devoted his attention to the rapidly expanding application of geology to urban environment. He has published extensively on urban geology, earthquakes, and landslides. He received his B.S. from the University of Virginia and his Ph.D. from Caltech.



Fred A. Donath is a consultant located in San Clemente, California. He had been Corporate Vice President for R&D in the Earth Technology Corporation. Donath was also Head of Geology at the University of Illinois and, before that, Professor of Geology at Columbia University where he became well-known for his contributions to experimental rock deformation and structural geology. He is a Fellow of the Geological Society of America and served as Acting Editor for the Society during 1964. Donath was recently appointed as the Executive Director for GSA's Institute for Environmental Education.

Peter Flawn received a B.A. Degree from Oberlin College and a M.S. and Ph.D. from Yale University. Flawn was Director of the Bureau of Economic Geology, a faculty member and president of the University of Texas. He is a member of the National Academy of Engineering, an honorary member of AASG and AAPG, and past-president of AGI. He received the Wilbur Lucius Cross Medal from Yale University and the Ben H. Parker Medal from AGI. A Fellow of the Geological Society of America, Flawn was Councilor from 1972-74 and President in 1978.

McLain J. Forman is president and chief executive officer of Forman Petroleum Corporation located in New Orleans, Louisiana. He received his bachelor of science degree in geology at Tulane University, and his M.A. and Ph.D. at Harvard University. A Fellow of the Geological Society of America and a member of the American Association of Petroleum Geologists. Forman has authored several publications dealing with sub-surface geology of southern Louisiana.

William B. Heroy earned a geology degree from Dartmouth and his Ph.D. from Princeton. His professional career included serving as a geologist at Texaco, as geologist, vice president and president of Geotech, and as a group executive of Teledyne. He was vice treasurer and professor at Southern Methodist University. He belongs to AAPG, SEG, SExG, AIPG, and AGI where he has served as treasurer, vice president and president. A Fellow of GSA, he has been a councilor, treasurer, and has served on numerous committees.

Philip E. LaMoreaux is Chairman of the Board of P. E. LaMoreaux & Associates, Inc. He is a past president of the American Geological Institute, the American Association of State Geologists, and the International Association of Hydrogeologists. He received his B.A. from Denison University and his M.A. from the University of Alabama, both in geology. He also served as Director of the Environmental Institute for Waste Management Studies, University of Alabama through January, 1989. A Fellow and former councilor of GSA, he is the author of many professional publications.

Charles J. Mankin, director of the Oklahoma Geological Survey, received his B.S., M.A., and Ph.D. in geology from the University of Texas. He served as President of the American Institute of Professional Geologists, the American Geological Institute, the Association of American State Geologists and the Mid-Continent Section of the Society of Economic Paleontologists and Mineralogists. A Fellow of GSA, he has served on the GSA Council and Executive Committee.

Philip Oxley is Exploration Advisor to the Board for Graham Resources, Inc., located in Covington, Louisiana. He received his M.A and Ph.D. from Columbia University. Oxley worked for several U.S. oil companies until 1971 when he joined Tenneco Oil Exploration and Production in Houston, Texas. Following his retirement from Tenneco in 1989 he joined the faculty at the University of Colorado in Boulder, Colorado. He is a Fellow of GSA, a Certified Petroleum Geologist, and belongs to AAPG and Sigma Xi. Oxley has been a frequent speaker on geology, exploration, and energy in the U.S. and Europe.

Brian J. Skinner is a professor at Yale University where he works on the geochemistry of mineral deposits. He is editor of Economic Geology, chairman of the Board of Overseers of the American Journal of Science, chairman of the U.S. National Committee on Geology, and of the Board on Earth Sciences and Resources (NAS/NRC). A Fellow of the Society, he was President in 1985 and chairman of the Committee on the Path to 2000.

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The Foundation's annual reception for Senior Fellows.

This popular GSA annual meeting event was well-attended in Dallas. Each year the Foundation hosts a party that immediately follows the Board of Trustees meeting, for GSA's Senior Fellows, the Foundation's major contributors, and GSA Council. The affair provides a unique opportunity for GSA's longest-standing members to remember the past, discuss the present, and look toward the Society's future.

Bob Coleman, Gary Ernst, John Crowell, E-an Zen, Larry Sloss

Priscilla Grew, Konnie Krauskopf

Tony Reso, Carel Otte

Dot Heroy, Konnie Krauskopf

Mrs. John Maxwell, John Maxwell, Bob Folinsbee

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FINANCIAL STATEMENTS

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Denver, Colorado 80202-5151
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Board of Trustees
The Geological Society of America
Foundation, Inc.
Boulder, Colorado

We have audited the accompanying combined balance sheets of The Geological Society of America Foundation, Inc. as of December 31, 1990 and the related combined statements of operations and fund balances and of cash flows for the year then ended. These financial statements are the responsibility of the Foundation's management. Our responsibility is to express an opinion on these financial statements based on our audit.

We conducted our audit in accordance with generally accepted auditing standards. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the combined financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audit provides a reasonable basis for our opinion.

In our opinion, such combined financial statements present fairly, in all material respects, the financial position of The Geological Society of America Foundation, Inc. as of December 31, 1990, and the results of its operations and its cash flows for the year then ended in conformity with generally accepted accounting principles.

We have previously audited the financial statements of the Foundation for the year ended December 31, 1989, and comparative financial information from which is presented herein. In our opinion, such comparative financial information (as adjusted) has been properly extracted from the prior year's financial statements.

Deloitte & Touche

March 25, 1991

COMBINED BALANCE SHEETS
(With comparative totals for 1989)

Assets	Operating	Unrestricted	Restricted	Totals December 31, 1990	Totals December 31, 1989 As Adjusted (Note 8)
Cash and cash equivalents	$ 3,654	$ 13,502	$ 98,770	$ 115,926	$ 101,558
Contributions receivable		1,147	4,506	5,653	29,014
Due from other funds	1,081			1,081	193
Investments, at market (Note 2)	928	182,412	1,124,236	1,307,576	823,289
DNAG publications inventory (Note 3)			807,900	807,900	878,352
Furniture and equipment, net of accumulated depreciation of $29,633 and $24,986	9,057			9,057	12,489
Other		140	496	636	
	$ 14,720	$ 197,201	$2,035,908	$2,247,829	$1,844,895
Liabilities and Fund Balance					
Accounts payable	$ 2,519		$ 137,140	$ 139,659	$ 25,099
Due to Geological Society of America (Note 4)			754,889	754,889	640,898
Due to other funds			1,081	1,081	193
Accrued vacation and sick leave					11,665
	2,519		893,110	895,629	677,855
Fund balances:					
Unrestricted	12,201	$ 197,201		209,402	29,404
Restricted			1,123,066	1,123,066	1,119,045
Held in trust for others (Note 5)			19,732	19,732	18,591
	12,201	197,201	1,142,798	1,352,200	1,167,040
See notes to combined financial statements.	$ 14,720	$ 197,201	$2,035,908	$2,247,829	$1,844,895

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FINANCIAL STATEMENTS *(continued)*

COMBINED STATEMENTS OF OPERATIONS AND FUND BALANCES

(With comparative totals for 1989)

	Operating	Unrestricted	Restricted	Totals Years Ended December 31, 1990	1989 As Adjusted (Note 8)
REVENUES:					
Contributions	$ 1,237	$ 27,985	$ 520,169	$ 549,391	$ 473,841
DNAG Program			384,831	384,831	264,798
Interest and dividends	172	14,711	57,591	72,474	67,667
Other	82,701		8,105	90,806	54,243
	84,110	42,696	970,696	1,097,502	860,549
EXPENDITURES:					
Operating expenses	144,894	773	3,245	148,912	141,274
DNAG Program			889,268	889,268	605,821
Distribution of assets held in trust					1,100
Grants - Geological Society of America Programs			70,587	70,587	67,779
	144,894	773	963,100	1,108,767	815,974
EXCESS (DEFICIENCY) OF REVENUES OVER EXPENDITURES	(60,784)	41,923	7,596	(11,265)	44,575
INVESTMENT ACTIVITY:					
Realized loss on investments	(125)	(26)		(151)	(6,250)
Net unrealized loss on investments (Note 2)	(23)	(997)	(2,404)	(3,424)	
TRANSFERS IN (OUT)	60,829	(60,799)	(30)		
EXCESS (DEFICIENCY) OF REVENUES OVER EXPENDITURES, including investment activity	(103)	(19,899)	5,162	(14,840)	38,325
FUND BALANCE (DEFICIT), beginning of year:					
As previously reported	(187,696)	217,100	259,284	288,688	354,317
Inventory adjustment (Note 8)			878,352	878,352	774,398
As restated	(187,696)	217,100	1,137,636	1,167,040	1,128,715
Cancellation of Geological Society of America advance (Note 4)	200,000			200,000	
FUND BALANCE, end of year	$ 12,201	$197,201	$1,142,798	$1,352,200	$1,167,040

See notes to combined financial statements.

COMBINED STATEMENTS OF CASH FLOWS

	Totals Years Ended December 31, 1990	1989 As Adjusted (Note 8)
CASH FLOWS FROM OPERATING ACTIVITIES:		
Excess (deficiency) of revenues over expenditures including investment activity	$ (14,840)	$ 38,325
Adjustments to reconcile excess (deficiency) of revenues over expenditures to net cash provided by operating activities:		
Depreciation	4,646	4,444
Changes in operating assets and liabilities:		
Contributions receivable	23,361	(6,069)
Due from other funds	(888)	34,997
Due to Geological Society of America	113,991	144,981
DNAG publications inventory	70,452	(103,954)
Accounts payable	114,560	18,245
Due to other funds	888	(34,997)
Accrued vacation and sick leave	(11,665)	11,665
Other assets	(636)	
Net cash provided by operating activities	299,869	107,637
CASH FLOWS FROM INVESTING ACTIVITIES:		
Additions to furniture and equipment	(1,214)	(1,248)
Purchase of investments	(720,418)	(1,739,192)
Proceeds from maturity of investments	236,131	1,581,798
Net cash used in investing activities	(485,501)	(158,642)
CASH FLOWS FROM FINANCING ACTIVITIES:		
Cancellation of Geological Society of America advance (Note 4)	200,000	
NET INCREASE (DECREASE) IN CASH AND CASH EQUIVALENTS	14,368	(51,005)
CASH AND CASH EQUIVALENTS, beginning of year	101,558	152,563
CASH AND CASH EQUIVALENTS, end of year	$ 115,926	$ 101,558

See notes to combined financial statements.

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Holly L. O. Huyck
Emilie Jager*
Charlotte K. Johnson
Marcia E. Knadle
Christina Lochman-Balk*
Lucy McCartan
Margaret O. Oros
J. R. Ouellette
Scott R. Paterson
Daniel B. Sass
Ruth A. M. Schmidt
Ruth D. Terzaghi
Paula Muir Watt
Karen L. Wetmore
Miriam A. Woods

*Second Century Club (gifts of $100 or more)

YOUNG SCIENTIST AWARD
Fred A. and Mavis Donath

GSA Foundation

NOTES TO COMBINED FINANCIAL STATEMENTS
YEAR ENDED DECEMBER 31, 1990
(With comparative totals for 1989)

1. SUMMARY OF SIGNIFICANT ACCOUNTING POLICIES

The Geological Society of America Foundation, Inc. (the Foundation) was established in December 1980 to promote the science of geology.

A primary objective of the Foundation is to provide funds for the Decade of North American Geology Program (the DNAG Program), which was established to publish a series of geological references in celebration of the 100-year anniversary of the Geological Society of America (the Society of GSA) in 1988.

The financial statements of the Foundation have been prepared on the accrual basis of accounting. The accounts of the Foundation are maintained in accordance with the principles of fund accounting which classify funds, for accounting and reporting purposes, according to the Foundation's activities or objectives.

Donor-restricted funds may be used only in accordance with purposes established by the donor, in contrast to use of unrestricted and operating funds. The Foundation board has full authority to use donated unrestricted funds for operational purposes.

The Foundation records investments at fair market value. The difference between cost and fair market value is reflected in the combined statements of operations and fund balances as unrealized appreciation or depreciation on investments.

The Foundation is exempt from federal income taxes pursuant to Section 501(c)(3) of the Internal Revenue Code of 11954, as amended.

Furniture and equipment are stated at cost. Depreciation is provided by the straight-line method over the estimated useful lives of various classes of assets.

In-kind contributions are recorded at fair value at date of gift.

The Foundation defines cash and cash equivalents as immediately accessible funds held in bank checking and savings accounts.

2. INVESTMENTS

Investments held at December 31, 1990 and 1989 are carried at fair market value and are summarized as follows:

	1990		1989	
	Cost	Market	Cost	Market
U.S. Treasury bonds	$ 59,794	$ 60,694		
U.S. Treasury bills	59,981	60,000	$192,699	$192,699
Short-term investments and demand notes	1,188,258	1,179,245	627,628	627,628
Stocks	170,000	6,562	170,000	2,813
Other	1,075	1,075	149	149
	$1,479,108	$1,307,576	$990,476	$823,289

3. DNAG PUBLICATIONS INVENTORY

The publications inventory of the DNAG Program has been recorded as a prior period adjustment (see Note 8). The inventory is stated at the lower of cost or market and consists of the following:

	1990	1989
Finished publications	$308,616	$320,909
Costs incurred for unfinished publications	499,284	557,443
	$807,900	$878,3522

4. DUE TO GEOLOGICAL SOCIETY OF AMERICA

The amount due to the Society in 1989 included a non-interest-bearing advance to the Foundation of $200,000 to enable it to begin operations. The advance was to be repaid from unrestricted funds of the Foundation as they became available. During 1990, the Society forgave the debt and the $200,000 has been reflected in the 1990 financial statements as an increase in operating fund balance.

Also due to the Society at December 31, 1990 is $754,889 for reimbursement of expenses incurred by the DNAG Program in excess of designated contributions received from the Foundation. The Foundation receives proceeds from the sale of DNAG publications, which are then applied to this amount due.

5. ASSETS HELD IN TRUST

The Foundation has an agreement with the Symposium of the Geology of Rocky Mountain Coal (the Symposium) whereby the Foundation will manage the assets of the Symposium. The Foundation receives a management fee equal to 1% per year of the market value of the funds. The agreement can be terminated by either party upon 90-day written notice.

6. PENSION PLAN

Employees of the Foundation participate in a discretionary pension plan covering substantially all employees. Contributions to the plan are made at the discretion of the Foundation's Board of Directors, and totaled $2,126 and $2,080 in the years ended December 31, 1990 and 1989, respectively.

7. RELATED PARTY TRANSACTION

The Foundation leases its office space from the Geological Society of America under a month-to-month agreement. Total rent expense paid in 1990 was $3,600.

8. PRIOR PERIOD ADJUSTMENT

Fund balance at December 31, 1989 has been restated from amounts previously reported to reflect a retroactive adjustment of $774,398 to record DNAG publications inventory as of January 1, 1989. In addition, revenues and expenditures in 1989 have been adjusted to reflect the gross sales and costs of sales related to the publications inventory. Costs had previously been expensed as incurred and certain revenues were netted against costs. This adjustment had the effect of decreasing the previously reported deficiency of revenues over expenditures by $103,954 for the year ended December 31, 1989.

1991 Annual Meeting
Field Trips and Symposia

San Diego GLOBAL PERSPECTIVE

October 21–24
San Diego, California

1991 Field Trips

All trips begin and end in San Diego unless otherwise noted. Further details will be given when registration begins in August 1991. Costs are preliminary estimates.

For further information contact the 1991 Field Trip Chairman, Michael J. Walawender, Dept. of Geological Sciences, San Diego State University, San Diego, CA 92182, (619) 594-6543, or the individual trip leaders.

Premeeting

Mesozoic and Cenozoic Geologic Evolution of the Mojave Desert Block and Environs. October 16–20. Roy K. Dokka, Dept. of Geology and Geophysics, Louisiana State University, Baton Rouge, LA 70803, (504) 388-2975; Darrell J. Henry; Christopher J. Travis; Timothy M. Ross; Michael M. McCurry; Carl Jacobsen; Michael O. Woodburne. Cost: $275.

High-Resolution Sequence Stratigraphy of Coal-Bearing Delta Complexes, Ferron Sandstone (Cretaceous), Western Interior, and Optional Geological Overflight over the Southwestern United States. October 17–19. Michael H. Gardner and Timothy A. Cross, Dept. of Geology and Geological Engineering, Colorado School of Mines, Golden, CO 80401, (303) 273-3278; John H. Shelton (overflight). Cost: $330. Optional overflight October 20. Cost: $700.

Miocene to Holocene Extensional Tectonics and Volcanic Stratigraphy, Northeast Baja California, Mexico. October 18–20. Joann M. Stock, Dept. of Earth Sciences, Harvard University, 20 Oxford St., Cambridge, MA 02138, (617) 495-8033; Arturo Martin Barajas; Francisco Suarez Vidal. Cost: $195.

Plate Tectonic History of the Central California Margin. October 18–20. Mark Cloos, Dept. of Geological Sciences, P.O. Box 7909, University of Texas, Austin, TX 78713-7909, (512) 471-4170; Eric James; Michael J. Apted. Cost: $250. Trip begins in San Francisco.

Upper Cretaceous Submarine-Fan Deposits, San Diego. October 19. Patrick L. Abbott, Dept. of Geological Sciences, San Diego State University, San Diego, CA 92182, (619) 594-5591; Tor Nilsen; John Warme. Cost: $45.

Geologic Hazards in San Diego. October 20. Patrick L. Abbott, Dept. of Geological Sciences, San Diego State University, San Diego, CA 92182, (619) 594-5591; William J. Elliott; Michael W. Hart. Cost: $60.

Igneous and Metamorphic Features of the Smartville Complex, Northern California. October 18 (evening)–20. Howard Day, Dept. of Geology, University of California, Davis, CA 95616, (916) 752-2882; Raymond Biersdorfer; James S. Beard; Eldridge M. Moores. Cost: $185. (With optional airfare from Sacramento to San Diego, $216.) Trip begins and ends in Sacramento.

Tectonic and Magmatic Evolution of the Central Death Valley Region. October 18–20. Lauren Wright, Dept. of Geosciences, Pennsylvania State University, University Park, PA 16802, (814) 238-2603; Ed DeWitt; Michael Ellis; Jim Otton; Ren Thompson; Bennie Troxel. Cost: $275. Trip begins in Las Vegas.

Gem-bearing Pegmatites of San Diego County. October 18–20. Eugene E. Foord, U.S. Geological Survey, Mail Stop 905, Federal Center, Denver, CO 80225-0046, (303) 844-4169; Anthony R. Kampf; David London; James E. Shigley. Cost: $245.

Lower Cambrian Depositional and Sequence Stratigraphic Framework of the Death Valley and Eastern Mojave Desert Regions. October 17–20. Anthony R. Prave, Dept. of Earth and Planetary Sciences, City College of New York, New York, NY 10031, (212) 650-6471; John Cooper; Chris Fedo. Cost: $260. (With optional airfare to San Diego, $309.) Trip begins and ends in Las Vegas.

Modern Eolian Processes of the Algodones Dune Field, California. October 19–20. Sponsored by the Sedimentary Geology Division. Michael Sweet, BP—Exploration, 5151 San Felipe, Houston, TX 77210, (713) 552-8604; Gary Kocurek; Karen Havholm. Cost: $190.

Active Folding and Reverse Faulting in the Western Transverse Ranges, Southern California. October 18–20. Edward Keller, Dept. of Geological Sciences, University of California, Santa Barbara, CA 93106, (805) 893-3471; Robert Yates; Tom Rockwell; Gary Huftile; Scott Lindvall; Robert West; Xiaolin Zhao; Racardo Zepeda. Cost: $230.

Mesozoic Evolution of Basement Terranes in the San Gabriel Mountains, Southern California. October 19–20. Andrew Barth, Dept. of Geology, Indiana/Purdue University, Indianapolis, IN 46202, (317) 274-1243; Daniel May; Carl Jacobsen. Cost: $150.

Quaternary Geomorphology and Geochronology of Owens Valley, California. October 17 (evening)–20. Alan Gillespie, Dept. of Geology, University of Washington, Seattle, WA 98195, (206) 543-2079; Paul Bierman; Doug Clark; Kelin Whipple. Cost: $255. Trip begins in Reno.

Active Faulting and Volcanism in the Trans-Mexican Volcanic Belt. October 16 (evening)–20 (morning). Max Suter, Institute of Geology, National University of Mexico, Apartado 70-296, Mexico DF 094510, (905) 548-87-47; G. Aquirre; C. Siebe. Cost: $220. (With optional airfare from Mexico City to San Diego, $440.) Trip begins and ends in Mexico City.

Ground-water Basins Along the Eastern Sierra Nevada: Tectonics, Water, and Politics. October 18–20. Wesley R. Danskin, U.S. Geological Survey, WRD, 5735 Kearney Villa Road, Suite O, San Diego, CA 92123, (619) 557-6700; Christopher D. Farrar; Shirley J. Dreiss. Cost: $225. Trip begins in Reno.

Archaeological Geology of the Point Conception–Vandenberg Areas, California. October 18 (evening)–20. Sponsored by the Archaeological Geology Division. Donald Johnson, Dept. of Geography, University of Illinois, Urbana, IL 61801, (217) 333-0589; Michael Glassow. Cost: $205. Trip begins in Santa Barbara.

Half-day Mini Trips
(held during the meeting)

Geology of San Diego. October 22 or October 23. Faculty and staff, Dept. of Geological Sciences, San Diego State University, San Diego, CA 92182, (619) 594-5586. Cost: $10.

The Downtown San Diego Blob. October 23 (morning). David Huntley, Dept. of Geological Sciences, San Diego State University, San Diego, CA 92182, (619) 594-5483; Robert Hawk; Gary Pischke; Barry Pulver. Cost: $10.

Postmeeting

Remote Sensing and Planetology at JPL. October 25. Ronald G. Blom, Radar Sciences Group, Jet Propulsion Laboratory, Mail Stop 300-233, 4800 Oak Grove Dr., Pasadena, CA 91109, (818) 354-4681. Cost: $25.

The Catalina Schist: Metamorphic and Fluid-flow Processes in a Paleo-Subduction Zone. October 25–27. Sorena S. Sorenson, Dept. of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, DC 20560, (202) 357-4010; Gary E. Bebout; Mark D. Barton, Cost: $320.

Geological Overflight of Southern California. October 25. John P. Ford, Radar Sciences Group, Jet Propulsion Laboratory, Mail Stop 300-233, 4800 Oak Grove Dr., Pasadena, CA 91109, (818) 354-6735; Roy K. Dokka; Ronald Blom. Cost: $450.

A Petrologic and Structural Transect Across the Peninsular Ranges Batholith, Southern California. October 25–27. Michael J. Walawender, Dept. of Geological Sciences, San Diego State University, San Diego, CA 92182, (619) 594-6543; Gary M. Girty; Marc Lombardi. Cost: $275.

Zoned Plutons of the Eastern Peninsular Ranges, Baja California Norte. October 25–26 or October 25–29. R. Gordon Gastil, Dept. of Geological Sciences, San Diego State University, San Diego, CA 92182, (619) 594-6443; Joan Calhoun; Susan Gunn. Cost: $170 (2 days only) or $370 (all 5 days).

Mesozoic Geology of Cedros Island, Baja California, Mexico. October 25–28. David L. Kimbrough, Dept. of Geological Sciences, San Diego State University, San Diego, CA 92182, (619) 594-1385; Cathy Busby-Spera; Douglas Smith; Richard Sedlock. Cost: $535 (airfare included).

Eocene Depositional Systems in San Diego. October 25–26. Sponsored by the Sedimentary Geology Division. Patrick L. Abbott, Dept. of Geological Sciences, San Diego State University, San Diego, CA 92182, (619) 594-5591; Jeff May; John Warme; Martin Link. Cost: $135.

Landslides in the Peninsular Ranges, Southern California. October 25–26. Michael W. Hart, Geocon Inc., 6960 Flanders Dr., San Diego, CA 92121, (619) 558-6900. Cost: $135.

Geologic Structure, Transpression, and Neotectonics of the San Andreas Fault in the Salton Trough, California. October 25–27. Arthur Sylvester, Dept. of Geological Sciences, University of California, Santa Barbara, CA 93106, (805) 893-3156; Michael Rymer. Cost: $240.

Late Cenozoic Sedimentation and Tectonics Along the Western Margin of the Salton Trough, California. October 25–27. Dennis Kerr, Bureau of Economic Geology, University of Texas, University Station, Box X, Austin, TX 78713-7508, (512) 471-1534; Charles Winker; Susan Kidwell. Cost: $275.

A Hydrogeologic Overview of the Regional Ground-water Flow System in Relation to Yucca Mountain, Nevada. October 25–27. Devin Galloway, U.S. Geological Survey, 2800 Cottage Way, Room W-2234, Federal Building, Sacramento, CA 95825, (916) 978-4648; Elisabeth Ervin; Michael Chornack; Alan Riggs. Cost: $180. (With optional airfare from Las Vegas to San Diego, $264.) Trip begins and ends in Las Vegas.

Low-angle Detachment Faulting and Rapid Uplift of Mid-Crustal Mylonitic Rocks in the Whipple Mountain Metamorphic Core Complex. October 25–27. Gregory A. Davis, Dept. of Geological Sciences, University of Southern California, University Park, CA 90089-0740, (213) 743-6126; Lawford Anderson. Cost: $250.

SEG-Sponsored Field Trips

Industrial Mineral Deposits of the Mojave Desert. October 18–19. Thomas P. Anderson, California Division of Mines and Geology, 107 S. Broadway, Suite 1065, Los Angeles, CA 90012, (213) 620-3560. Cost: $200.

Active and Fossil Rhyolite-hosted Epithermal Systems. October 18–19. Alan E. Williams, Dept. of Earth Sciences, University of California, Riverside, CA 92521, (714) 787-4611; Wilfred A. Elders. Cost: $200.

Active and Fossil Hydrothermal Mineralization in the Salton Trough Rift. October 25–26. Michael A. McKibben, Dept. of Earth Sciences, University of California, Riverside, CA 92521, (714) 787-3444. Cost: $200.

1991 Symposia

Invited Papers (Symposia)

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

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

This symposium focuses on the effects that geologic processes have had on the preservation of evidence for human activity during the period from 8 to 3 ka in North America. This period witnessed dramatic environmental changes whose impacts on biotic, geomorphological, and cultural systems varied across the continent. The biotic and geomorphic response to climatic change during this period, as deduced from the stratigraphic record, is our best analog for a global warming scenario. The symposium will point to similarities in the processes shaping

Symposia *continued on p. 134*

Symposia *continued from p. 133*

the archaeological record from this period, as well as differences that may be particular to certain regions. This information will provide a sound stratigraphic basis for understanding North American prehistory.

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

This symposium will focus on natural gas produced from coal seams (coalbed methane), which is one of the most active natural gas plays in the United States. In the past five years, more than 2500 coalbed methane wells have been drilled in basins throughout the country. Drilling activity has been greatest in the Black Warrior and San Juan basins. Generally, coalbed gas is pipeline-quality methane. However, reservoir characteristics of coal beds differ markedly from conventional gas reservoirs. Therefore, success of the coalbed methane industry requires new technology that must be developed through cooperative studies among geologists, hydrologists, and engineers. More than 400 trillion cubic feet of methane is estimated to be present in coal beds in the United States; the percentage of this resource that is economically recoverable (reserves) is uncertain, but given the magnitude of the resource, significant quantities of clean-burning natural gas are available to help meet the energy needs.

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

The purpose of this symposium is to examine various techniques and methodologies of assessing risk to human health and welfare from several geologic hazards and to consider how the evaluation of risk can be transmitted to the general public in a meaningful and useful way. Speakers will address geologic factors associated with diverse geologic risks such as ground-water contamination from point sources and nonpoint sources, earthquakes in the eastern United States, landslides, and coastal erosion. An insurance-industry perspective of risk management associated with geologic hazards will be presented. It is anticipated that the papers and discussions will render improved and new perspectives of how risk from geologic hazards can be evaluated scientifically and efficiently and how the evaluations may best be presented to the general public.

S4. **Hydrogeologic Significance of Depositional Sequences and Cyclic Processes.** Hydrogeology Division. Mark W. Evans, Emory University; Robert L. Laney, USGS, Reston, Virginia.

This symposium will address the evolution of aquifers in relation to the cyclic processes that control depositional sequences. The significance of these processes in regard to aquifer development includes: (1) deposition of stacked, lithologically heterogeneous sequences that control primary porosity, (2) sea-level–controlled diagenetic events that may increase or decrease porosity and permeability, (3) lateral variations in porosity and permeability, and (4) climatically induced changes in ground-water flow systems. Unconformity-bounded depositional sequences are providing a strong conceptual framework for regional stratigraphic correlations and for integrating depositional processes with the stratigraphic record. This symposium will examine the linkage between depositional processes and ground-water systems and promote the interaction of hydrogeologists, sedimentologists, and stratigraphers.

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

The main focus of this symposium is to highlight the upcoming 29th International Geological Congress to be hosted by Japan in 1992; the symposium is in keeping with the theme of the 1991 GSA Annual Meeting, Global Perspective. The symposium will feature three talks on the tectonics, metallurgy, and earthquakes and volcanism of the Japanese archipelago, to emphasize and set the stage for the 29th IGC. This will be followed by a talk on the seismological history of the entire Pacific plate, then a talk on the Aleutian arc, followed by a discussion of the accreted terranes of the southern Andes. The final talk will emphasize the behavior of arc systems in the western Pacific region. Interest in the circum-Pacific region has been growing rapidly in the past few years. The symposium should have broad interest to a large number of geologists and, because of the increased focus on the region from a geological standpoint, should be of considerable interest to the general public.

S6. **Quaternary Climatic Change in Arid and Semiarid Western North America: Evidence from the Great Basin, Desert Southwest, and Great Plains.** Quaternary Geology and Geomorphology Division. Richard F. Madole and Daniel R. Muhs, USGS, Denver, Colorado.

The arid and semiarid parts of western North America are among some of the most climatically sensitive regions on the continent. A better understanding of how climate has varied in these drought-prone regions during Quaternary time is important to prediction of future climatic change and the potential effects of global warming. Accordingly, this symposium focuses on (1) the history of climatic change; (2) the responses of geologic, hydrologic, and biologic systems to climatic change; and (3) the differences and similarities in climatic controls and effects in the Great Basin, desert Southwest, and Great Plains. The time intervals emphasized will vary by region, but much of the attention will focus on the record of change for Holocene time (10–0 ka) and late Pleistocene time (30–10 ka).

S7. **Fluvial Response to Base-level Changes: Eustatics vs. Tectonics—Part I.** Sedimentary Geology Division. Paul L. Heller, University of Wyoming; Christopher Paola, University of Minnesota, Minneapolis; Henry Posamentier, ESSO Resources Canada, Calgary, Alberta.

The response of alluvial systems to changes in base level, whether caused by tectonic and/or eustatic events, has far-reaching implications for stratigraphic and geomorphic problems. The types and magnitude of fluvial response affect stratal geometry, unconformity development, alluvial architecture, and the generation of sequence-bounding surfaces. Understanding the development of these features is a key part of interpreting aspects of sequence stratigraphy and may be used in discriminating between tectonic and eustatic causes. This symposium, along with the associated theme session, focuses on the geometry, dynamics, and time and length scales over which fluvial systems adjust to base-level changes, how effects due to base level can be discriminated from other influences, such as changes in water and sediment supply, and how these changes are preserved in the statigraphic record.

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

The geophysical half of the symposium is concerned with the physical processes of strike-slip faulting (dynamics of the lithosphere and asthenosphere). Topics to be discussed include the role of strike-slip faulting in global plate motions, kinematic models and conventional and space-based geodetic measurements of strike-slip deformation, stress and strain partitioning near strike-slip faults, the physics of strike-slip rupture events, and lithospheric and asthenospheric controls on strike-slip faulting. The importance to geology is to provide a deep lithospheric and asthenospheric perspective on strike-slip faulting and provide a physical framework for structural and tectonic observations of strike-slip faults. The general public should find the constraints on current deformation and large rupture events on strike-slip faults of interest, particularly where they affect large population centers such as in California.

The geological half of the symposium is aimed at an audience interested in hearing the answers to exciting and perplexing problems regarding strike-slip faulting. The symposium will focus on how strike-slip faults extend to depth, whether they remain steep to depth or flatten; whether overstepping faults converge at depth beneath fault blocks or are vertical boundaries of fault blocks; how and why basins along strike-slip faults subside so rapidly; how they are deformed in strike slip subsequent to their formation. These are important scientific topics, because strike-slip faults were previously thought to be vertical throughout their extent, but accumulating geologic, geophysical, and seismological information leads us to believe that this is not necessarily so. Definitive answers to these questions are especially important to the petroleum industry that explores accumulations of sedimentary rocks in these basins. They are also important to seismologists who seek to understand how earthquakes work on faults in general, and on strike-slip faults in particular.

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

This symposium will focus on the dramatic changes in climate that occurred from the late Paleocene through the early Eocene. A large warming near the Paleocene/Eocene boundary resulted in the warmest global conditions of the Cenozoic, perhaps reflecting a time of increased CO_2 levels. This early Eocene greenhouse world provides an opportunity to evaluate operation of the ocean-atmosphere system under significantly warmer conditions than today. The warming was accompanied by large changes in the carbon budget and in the deep water system. Cooling began near the end of the early Eocene, leading toward development of the Oligocene-Holocene icehouse world. We will assemble isotope paleoceanographers, micropaleontologists, sedimentologists, and climate and ocean modelers to address the scientific challenges of this important climate transition.

S10. **MASHing and Smashing: Geochemical Evidence for Long-term Crust-mantle Interaction Along a Cratonic Margin, Northwest U.S.** Geochemical Society. Paul A. Mueller, University of Florida; Joseph L. Wooden, USGS, Menlo Park, California.

Secondary isotopic systematics such as Pb-Pb isochrons and Sm-Nd model ages of young rocks have been used extensively to improve our understanding of Precambrian continental growth and the geochemical evolution of the crust-mantle system in western North America. For mantle-derived rocks, secondary Pb isochrons have been used to identify the influence of Archean subcontinental lithosphere in the petrogenesis of Cenozoic basalts. For crustally derived rocks, Sm-Nd isotopic systematics of Mesozoic and Cenozoic granitoids indicate generally more negative epsilon values with proximity to the Archean Wyoming craton. This symposium will provide a forum for discussing the various lines of geochemical evidence that bear on the Archean through Cenozoic history of crust-mantle interaction and crustal growth in the region proximal to the western edge of the Wyoming craton. Contributions will focus on a variety of rocks ranging from mantle xenoliths to Cenozoic basalts and granitoids.

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

The geoscience community is turning its focus toward a "global perspective," recognizing the worldwide occurrence of processes and phenomena, as well as international cooperation in research and problem-solving in the areas of environment, geology, geophysics, and other geoscience-related aspects of our world. The geoscience information community must be ready to support this international research and global cooperation in the various fields of geoscience.

It is appropriate, therefore, that the Geoscience Information Society, in support of its goal to facilitate the exchange of geoscience information, provide a forum to discuss two main concepts: (1) what opportunities are available to support the global information needs of geoscientists in their worldwide research efforts, and, (2) what opportunities exist for sharing geoscience information and its management techniques with those in less developed countries, to help promote and support their participation in this global effort.

The public is aware of the ongoing global cooperative efforts in the geosciences. They learn about damaging earthquakes, global warming, holes in the ozone layer, and volcanic eruptions that deposit ash over miles. The cooperative efforts to be discussed give insights into how geoscientists can be well-informed problem solvers as researchers on an international level, how we can help foreign colleagues in their efforts to do the same, and how we can support the international dis-

semination of geoscience data and publication. Specific examples include options for transferring unwanted or duplicate technical publications to someone who will find them valuable and discussion of issues involved in the transfer of technical information across political boundaries.

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

This symposium is designed to complement the MSA-sponsored short course offered by Derrill Kerrick prior to the Annual Meeting. The symposium will emphasize any and all physical and chemical effects on country rocks due to heat and fluids introduced into the crust by magmas. Abstracts are solicited from individuals working on any aspect of the general theme including, but not limited to: geochemistry, petrology, stable and radiogenic isotope studies, thermal models, and associated ore deposits. To be included in this symposium, submit an abstract on the GSA Abstracts Form to M. L. Crawford, Dept. of Geology, Bryn Mawr College, Bryn Mawr, PA 19010, *not later than June 15*.
Note: this deadline is prior to the GSA deadline, and it will be strictly enforced.

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

This symposium will address the rationale and techniques for new approaches to introductory geology courses. In this age of science anxiety, what can an instructor expect and what are some successful approaches to the first and perhaps only science courses many students will take? Some speakers will address new approaches to traditional physical and historical geology courses. Others will suggest alternatives to those courses. Topics will include: (1) the use of critical thinking, (2) structuring and responding to writing assignments, (3) theme courses (earthquakes, dinosaurs, etc.), (4) the use of computers and off-the-shelf software to encourage analytical thinking, and (5) the logistics of large introductory courses. Ample time will be scheduled for discussion after each paper. The symposium should be of interest to anyone who teaches or has a stake in introductory geology courses. Anyone interested in the teaching of science, and particularly geology, at the introductory level might be interested.

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

New ideas on extinction mechanisms have helped to foster a plethora of studies on patterns of biotic turnover. Most of these studies utilize supra-specific taxa and employ fairly simple counts of appearances and disappearances as indicative of turnover patterns. Some individuals interested in this topic have become concerned that an important aspect of these sorts of studies may be absent—the phylogenetic component. For example, Norrell has argued that the first appearance of particular taxa in the fossil record commonly represents the appearance of traits affording the recognition of that clade, whereas the actual first appearance of the clade might be much older. Patterson, Smith, and others have argued that the apparent extinction of taxa in some studies probably represents the loss of paraphyletic taxa rather than true extinction. Archibald has noted that the apparent extinction of some species may be the result of pseudoextinction caused by speciation events. In each of these instances phylogenetic (i.e., cladistic) hypotheses have permitted these reassessments of biotic turnover.

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

As the need for resources to support our way of life increases, the number of obvious ore deposits decreases, and the quest for an improved picture of how and when orebodies formed becomes more critical. Developing proper genetic models to frame exploration programs may benefit greatly from experimental and orebody studies that investigate the questions of material sources, metal transport, metal precipitation, and timing of mineralization on a scale actually approaching the one on which ore minerals form. The purpose of this symposium is to familiarize economic geologists with the latest in microanalytical technology and its application to solving such highly relevant problems. The topics covered represent frontier research and will benefit economic geologists as well as those with interests ranging from possible applications in stratigraphy to materials science.

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

Large-scale crustal processes are recognized as having significantly influenced the generation of many of the world's valuable mineral deposits, and a full understanding of crustal-scale processes is critical in our search for new deposits of nonrenewable resources. This symposium will review principles and case studies of crustal-scale processes, their importance in the genesis of mineral deposits, and variations in their styles throughout Earth's geologic history. The symposium is divided into four sections, covering tectonic and structural controls, regional metallogeny and ore deposits, regional isotopic patterns related to mineralized processes, and fluid-flow associated with mineralization. The large-scale theme of this symposium complements that of the other SEG symposium, which will focus on micro-scale studies of mineralizing processes.

S17. **Survivability of Organic Matter at High Temperature: Implications for Life.** Organic Geochemistry Division of the Geochemical Society. Stephen A. Macko, University of Virginia; Everett L. Shock, Washington University; Michael H. Engel, University of Oklahoma.

This symposium will emphasize the wide array of perspectives on the survival of organic matter at high temperatures and how this may influence our views on the geologic record of organic matter and on the origin of life—how and where it started, and what kinds of materials may have been involved. Views resulting from field observations, laboratory experiments, and theoretical approaches will be expressed. We intend to explore the role of thermophilic bacteria in geologic processes while evaluating the possible limits of life in hydrothermal biogeochemistry. Issues to be raised include: temperature and pressure limits of fossil-fuel deposits during deep burial, alteration of organic fossil materials, and synthesis and delivery of organic matter to early Earth. We are encouraging speakers to incorporate introductory material in all talks, to appeal to non specialist educators as well as students. Our hope is that much of the information presented will be used in courses involving perspectives on earth sciences.

S18. **Canceled**

S19. **Continental Drift, Plate Tectonics, and Biogeography: The History of a Synthesis of Two Cultures.** History of Geology Division. Alan E. Leviton, California Academy of Sciences, San Francisco; Michele L. Aldrich, American Association for the Advancement of Science, Washington, D.C.

In the 1959 symposium, The Problem of Land Connections Across the South Atlantic ..., in which the notion of continental drift was rejected, the conveners took pains to observe, "The evolution of faunas and floras is one of the great problems in the field of evolution. It is not a problem that the biologist alone can solve; he needs the assistance of the geologist, because the history of faunas is intimately connected with the history of the continents." For at least 150 years, geological conjectures about Earth history have profoundly influenced evolutionary biologists and biogeographers. From the earliest notions of Gondwanaland by Geological Survey of India geologists in the 1860s, to Suess's global vision of Earth history, especially the themes of Tethys and Gondwanaland, to the rejection of continental drift by the AAPG colloquium of 1928, followed by postulates of isthmian links by Willis, Schuchert, and others (and institutionalized by Simpson and Darlington, at least in North America), and the daring hypotheses of sea-floor spreading by Vine and Matthews and by Morley and of plate tectonics by Morgan and McKenzie, to the proposition of vicariance biogeography, introduced to a reluctant audience by the maverick biogeographer-geologist-biologist Leon Croizat, and finally, the novelty of accretionary terranes, progress in historical geology and evolutionary biology have been intimately linked. This symposium will look at the way geologists and their changing views of Earth history lead to major restructuring of paradigms in biogeography, how puzzles in biogeography tease geologists to explore new explanations for paradoxes in another discipline, and how in the history of science, convention, conformity and "authority" often suppress open-minded discussion and frustrate expression of unconventional views.

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

The Magellan spacecraft has completed its first orbital tour of Venus, obtaining high-resolution radar images of most of the planet. Many new discoveries have resulted from this first close-up view, and hypotheses about the evolution of Venus are now being formed. Because Venus is Earth's sister planet, having similar size and density, the new discoveries will give food for thought in assessing the evolution of Earth. The symposium will provide a stimulating review of terrestrial processes and should be of wide interest to all who want to learn how the investigation of other planets reflects on the understanding of Earth.

The symposium will highlight internal and external processes that may have shaped the two planets. More specifically, a discussion of the internal evolution of large terrestrial planets in general will be followed by a global overview of the structural patterns on Earth, which are dominated by plate tectonics. We will then look at Venus, where the lithosphere is thinner, hotter, and drier, and tectonic patterns take on different forms. We will discuss the type of volcanism one might theoretically expect on large planetary bodies, then give an overview of the style of volcanism and of volcanic features seen on Earth, and conclude with an analysis of volcanic features seen on Venus. Such features include small cones, shield volcanoes, gigantic central-vent volcanoes, large circular volcano-tectonic structures, and flood lavas.

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

This symposium will present a timely integration of results from diverse geophysical techniques and geology that have enhanced our current understanding of the southwestern Cordillera. Active researchers representing seismo-tectonics; potential methods; seismology including earthquakes, tomography, and reflection profiling; thermal methods; satellite geodesy; paleomagnetics; and electrical soundings will take part. All presentations will focus on how their findings relate to the past and present tectonics of the southwestern Cordillera. Therefore, the results will provide new insights and constraints for geologists interested in the Cordillera. Some talks will address the seismic hazard in the North American Southwest, a concern of importance to the general public.

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

This symposium focuses on the preserved stratigraphic record of depositional, climatic, and tectonic processes during the accretion, zenith, and break-up of the supercontinent Pangea. Pangea forced an icehouse-disposed environment that influenced climatic change, yet during Pangea's existence (Early Pennsylvanian through late Early Jurassic time), the stratigraphic record showed evidence of major tectonic, climatic, and facies variability. The nature, rate and magnitude of variability of depositional processes in Pangea's stratigraphic record will be evaluated so as to provide a potential predictive baseline for estimating rates and variability of ancient and modern global change. This symposium will contribute to understanding the geology of global change and establishing ways and means to determine the quantitative variables and limits of that change. Analysis of past global changes should be of interest to those concerned about global warming and its environmental consequences. This symposium is part of the second initiative of the Global Sedimentary Geology Program dealing with processes and events during the history of Pangea. ■

MEETINGS

■ Indicates new or changed information

1991

June

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

July

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

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

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

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

August

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

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

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

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

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

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

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

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

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

September

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

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

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

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

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

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

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

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

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

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

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

■ **Hydrocarbon Contaminated Soils: Analysis, Fate, Environmental & Public Health Effects, and Remediation, Sixth National Conference**, September 23–26, 1991, Amherst, Massachusetts. Information: Paul T. Kostecki, Division of Public Health, University of Massachusetts, Amherst, MA 01003; or Linda S. Rosen, Morrill Health Program, University of Massachusetts, Amherst, MA 01003-0081; (413) 545-2934.

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

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

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

■ **56th Annual Field Conference of Pennsylvania Geologists: The Geology of South Mountain**, September 26–28, 1991, Carlisle, Pennsylvania. Information: Field Conference of PA Geologists, P.O. Box 1124, Harrisburg, PA 17108-1124; (717) 787-2169.

New England Intercollegiate Geological Field Conference, September 28–30, 1991, Princeton, Maine. Information: Allan Ludman, Department of Geology, Queens College, 65-30 Kissena Blvd., Flushing, NY 11367-0904.

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

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

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

October

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

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

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

■ **Association of Engineering Geologists Annual Meeting**, October 6–11, 1991, Chicago, Illinois. Information: Theodore Maynard, Bur. Engr. Dept., 320 N. Clark Street, Rm. 700, Chicago, IL 60610; (312) 744-3530.

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

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

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

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

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

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

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

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

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

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

November

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

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

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

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

■ **Eastern Oil Shale Symposium**, November 13–15, 1991, Lexington, Kentucky. Information: Geaunita H. Caylor, University of Kentucky/OISTL, 411 Breckinridge Hall, Lexington, KY 40506-0056; (606) 257-2820; fax 606-258-1049.

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

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

December

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

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

1991 Penrose Conference

October

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

1992

February

■ **6th International Symposium on Landslides**, February 10–14, 1992, Christchurch, New Zealand. Information: ISL 1992 Secretariat, c/o Guthreys Pacific Ltd., P.O. Box 22-255, Christchurch, New Zealand; fax 643-790-175; telex NZ4243 Guthreys.

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

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

March

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

April

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

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

May

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

■ **The Euramerican Coal Province: Controls on Tropical Peat Accumulation in the Late Paleozoic**, May 24–27, 1992, Wolfville, Nova Scotia, Canada. Information: John H. Calder, Nova Scotia Dept. of Mines and Energy, P.O. Box 1087, Halifax, Nova Scotia B3J 2X1, Canada; (902) 424-5364, fax 902-424-0528; or Martin R. Gibling, Dept. of Geology, Dalhousie University, Halifax, Nova Scotia B3H 3J5, Canada; (902) 494-2355.

■ **Geological Association of Canada/Mineralogical Association of Canada Joint Annual Meeting**, May 25–27, 1992, Wolfville, Nova Scotia, Canada. Information: Aubrey Fricker, General Secretary, Atlantic Geoscience Centre, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia B2Y 4A2, Canada; (902) 426-6759; fax 902-426-4465.

June

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

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

July

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

August

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

September

■ **5th International Symposium on Seismic Reflection Profiling of the Continental Lithosphere**, September 6–12, 1992, Banff, Alberta, Canada. Information: R. M. Clowes, Lithoprobe Secretariat, 6339 Stores Road, University of British Columbia, Vancouver, BC V6T 1Z4, Canada; (604) 822-4202; fax 604-822-6958; or A. G. Green, Geological Survey of Canada, 1 Observatory Crescent, Ottawa, Ontario K1A 0Y3; fax 613-992-8836.

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

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

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

October

■ **Association of Engineering Geologists Annual Meeting**, October 3–9, 1992, Long Beach, California. Information: John Byer, Kovacs-Byer, Inc., 11430 Ventura Blvd., Studio City, CA 91604; (818) 980-0825.

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

1992 Penrose Conference

March

■ **Continental Tectonics and Magmatism of the Jurassic North American Cordillera**, late March 1992, Twentynine Palms, California. Information: David M. Miller, U.S. Geological Survey, 345 Middlefield Road, MS-975, Menlo Park, CA 94025, (415) 329-4923; or Richard M. Tosdal (same address), (415) 329-5423.

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

GSA *BULLETIN* and *GEOLOGY* Contents

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Forum

GSA ANNUAL MEETINGS

■ 1991

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

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

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

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

■ 1992

GSA Annual Meeting, Cincinnati, Ohio
October 26–29

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

■ FUTURE

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

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

GSA SECTION MEETINGS

■ 1992

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

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

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

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

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

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

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

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

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

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

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

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

CLASSIFIED ADVERTISING

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Opportunities for Students

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

DNAG NEWS

Allison R. (Pete) Palmer

Still More Kudos

Things are moving foreward at a reasonably good clip as DNAG winds down to the last few pieces. *The Quaternary Non-glacial Geology of the Conterminous U.S.* is now in final production and we can acknowledge all of those patient authors whose texts will finally see the light of day. All of those whose chapters are more than 1½ years old have been given the opportunity (through their senior authors) to provide Notes Added in Proof to bring up any important items that have transpired since their manuscripts went into the mill. The 101 authors listed here bring to 1792 the total number of contributors to completed DNAG volumes. These and all earlier authors have provided the quality input that has made the DNAG set widely acclaimed.

One more chapter has been received for the Gulf of Mexico volume (two to go), for the Neotectonics volume (one to go); and for the volume on the Cordilleran Orogen, U.S. (two to go). The Alaska, Precambrian, and Transect volume editors haven't moved anything in this direction for a couple of months.

By June you or your library should have received *The Heritage of Engineering Geology, Economic Geology of Mexico,* Transect A-3 (*Gulf of Alaska to the Canada Basin*), Transect E-4 (*Eastern Kentucky to the Carolina Trough*), and *Comparative Tectonic Sections of North America,* and three more major products are in the pipeline. ■

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