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GSA TODAY

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Seismic Images of the Core-Mantle Boundary

Michael E. Wysession, Department of Earth and Planetary Sciences, Washington University, St. Louis, MO 63130

ABSTRACT

Seismology presents several ways of providing images of the geologic structures that exist in the lowermost mantle just above the core-mantle boundary (CMB). An understanding of the possibly complex geophysical processes occurring at this major discontinuity requires the combined efforts of many fields, but it is the role of seismology to geographically map out this largely uncharted territory. Seismic phases that reflect, diffract, and refract across the CMB can all be used to provide different information in different ways. Profiles of core-diffracted and core-reflected waves are especially powerful when used as differential traveltimes in relation to direct phases. The resulting seismic maps show long-wavelength lateral heterogeneity in the lowermost few hundred kilometers of the mantle (a region called D″) with a magnitude of at least 6%, which is comparable only to Earth's upper few hundred kilometers. The maps of lateral seismic variations show significant continent-sized features that are most likely a result of the convective dynamics occurring at the base of the mantle. The geophysics of the CMB and lowermost mantle probably has many analogies with that of Earth's lithosphere and crust, and variations in the structure of D″ may likewise be a combined result of thermal, chemical, and mineral phase variations. Interpretations of the seismic images, requiring knowledge of the mineral physics of expected mineralogical assemblages at these depths, suggest that the CMB plays a very important role in controlling the dynamics of the core and lower mantle, and therefore of the evolution of the interior of Earth.

INTRODUCTION

While most geologists, including specialists in the field of seismology, study rocks at Earth's surface, more attention also is being paid to the planet's other major boundary, that between the core and mantle. With a density jump of 4.3 kg/m^3 between the silicate lower mantle and the liquid iron outer core, as well as a temperature increase of possibly 1500 °C between the lower mantle adiabat and outer core, the core-mantle boundary (CMB) may well be Earth's most significant and dramatic discontinuity. Our increasing knowledge of this highly variable and heterogeneous region has come though the combined efforts of geoscientists in a wide array of fields, and an important part of this effort has been the use of seismology to map out the structures that exist there. Because of the limitations of imaging a surface nearly 3000 km beneath us through a heterogeneous mantle, our images lack clear resolution. In a sense we are like the seafaring explorers of 500 years ago who had mapped out the outlines of the world's continents but still knew little of what lay within them. In this article I discuss a few attempts to get clearer maps of the "continents" at the CMB, speculate about what these maps may mean, and describe some of the directions that may be taken to develop a sharper image.

The red-and-blue seismic maps that we produce, which represent the velocities with which P and S waves propagate through a given region, do not mean very much by themselves. However, these two velocities are a function of density, rigidity, and incompressibility, which are complicated functions of temperature, composition, and mineralogical phase. Hope for better understanding exists because different disciplines complement each other in providing constraints about the state of the deep Earth. Long wavelength signals in the geoid are affected by mass variations in the lowermost mantle. Variations in the wobble of Earth's axis of rotation and in the length of days are also a result of mass variations and provide constraints on the topography of the CMB. Effects of CMB topography and the thermal variations of the lowermost mantle create observable variations in the geomagnetic field by affecting core flow. Geodynamic modeling, both experimental and numerical, is providing realistic time histories of the patterns of convection that might occur in the lower mantle. Mineral physicists, through both high-pressure diamond anvil experiments and theoretical equations of state, are delineating the kinds of materials we might expect to occur at these great pressures and temperatures. The stories emerging about the CMB are quite exciting, involving rising hot plumes, sinking cold mantle, laterally swept mantle dregs, core-mantle chemical reactions, and core-mantle dynamic coupling, but because they are compatible with evidence across many independent disciplines, they are not quite as speculative as they may seem.

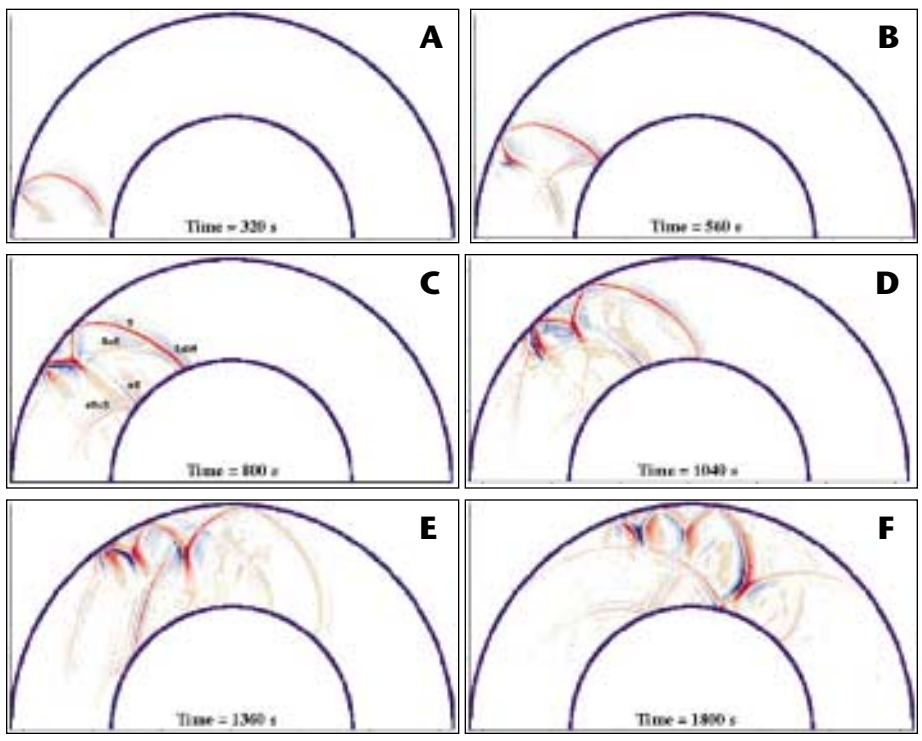

Figure 1. Images from a motion picture showing the propagation of seismic shear energy through the mantle (Wysession and Shore, 1994). The images correctly show the locations of the seismic shear wave fronts at (A) 320, (B) 540, (C) 800, (D) 1040, (E) 1360, and (F) 1800 s after the occurrence of a 600-km-deep earthquake at the lower left of the images. Red is out of the page; blue into the page. Amplitudes are normalized and raised to a power of 0.8 to enhance smaller features. Images were made by interpolating between a grid of 72,846 synthetic seismograms calculated by the superposition of all torsional normal modes (28,585) with periods greater than 12 s.

The examination of the CMB using the seismic waves from large earthquakes has a long history. R. Oldham first identified the core in 1906, and I. Lehman discovered the inner core in 1936. By the 1940s, scientists like K. Bullen had not only determined reasonable radial models of Earth's seismic velocities, but had even noted the unusual behavior of the then-named D″ layer at the bottom of the mantle. As late as the 1980s most seismologists observed a decrease in D″ velocities relative to the rest of the mantle, which made sense thermodynamically; if the CMB is a chemical boundary between rock and iron, then heat must be conducted across it, and a thermal boundary layer will likely form at the bottom of the mantle. This thermal boundary layer will have temperatures hotter than the rest of the lower mantle adiabat and will have appropriately slower velocities.

The 1980s, however, brought two seismological findings of primary

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Editor's Note:

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

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In a step strongly urged by many readers, we're making your 1996 *GSA Today* smaller in format, but thicker: down to 8½ by 11 inches and up to 40 pages. The new format will make the magazine easier to handle and read, will make possible the addition of special supplements, and will give you more storage options—three-ring binders and normal-size file cabinets, for example. The change in size also allows GSA to take advantage of postage discounts for address bar-coding, an option not available with the larger format.

The new *GSA Today* normally will feature eight pages of full color, and two colors on other pages. Additional pages can be converted to color when necessary. A newsworthy science article will continue to lead off most issues, and you'll still get GSA news and views, preliminary and final announcements for section meetings and the annual meeting of GSA and its associated societies, the Washington Report, Forum, and a list of geological meetings; classified and display advertising will continue, too.

Look for the new size in January, and watch these pages for other improvements in your new GSA Today!

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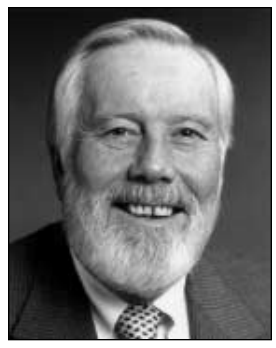

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Kay Named Science Editor for *GSA Today*

Suzanne M. Kay (Cornell University) has been named science editor for *GSA Today,* while Eldridge Moores serves as president of GSA for 1996. Moores (University of California, Davis) has been science editor for *GSA Today* since publication began, in 1991. The science editor handles review and disposition of solicited or volunteered science articles, as well as book reviews, for *GSA Today.*

Suzanne Kay can be reached at Department of Geological Sciences, Cornell University, Ithaca, NY 14853, (607) 255-4701, E-mail: kay@geology.cornell.edu.

Field Trip Added to Southeastern Section Meeting

Add to the Southeastern Section's final announcement published in the November issue of *GSA Today* (p. 227–228) this information under the heading Field Trips:

3. **Stratigraphy and Paleoecology of the Salt Mountain Limestone, Clarke County, Alabama.** Saturday, March 16, $50/person. Depart from Jackson, Mississippi; end at Jackson, Alabama. Contact Michael A. Gibson, Dept. of Geosciences and Physics, University of Tennessee, Martin, TN 38238.

Add to the registration form (p. 228) under Field trips:
3. Stratigraphy and Paleoecology, Salt Mountain Limestone, March 16 ..... $50

CORRECTION: The advance registration one-day fee amounts for the Southeastern Section meeting are incorrect on the registration form (see table.) For a corrected form, call Julia Phillips at GSA (303) 447-2020, ext. 113.

REGISTRATION FEES — *Southeastern Section, March 14–15, 1996*

Advance registration by 2/6/96	Full Meeting	One day
Professional—Member	$65	$40
Professional—Nonmember	$70	$50
Student—Member	$20	$15
Student—Nonmember	$23	$20
K–12 Professional	$20	N/A
Guest or Spouse	$12	N/A

New USGS Program to Fund Student Geologic Mapping

The U.S. Geological Survey has initiated a new program to increase academic interest in geologic mapping. Educational Mapping (EDMAP) will provide funds to students in M.S. and Ph.D. programs that include geologic mapping as part of the research. The EDMAP Program resides within the National Cooperative Geologic Mapping Program. It will complement and be coordinated with ongoing USGS and State Survey mapping projects. Cooperative agreements of up to $15,000 a year will be considered through a yearly proposal process. The funds are for salary and operating expenses incurred during the field mapping season. Federal funds must be matched by the university receiving the award.

The details of the EDMAP Program are outlined in a formal request for proposals. More than 200 of these proposal booklets were mailed to universities and colleges across the country in early November 1995. Mailings went only to schools with a masters or doctorate program in geoscience listed in the Directory of Geoscience Departments, published by the American Geological Institute. Additionally, a copy of the request for proposals resides with each of the state geologists and with the USGS regional geologists at each of the three National Centers, in Reston, Virginia, Denver, and Menlo Park, California. The deadline for proposal submission is February 1, 1996. Anticipated starting dates will be between May 1, and June 1, 1996. Questions about the program should be addressed to Art Schultz, Program Scientist for External Affairs, U.S. Geological Survey, Mail Stop 908, Reston, VA 22092, (703) 648-6501, fax 703-648-6937, E-mail: aschultz@gccmail.cr.usgs.gov.

GSA ON THE WEB

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If you want to know more about the GSA Employment Service or about becoming a GSA Campus Representative, check the **Membership** section, which also has information on nominating a member to fellowship and on obtaining forms for applying to become a GSA Member or Student Associate.

See the **Geoscience Calendar** section for a listing of meetings of general geological interest.

The **Publications** section has a monthly table of contents and abstracts of articles for the *GSA Bulletin* and *Geology.* Also in this section is a guide for authors preparing manuscripts for submission to GSA publications. *GSA Today* issues are posted here for downloading and viewing.

For Congressional Contact Information, see the **Administration** section. ■

Core-mantle *continued from p. 237*

importance about D". Global tomographic inversions of huge seismic data sets began to show coherent patterns of very long wavelength variations at magnitudes comparable only to those of Earth's surface. In addition, mounting evidence supported the findings of Lay and Helmberger (1983) that in many if not most regions of the CMB, the top of D" is characterized, surprisingly, by a significant increase in velocity. The current state of CMB seismology is very active. Many seismologists are now studying the CMB with both global and regional approaches and with types of data that range from high-frequency (1–10 Hz) CMB-scattered P waves to very low frequency (<0.01 Hz) normal modes.

SEISMIC TOOLS FOR STUDYING THE CMB

There are three categories of waves that can be used to examine the CMB: reflected, refracted, and diffracted. These are usually demonstrated by ray-tracing, where the wave paths are represented by the straight lines of particle paths. This simple ray-tracing, however, is inadequate for describing the true nature of the interactions; the waves that leave the earthquake do not behave like particles, but travel as three-dimensional wave fronts. For this reason, a better picture of the waves that interact with the CMB can be seen in Figure 1, which is an accurate representation of the horizontal shear (SH) waves that would propagate through the mantle from an earthquake, in this case at a depth of 600 km. The images represent the displacement of the waves in slices through the mantle at different times after the earthquake. The images are part of a movie created through the summation of torsional normal modes of Earth's oscillations (Wysession and Shore, 1994).

In Figure 1A, 320 s after the earthquake, the initial wave front(ScS) is still quite simple, having only just reflected off the surface, but as time passes the waves become more and more complex because of their continued interactions with the surface, CMB, internal mantle discontinuities, and a velocity structure that increases with depth. By 560 s (Fig. 1B) the ScS wave can be seen leaving the CMB and heading back to the surface. This core-reflected phase is easily recorded at the surface at distances of up to 85° away from the earthquake and has provided the majority of information about the seismic shear structure above the CMB. By 800 s (Fig. 1C) a second wave is reflecting off the CMB, the surface-reflected sScS, but by this time the bottom part of the initial wave front is no longer "reflecting" off the core; the wave has turned the corner around the core and is now diffracting along the CMB. The diffracted waves (Sdiff, or equivalently, Pdiff), which are recorded at distances of greater than about 100° from the earthquake, theoretically continue indefinitely around the core, but in reality quickly lose their energy and are rarely observed beyond about 150°. This means, however, that in the distance range of 100°–150° Sdiff and Pdiff arrivals at the surface provide a lot of information about the very base of the mantle. This article provides two examples of CMB studies, one using core-diffracted Sdiff and Pdiff waves, and the other using core-reflected ScS and PcP waves.

CORE-DIFFRACTED WAVES

Sdiff and Pdiff are excellent waves for looking at the structure of the base of the mantle because they can spend up to one-third of their total traveltime within D". They are also the first arrivals of their kinds (Pdiff is the first arrival of any kind beyond 100°, and Sdiff is the first shear arrival), which often makes them easy to detect. Some complications with these phases have prevented their widespread incorporation into seismic studies. High-frequency energy dissipates very quickly during diffraction, so the very long period arrivals do not allow the picking of clear onset times. The high-frequency decay does not resemble seismic anelastic attenuation and cannot be easily corrected. In addition, because the diffracted waves also travel a great distance through the heterogeneous mantle and crust on their way to and from the CMB, it is difficult to distinguish D" heterogeneities from those present elsewhere.

The studies of Wysession et al. (1992) used a stringent set of requirements and corrections to map out D" variations from profiles of Sdiff and Pdiff. The ray parameters, or slownesses, were determined for many arrivals traveling a long distance along a narrow swatch of the CMB. Combined with mantle path corrections using three-dimensional (3-D) tomographic models as well as synthetic modeling, this technique reduces contamination from source mislocation, slab diffraction, upper-mantle path heterogeneity, ellipticity, and high-frequency energy dissipation. An example (Fig. 2) shows six WWSSN Sdiff arrivals (top), modeled by their reflectivity synthetic counterparts (bottom). The slope through the arrivals is the ray parameter and is a direct result of the average velocity structure in D". Maps of the results for 12 Sdiff and 20 Pdiff profiles (Figs. 3 and 4) show the windows onto the core where enough diffracted arrivals meet our criteria. The total variation for both P and S velocities, determined at very long wavelengths, was about 4%. The most striking feature in both maps is a region of D" beneath the western Pacific islands where the seismic velocities were 3% slower than for the radial Earth model PREM (Dziewonski and Anderson, 1981). Just to the west, the inferred P and S velocities were found to be about 1% faster than PREM. This pattern correlates well with the results of other seismic studies done using totally independent data sets, such as the tomographic mantle shear velocity models of Su et al. (1994). A possible explanation for this pattern is discussed below.

Another interesting pattern was found for the D" velocities beneath the northern Pacific, which were sampled by paths from earthquakes near Japan to stations in North and South America. Here it was found that the shear waves were consistently faster than average, whereas the P velocities were slower than average. This suggests that the P and S velocities may not always vary in the same manner, an observation that has also been made in tomographic models of the lowermost mantle. This variation in the Poisson ratio of the lowermost mantle may be real, just as the Poisson ratio in Earth's crust is seen to vary regionally.

Core-diffracted waves also provide information about the poorly known vertical velocity structure in D", in much the way surface waves can be used to determine upper-mantle structure. Because all seismic phases that sample the CMB must pass vertically across D" and back, there is difficulty in resolving the layer's vertical structure. It is hard to tell whether the heterogeneities are at the top or bottom of the layer. Studies similar to that by Lay and Helmberger (1983) identify the top of D" where a sharp velocity increase creates an additional seismic precursor (SdS) to ScS. Core-diffracted waves provide additional information about the rest of D", longer wavelengths sampling more of D" and shorter wavelengths staying closer to the CMB. Valenzuela et al. (1994) showed preliminary results using core-grazing S waves from five northern California earthquakes recorded at the Tibetan Plateau PASSCAL array. The data were forward-modeled by synthetic seismograms for a wide array of seismic models, and the structure in Figure 5 was found to be the best fit, a sudden increase in velocity 290 km above the CMB, with a rapid decrease at the bottom of the layer. This structure is very similar to the model proposed by Young and Lay (1990), using SdS waves to model a region of D" nearby to the east. As more high-quality data are obtained from portable arrays of broad-band

Core-Mantle *continued on p. 240*

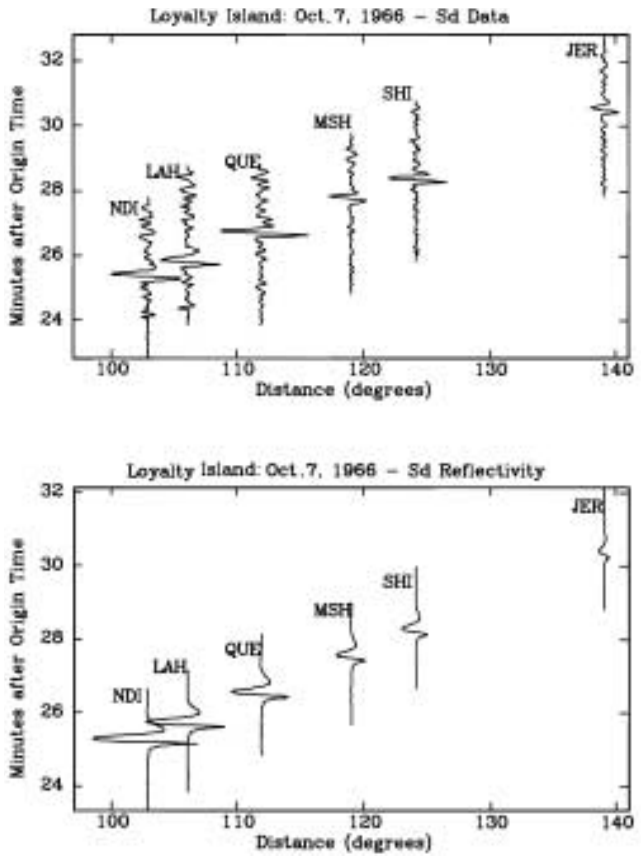

Figure 2. An example of six data (top) and synthetic (bottom) core-diffracted Sdiff seismic arrivals from an earthquake (October 7, 1966) in the Loyalty Islands (from Wysession et al., 1992). All arrivals are along a narrow azimuthal window, so a single patch of the CMB is investigated. Because all of the diffracted waves bottom at the base of the mantle, they share the same ray parameter, represented by the slope through the arrivals. A change in the slope relative to that of the synthetic counterparts implies anomalous velocities in D".

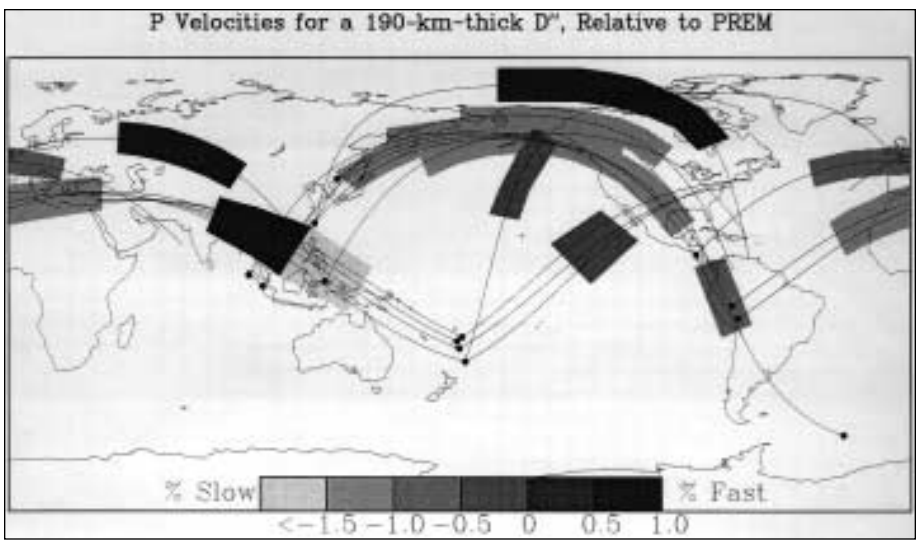

Figure 3. A map from Wysession et al. (1992) showing the very long wavelength average D"P velocity variations, determined from 20 profiles of core-diffracted Pdiff arrivals like those shown in Figure 2. The solid circles are earthquakes used, lines represent average paths for each profile, and the shaded areas are the regions of D" sampled by the waves. Note the unusual transition from slow to fast velocities beneath the western Pacific.

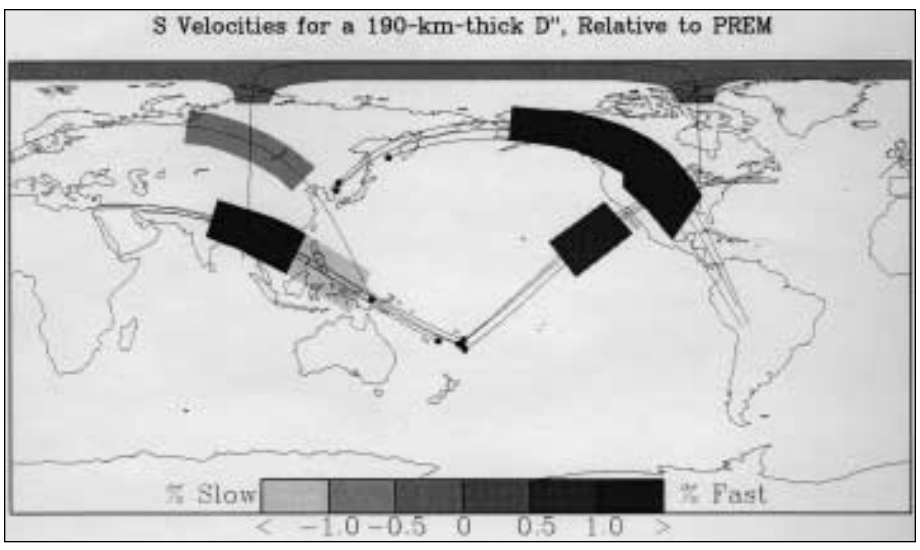

Figure 4. Similar to Figure 3, but for long-wavelength S velocity variations based on 12 independent profiles of Sdiff arrivals (from Wysession et al., 1992).

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seismometers (recording a "broad band" of frequencies) this technique of using Sdiff or Pdiff amplitudes as a function of distance and frequency should play an important role in helping resolve vertical structure for limited regions within D".

CORE-REFLECTED WAVES

Because of the unusual nature of the D" region beneath the western Pacific, Wysession et al. (1994, 1995b) further investigated this region using ScS-S and sScS-sS differential traveltimes (the S, ScS, sS, and sScS waves are the first four wave fronts shown propagating away from the earthquake in Fig. 1C). Using 747 differential traveltimes between direct and core-reflected shear waves, we attained a higher resolution map of the lateral variations in D" shear velocities for this region (Fig. 6). The use of differential times of seismic phases from the same earthquake is a powerful tool for examining Earth structure, because source and receiver effects are canceled out (Wysession et al., 1995b). After the different phase paths were corrected by ray tracing through a 3-D tomographic mantle S-velocity model (SH8/WM13 of Woodward et al. (1993) to help remove middle and upper-mantle heterogeneity effects, any remaining traveltime residuals were converted into velocity variations along their computed paths through the lowermost 300 km. These velocity variations were superimposed by moving a weighted Gaussian cap with a 300 km radius across them to average the geographical contributions and help simulate the CMB Fresnel zones, or sampling regions, of the ScS and sScS footprints. The resolution of the result (Fig. 6) is on the order of about 300 km, or 5°. (Note that the amplitudes of the original figure in Wysession et al. [1994] were erroneously amplified by a factor of two; this was corrected in Wysession et al. [1995a].)

The variations in seismic velocity found for this part of the lowermost mantle range over about ±3%, with several notable features. Not all of the region is sampled because of our inability to install permanent seismometers in the oceans and because of the uneven distribution of earthquakes across Earth. In the middle of the region where we do have coverage, corresponding to D" beneath Micronesia, we find a broad low-velocity region. The average velocity is 1.5% slower than for PREM, but reaches values up to 3%, especially in the slow-velocity arm that extends toward the west. This broad low-velocity zone (LVZ) is surrounded on three sides by regions showing fast velocities. The average of these regions is about 2% faster than for PREM but reaches values greater than 3%. The fast velocities to the south and west of the D" LVZ seem to form one continuous feature that extends from beneath China to beneath eastern Australia. There is a correlation between this fast D" rock and the location of the paleotrench of the Tethys plate. The fast-velocity region northeast of the LVZ is poorly constrained in its lateral extent and is beneath the northern part of the Pacific Ocean. We have no coverage of what happens to the LVZ east of the study region, but if current tomographic images like those of Su et al. (1994) are an indication, it probably extends a long way eastward as part of a broad low-velocity region beneath the central Pacific.

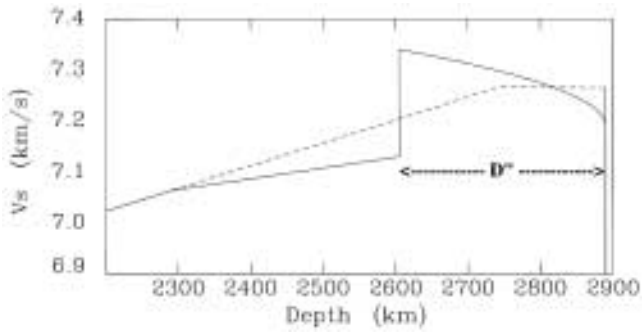

Figure 5. Profile from Valenzuela et al. (1994) showing the S velocity model for a patch of the lowermost mantle beneath eastern Siberia that best modeled the amplitude decay of core-grazing S waves as a function of frequency and distance. The study used five northern California earthquakes recorded in Tibet. The dashed line is the reference model PREM of Dziewonski and Anderson (1981), and the solid line is our best preliminary fit to the amplitude data—a model based on D" structures proposed by studies like that of Young and Lay (1990).

In an attempt to get at what the P velocities might be doing in the same region, Zhu and Wysession (1995) presented a map of D" P velocities by stacking the differential times of PcP and P for those seismic stations that reported arrivals of both to the International Seismological Centre during the time 1964–1987. While these times, especially for the secondary and often much smaller PcP arrivals, are not as reliable as times determined through personal analyses, there is statistical significance in the picture obtained from combining the very large number of data available—in this case, 78,793. Figure 7 shows the resulting map for D" P velocities in the same region as that previously shown for S, and determined by the same procedure. The PcP-P residuals were determined relative to the IASP91 reference Earth model of Kennett and Engdahl (1991), and the mean of the entire data set was 0.35% slower than for IASP91. This could partly be an indication that IASP91 is on average too fast for the lowermost mantle or for the regions that had the greatest coverage, but it may also be the result of a systematic bias in picking the PcP arrivals too late. It is interesting to note that Figure 7 shows a large central low-velocity region, but it extends farther west than for the S velocities in Figure 6. An examination and careful analysis of available PcP waveforms for this region will be required before an accurate comparison of P and S velocities in this region can be made.

INTERPRETATION AND SPECULATION

It is clear that there are some interesting and unusual geologic processes at work at the CMB, but it is not clear what they are. Many recent papers have discussed the potential causes and implications of geophysical observations such as the seismic images just shown. Both general and detailed discussions can be found in a variety of papers, which are far too numerous to mention in full (e.g., see Loper and Lay [1995] and Wysession [1995a]). As yet there are more interpretations than hard facts, and each strong argument seems rebutted by an equally strong counter-argument. There are, however, three major categories of possible contributions to the structures seen in D": thermal variations, chemical variations, and mineralogical phase changes. Each of these in turn presents a variety of geodynamic interpretations. In many places I draw analogies between D" and the surface's crust and lithosphere. Although there clearly are dangers and limitations with doing so, because of the extreme differences in temperature and pressure, these are Earth's two major boundary layers, and it is likely that we can gain some understanding of CMB geology from processes observed at the surface.

Thermal Variations

Some estimates of the temperature difference between the lower-mantle and outer-core adiabats are as large or larger than 1500 °C (Boehler, 1994). As little or no mass seems to be transported across the CMB, this heat must pass into the mantle via conduction, and although there are some reports that a very high thermal conductivity in D" could lessen the effect, the result will be a thermal boundary layer. This would be analogous to the thermal lithosphere at the surface, where heat brought near to the surface by convection must be conducted across the lithosphere boundary before radiating into space.

As with the thermal lithosphere, we would expect horizontal mass movements to cause lateral variations in the temperature within such a thermal boundary layer. The temperature 50 km below a mid-oceanic ridge is much hotter than the temperature 50 km beneath an oceanic abyssal plain, and this can be observed as an increase in seismic velocities as waves move away from ridges. Something analogous is probably happening in D", and some of the lateral seismic variation seen there probably has a thermal component. If the vertical change in temperature across D" is 1500 °C, then it is possible to have lateral temperature variations approaching this amount. Seismic variations would then be representative of vertical mass movements associated with lower mantle convection. Fast regions are cold and sinking, or recently sunk. Slow regions are hot, buoyant, and on their way up. Three-dimensional tomographic mantle models interpreted as buoyancy forces resulting from temperature variations do a good job of modeling the observed long-wavelength geoid (Forte et al., 1994).

The thermal model of D" can be taken a step further to incorporate a direct connection with plate tectonics, showing that the CMB is not immune to arguments about the degree of intermixing between the upper and lower mantles. A correlation has long been identified between the location of major subduction zones and bands of fast seismic shear velocities in D" (as in Fig. 6), and likewise between slow D" velocities and regions that have a high density of hotspots, like the central Pacific and the western African plates. It is exciting to think of a mantle-wide circulation system bringing subducted plates all the way to the CMB where they heat up and eventually rise to the surface as hotspot mantle plumes; however, the correlations between D" seismic variations and paleosubduction would be equally satisfied by thermal coupling between an independent upper and lower mantle. It is doubtful that a solution to the whole-mantle vs. layered-mantle convection argument will be found at the CMB.

Chemical Variations

Earth's surface has not only thermal variations but also compositional variations, and it is possible that a chemical boundary layer analogous to the crust exists in D". Chemical "dregs," dense iron alloys, could have formed at the base of the mantle early on in Earth's evolution, or could be continually settling out of the lower mantle during convection. Core-mantle reaction byproducts could be stripped away from the CMB by horizontal convection to form laminar aggregates. The eclogitic crust of sub-

Core-Mantle *continued on p. 256*

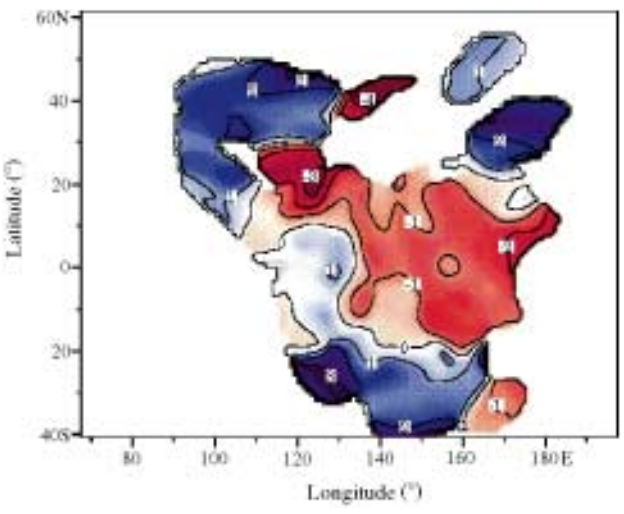

Figure 6. A map from Wysession et al. (1995b) of lateral S velocity variations in D" beneath the western Pacific, computed from ScS-S and sScS-sS differential traveltimes. All ray paths are corrected for mantle path heterogeneities outside of the bottom 300 km of the mantle, and the velocity magnitudes are computed assuming that the traveltime residuals are the result of heterogeneities only within this bottom layer. The data are robust, containing little scatter, and the resulting image shows coherent velocity variations at continent-sized long wavelengths.

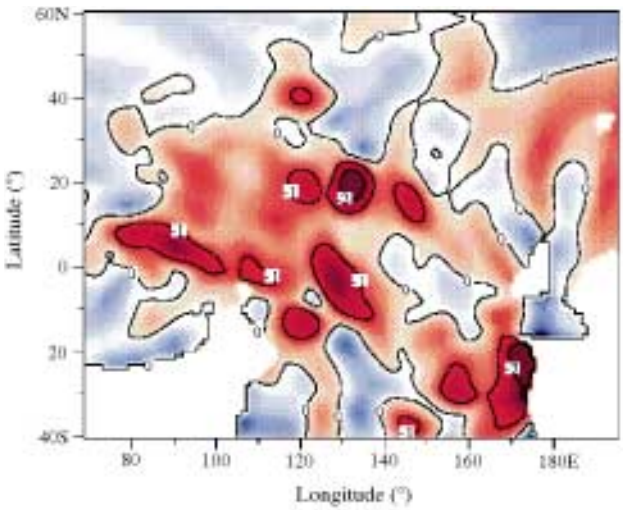

Figure 7. A map from Zhu and Wysession (1995) of the average P velocity variations in a 300-km-thick D" layer for the same region shown in Figure 6 for S velocities, incorporating more than 10,000 PcP-P differential traveltimes reported to the International Seismological Centre. As with Figure 6, the dominant feature is a broad low-velocity region in the center surrounded by slightly faster velocities, although the low velocities here extend farther to the west than in Figure 6.

WASHINGTON REPORT

Bruce F. Molnia

CD-ROMs Feature National Environmental Technology Strategy

Our views about the environment have evolved and become more sophisticated over the past 25 years. One lesson that we have learned is that economic growth and environmental stewardship go hand in hand. A clean environment means a higher quality of life, and technology advancement means economic growth and better jobs for American workers.

— Introduction, *Bridge to a Sustainable Future*

In July 1994, the Clinton-Gore Administration launched an initiative to develop a national environmental technology strategy for strengthening the American economy while working to solve the nation's environmental problems. A complete description of the planned initiative, including its objectives and an implementation strategy, is described in *Technology for a Sustainable Future*, a report available from the National Science and Technology Council (NSTC, see March 1994 Washington Report). After nine months, under NSTC's guidance, the development of the national technology strategy was completed in partnership with the private sector. The resulting strategy report, titled *Bridge to a Sustainable Future*, was released in April 1995.

Using state-of-the-art technology, the Global Environment and Technology Foundation (GETF) has developed for the Environmental Technology working group of NSTC a new resource for it to use in its efforts to promote the new strategy, to promote the growth of the American environmental technology industry, and to maximize the distribution of the new strategy. This new resource, two exceptional CD-ROMs, has resulted in the placement of two impressive wheels on the rapidly evolving environmental information super-chariot on the information superhighway. The development effort for these CD-ROMs was coordinated by E. J. (Jerry) McFaul of the U.S. Geological Survey. The two CD-ROMs, titled, *Bridge to a Sustainable Future* and *Leadership for a Sustainable Future*, are first-of-a-kind collections of environmental technology information and resources.

As my teenage sons would say, the CDs are "hot." Among the criteria that I use when selecting a topic for Washington Report are uniqueness, applicability to the earth science community, timeliness of information, and perceived level of interest. Being "hot" is also a very important criterion. As there is a delay of about six weeks between the completion of my column and its publication, I try to avoid addressing topics that you, the reader, have already seen in your local newspaper or in a scientific news magazine. In addition to presenting "who, what, when, and where" information, I also attempt to present interpretation and "why" information. The "why" for this month's report is very simple. As virtually all aspects of our profession, except for environment and hydrology, continue to shrink and decline, the appearance of an environmental technology resource that is easily usable, information packed, timely, and free are criteria that prompted this column. Get yourself this pair of discs!

The CDs were developed through the leadership of the White House Office of Science and Technology Policy (OSTP) in partnership with eleven federal agencies, the GETF, and others. The federal agencies are the Departments of Agriculture, Commerce (DOC), Defense (DOD), Energy (DOE), Health and Human Services, Interior, and State (DOS), the Environmental Protection Agency (EPA), the National Science Foundation (NSF), the National Aeronautical and Space Administration (NASA), and the Small Business Administration (SBA). Jack Gibbons, the President's science advisor and head of OSTP, officially announced the release of the *Bridges* CD on September 19, 1995. The *Bridges* CD was developed to help people "connect with environmental resources." It showcases federal programs, strategies, and technologies directed to capturing the growing domestic and international technology market. A goal of the CD is to promote "partnering of the public and private sectors in advancing" environmental technologies.

The *Bridges* CD contains more than 150 text documents, guides to associations, and technology export opportunities. Among the documents are 26 "resources documents," such as the full text of the *Bridges* strategy released last April and the USAID *Strategy for Sustainable Development*; 96 "program related documents" such as a complete description of the *DOS Coral Reef Initiative*; 13 "technology related documents" from the DOD, DOE, EPA, and NOAA, such as EPA's *Superfund Innovative Treatment Technology Report*; and numerous "program" descriptions, presenting in great detail the environmental technology capabilities and accomplishments of the federal agencies. All of the text material on the CD is fully searchable.

The CD also contains a variety of other videos, including speeches by U.S. leaders such as Vice-President Gore's speech at the December 1994 White House Conference on Environmental Technologies. Thirty other videos illustrate the application of individual environmental technologies. Also included are interviews with nine federal agency leaders in which they discuss the roles of their agencies in developing environmental technologies. Each of the nine, Tim Wirth (DOS), Thomas Grumbly (DOE), Sally Shelton (USAID), Ron Brown (DOC), Sherri W. Goodman (DOD), Daniel Goldin (NASA), Phil Lader (SBA), Carol Browner (EPA), and Neal Lane (NSF) answer the following five questions: (1) What is the appropriate role of the federal government in advancing environmental technologies? (2) How should the federal government interact with industry and the private sector to advance these technologies? (3) What are the main environmental challenges you think we will have to address with technologies over the next 20 years? (4) What is your agency doing to advance the development and diffusion of environmental technologies? and (5) What are the major opportunities you see for environmental technologies both domestically and globally? Because the CD was prepared with interactive multimedia technology, you can select which question you would like answered and which individual you wish to interview.

The second disc, *Leadership for a Sustainable Future*, also released in September, was also developed by GETF, under the guidance of the White House, to promote the growth of the environmental technologies industry. It showcases leading American companies offering innovative environmental products and services. Designed to complement the *Bridges* CD-ROM, this CD offers environmental technology leaders in American industry a new and innovative means of describing their companies' products and services to the growing international marketplace. GETF helped develop and organize more than 30 workshops, held throughout the United States and sponsored by the White House. The workshops, designed to strengthen the initiative, focused on how government, industry, and academic institutions could work together to advance the growing environmental technology industry. The CD features profiles of major American companies in the environmental technology field, including such industry leaders as 3M Corporation, Arm & Hammer, CH2M Hill, the Low Companies Group, Xerox Corporation, Johnson Controls, and many others. Each of the premier profiles presents detailed information on products and services. The CD-ROM also includes a database with information on more than 1200 environmental companies. As with the *Bridges* disc, all of the text material on this disc is fully searchable.

Tom Harvey, chief executive officer of GETF, stated that the companies featured on the CD "exemplify the vibrance and innovative spirit of the $400 billion a year international environmental industry. These companies have discovered that environmental stewardship through technology is good business." The U.S. environmental technology industry, with an annual budget of $130 billion, comprises more than 35,000 businesses and employs more than one million American workers. Over the next four years, the industry is projected to generate an additional 180,000 jobs.

Free copies of the discs are available from GETF, 7010 Little River Turnpike, Suite 300, Annandale, VA 22003-9998. The minimum computer configuration required to run these discs is a PC meeting the MPC Level 1 specifications. These are: a 386SX or compatible CPU, 4 megabytes of RAM, a super-VGA video card (256 colors), Windows (version 3.1 or higher), an MSCDEX driver (version 2.2 or higher), a single-speed CD-ROM drive (sustained transfer rate of 150 kilobytes/second), and an 8-bit sound card. The information contained on both of the CD-ROMs can be found on the World Wide Web at: http://www.gnet.org.■

Washington Report provides the GSA membership with a window on the activities of the federal agencies, Congress and the legislative process, and international interactions that could impact the geoscience community. 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.

Penrose Conference Scheduled

Exhumation Processes: Normal Faulting, Ductile Flow, and Erosion

Mark T. Brandon, Uwe Ring

A Geological Society of America Penrose Conference, "Exhumation Processes: Normal Faulting, Ductile Flow, and Erosion" will be held October 9–13, 1996, at the Orthodox Academy of Greece, located near the town of Chania on the island of Crete in southern Greece.

Over the past 25 years, there has been a growing appreciation of the role that tectonic processes play in exposing high-grade metamorphic rocks. This trend was initiated early on by the discovery of highly attenuated crustal sections in the Basin and Range province and the recognition that the attenuation was caused by regional-scale horizontal extension, as manifested by normal faulting. This discovery, which has a long history and an equally long list of contributors, forced many geoscientists to rethink the role that horizontal extension or, as it is more commonly called, tectonic extension might play in other orogenic settings. Of particular interest is the possibility that tectonic extension may be responsible for exhuming metamorphic rocks within convergent orogens, such as onland thrust belts (i.e., Himalaya, European Alps, Betic Cordillera of southern Spain, Brooks Range of Alaska) and subduction-related convergent margins (i.e., Franciscan of California, Sanbagawa of Japan, Hellenic/Aegean convergent margin of western and southern Greece, Hikurangi accretionary wedge of northeastern New Zealand).

There are really several processes that contribute to exhumation of metamorphic rocks. The first two—normal faulting and extensional ductile flow—operate within the earth and are a direct manifestation of tectonic deformation. The third process—erosion—operates at the surface, but can be indirectly influenced by tectonically driven uplift and subsidence. One of the most difficult questions to answer in most orogenic belts, especially in the older ones, is the relative contributions that these processes have made to the overall exhumation of deep crustal rocks. Even so, the tectonics community has gradually moved toward a casual consensus that deep exhumation is typically a result of tectonic processes, especially normal faulting. The most commonly cited evidence for crustal-scale normal faults is the recognition of "younger-over-older" relationships, where large faults, with low or moderate dips, have placed young rocks on older rocks or low-grade rocks on high-

Penrose Conference
continued on p. 243

1996 GeoVentures

GeoHostels

Mount St. Helens and Mount Rainier

Packwood and Kelso, Washington
Saturday, June 22, through Thursday, June 27, 1996

This GeoHostel will focus on field trips to Mount St. Helens, especially to explore processes and effects of the cataclysmic eruption of May 18, 1980. Among these are decapitation of the former summit, world's largest historic landslide, a tsunami wave as high as 800' on Spirit Lake, a gigantic pyroclastic surge (the so-called "lateral blast"), that in four minutes mowed down 235 square miles of mature forest, and great muddy floods (lahars). Everyone should see this world-class natural extravaganza before it becomes muted by revegetation. The ever-changing processes of revegetation, reforestation, and reentry of fauna to the devastated area is part of the scientifically unique experience—one of the reasons Congress set aside the heart of the affected area as Mount St. Helens National Volcanic Monument. Two days will be devoted to the east and southeast sides of Mount St. Helens, two days to the west side, including the stunning new visitor facilities in the heart of the devastated area, and one day at spectacular Mount Rainier (northeast, east, and south flanks) within Mount Rainier National Park. While at Mount St. Helens, we will hike through a remaining stand of old-growth coniferous trees, many as tall as 230 feet. Each day involves a hike through a unique landscape, none longer than about three miles nor with an altitude change of more than about 900 feet. Snow will still be visible on the higher mountain peaks, offering stunning scenes for photography.

About the Leaders

Richard B. Waitt, U.S. Geological Survey, Cascades Volcano Observatory, Vancouver, Washington; **Donald A. Swanson,** U.S. Geological Survey, Seattle, Washington; **Patrick T. Pringle,** Washington Department of Natural Resources, Olympia, Washington.

All three leaders have many years of geological field experience, summarized in numerous scientific publications, at Mount St. Helens and/or Mount Rainier, as well as extensive experience at other Cascade or Alaskan volcanoes.

Geology of the Glacier Park Region

Big Mountain Resort, Whitefish, Montana
Saturday, July 20, through Thursday, July 25, 1996

The geology of northwest Montana is some of the most spectacular in North America. It was first studied by Bailey Willis of the U.S. Geological Survey in 1902 as part of a reconnaissance study of the 49th parallel. Today, the region is best known by the geoscience community for research into the depositional history of the Proterozoic Belt Supergroup. These rocks contain some of the best sedimentary and biogenic structures in the world, and the depositional-tectonic setting of the "Belt basin" has been a matter of debate since the turn of the century. The region is also known for world-class thrust-belt structure, economic deposits of base metals, dinosaur remains in foreland-basin deposits, Cenozoic extensional tectonics, and glacial geology. The GeoHostel will include field trips in Glacier National Park to look at the stratigraphy and sedimentology of the Belt Supergroup, the Lewis thrust fault, foreland-basin deposits, alpine glacial geology of the park, and continental glacial geology of the Flathead Valley. A half-day rafting trip down the middle fork of the Flathead River will also be included. The trips are both full and half-day, and plenty of leisure time will be available to enjoy the spectacular scenery of northwestern Montana!

About the Leaders

Robert C. Thomas is currently an assistant professor of geology at Western Montana College in Dillon, Montana. Rob developed a passion for geology of the Belt Supergroup under the tutelage of Don Winston at the University of Montana. A graduate of the University of Washington, Rob's research has focused on the patterns and processes of Cambrian mass extinctions, the dynamics of carbonate platform development and destruction, extensional tectonism in southwestern Montana, and geoscience teacher-education reform. Rob is currently the president of the Rocky Mountain Paleontological Society and the Tobacco Root Geological Society.

Sheila M. Roberts is also an assistant professor of geology at Western Montana College. She developed an interest in the geology of northwestern Montana while growing up in the Mission Valley of Montana. Sheila did her doctoral work at the University of Calgary, where she studied Pleistocene paleoclimates recorded in saline lacustrine sediments of Death Valley, California. Sheila has also been a geoscience editor, a mining geologist, a petroleum geologist, and a geoscience educator focused on outreach projects with K–12 schools.

Geology of the Wine Country in Western Oregon

Portland State University, Portland, Oregon
Saturday, August 17, through Thursday, August 22, 1996

The geology of western Oregon is exciting and diverse. The Coast Range is a combination of Tertiary sedimentary rocks and basalts folded into a north-plunging anticline. The Cascade Range is mainly volcanic rock with Pleistocene volcanic cones sitting on top of older Tertiary volcanics. Between the two mountain ranges is the Willamette Valley, a deep trough filled with late Cenozoic age sedimentary rock. In southwest Oregon the ancient terranes of the Klamath Mountains dominate the geology. In the past 30 years, more than 100 wineries have started production in western Oregon, and some of the fine wines produced there win international prizes. This GeoHostel will focus on the rocks that affect the soil that produces these high-quality grapes. The class will visit at least two wineries each day, while discussing the local geology of the region. We will visit the Tualatin Valley, the Yamhill Valley and the coast, the Willamette Valley near Salem, and southwest Oregon, including Crater Lake and the Oregon Caves. Participants will stay on the beautiful campus of Portland State University, near the heart of downtown Portland, a vibrant city with a multitude of cultural activities, especially in August. An overnight field trip to southern Oregon will happen mid-week. The weather is almost guaranteed to be perfect in August. Come to Oregon for high-quality geology and high-quality wine!

About the Leader

Scott Burns is an Associate Professor at Portland State University and a native Oregonian who knows the geology of western Oregon well. In his teaching at the college level in Switzerland, New Zealand, Washington, Colorado, Louisiana, and Oregon for the past 20 years, Scott has received many outstanding teaching awards. He enjoys wine making and wine tasting, and his first published paper, in 1976, was on developing a student lab project on wine making. Much of his current research in environmental and engineering geology, geomorphology, Quaternary geology, and soil is directly related to the production of good grapes and fine wine.

Full information in January *GSA Today.*

Registration begins January 1, 1996

Space will go quickly, so get in touch with us if you are interested. Detailed information on itineraries, registration fees, and travel arrangements will be sent on request. No obligation. Questions welcomed.

For details on the 1996 GeoVentures contact the GeoVentures Coordinator today:
1-800-472-1988, ext. 134 or 303-447-2020
E-mail: ecollis@geosociety.org
fax 303-447-0648

Penrose Conference
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grade rocks, with a significant omission of stratigraphic or metamorphic section, respectively. Recent papers, however, have shown that this type of evidence by itself is not diagnostic and that contractional faults can also result in missing section if the section was already tilted back toward the hinterland prior to development of the fault system. Kinematic indicators can be used to resolve this problem, but there remains another more fundamental problem. The throw on many crustal-scale normal faults, especially those that involve deep crustal rocks, is typically difficult to resolve because of uncertainties about the original dip of the fault and the total amount of fault slip. In these cases, there is no easy way to assess the contribution that normal faulting has made to the overall exhumation.

We maintain that the time has come for a broad and critical evaluation of the exhumation problem. Penetrative deformational fabrics are present in most exhumed mountain belts and provide clear evidence that ductile flow is an important process that can either contribute to or hinder exhumation of metamorphic rocks, depending upon whether ductile flow caused thinning or thickening in the vertical direction. Furthermore, any quick inspection of the huge volumes of sediment shed from most contractional orogens makes it clear that erosion cannot be ignored as an exhumation process.

Within this context, we are convening a Penrose Conference to examine all processes that contribute to exhumation of deep-seated rocks in ancient and modern orogenic belts. At the broadest scale, the conference will have three distinct goals: (1) to review and synthesize our knowledge about normal faulting, ductile flow, and erosion as exhumation processes; (2) to examine the geologic evidence relevant to resolving a quantitative understanding of the relative contributions of these different exhumation processes, as deduced from metamorphic petrology, isotopic thermochronology, structural and kinematic analysis, synorogenic stratigraphy, geomorphology, and paleoelevation data; and (3) to examine relevant geodynamic models and their predictions for conditions that might trigger the onset of gravitational collapse.

The conference will be five days long, including two days of field trips and three days of presentations. The presentations will consist of six half-day sessions. Each session will have about two hours of oral presentations, including a keynote speaker, a one-hour discussion session, and a one-hour poster session. During the discussion session, individuals will be able to show one or two slides to emphasize a point, but no formal presentations will be allowed. We want to avoid the typical meeting format with back-to-back talks, and instead focus on fleshing out old controversies and new ideas.

Tentative session titles are: (1) Local expression of tectonic exhumation: extensional faulting and ductile flow; (2) The role and significance of erosional exhumation; (3) The ultimate cause of tectonic exhumation: active rifting versus passive gravitational collapse; (4) Formation and exhumation of ultra-high-pressure metamorphic rocks; (5) The influence of surficial phenomena on the geodynamic evolution of mountain belts: topography, climate, and erosion; and (6) The influence of deep-seated phenomena on the geodynamic evolution of mountain belts: thermal relaxation, lithospheric delamination, and gravitational collapse.

The conference will be held on the island of Crete, which sits between the active Hellenic subduction zone to the south and the active extensional terrain underlying the Aegean Sea to the north. The island has spectacular exposures of deep-seated metamorphic rocks that were exhumed from depths as great as 30 km. The field trips, which will be lead by Bernard Stöckhert (Ruhr-Universität Bochum, Germany) and Eberhard Seidel (Cologne University, Germany), will focus on contrasting exhumational events: a Late Cretaceous event that resulted in unroofing of high-*T*/low-*P* metamorphosed basement and cover, and a Miocene event that exposed high-*P*/low-*T* aragonitic marbles.

Our objective in selecting this site for the meeting is to expose participants, especially those from North America, to an exhumational setting different from that of the Basin-and-Range, which would be the natural site of choice if the conference were to be held in the United States. The locations will mean a slightly more expensive air fare for North American participants, but will encourage participants from Europe to attend.

The conference will be limited to 70 persons. Participants will be selected to ensure broad representation by nationality, by occupation (i.e., faculty, graduate students, industry and government scientists), and by research interest (i.e., structural geology, metamorphic petrology, isotope geochronology, sedimentology, geomorphology, and geodynamics). The registration fee will be about $700, which will cover lodging, meals, and field trips, but not airfare. We hope to be able to partially subsidize the participation of some graduate students.

Co-conveners of the conference are: ***Mark T. Brandon,*** Department of Geology and Geophysics, Yale University, P.O. Box 208109, New Haven, CT 06520-8109, (203) 432-3135, fax 203-432-3134, E-mail: mark.brandon@yale.edu; and ***Uwe Ring,*** Institut für Geowissenschaften, Johannes Gutenberg-Universität, Postfach 3980, 55099 Mainz, Germany, 49-6131-392164, fax 49-6131-394769, E-mail: ring@mzdmza.zdv.uni-mainz.de.

APPLICATION DEADLINE: MARCH 15, 1996

Interested persons should send a letter of application to Uwe Ring at the address given above. The letter should include a brief statement of the applicant's research interests, relevance of those interests to the focus of the conference, and a potential topic that the applicant might want to present. Note that we are planning only a limited number of oral presentations, but we strongly encourage poster presentations and comment presentations in order to ensure an informal and interactive conference. ■

The Geological Society of America

Research Grants Program 1996

The primary role of the Research Grants Program is to provide partial support for research by graduate students at universities in the United States, Canada, Mexico, and Central America. GSA strongly encourages women, minorities, and persons with disabilities to participate fully in this grants program. Eligibility is not restricted to GSA members. New application forms are available each fall in the geology departments of colleges and universities offering graduate degrees in earth sciences. Forms are mailed in October to GSA Campus Representatives and department secretaries and chairpersons in the United States, Canada, and Mexico. They are also available upon request from the Research Grants Administrator, Geological Society of America, P.O. Box 9140, Boulder, CO 80301. *Please use only the 1996 application and appraisal forms.*

Confidential evaluations from two faculty members are required from candidates for the M.S. or Ph.D. degree and must accompany applications submitted. PLEASE USE THE "APPRAISAL OF APPLICANT" FORMS, WHICH ACCOMPANY THE 1996 APPLICATION FORMS. Application forms will not be accepted by facsimile.

The Geological Society of America awarded over $300,000 in grants in 1995. The grants went to 218 students doing research for advanced degrees. The average amount awarded was $1465. The largest grant was $2500, but there is no predetermined maximum amount.

The Committee on Research Grants will meet in March to evaluate applications and award grants. In April, all applicants for grants will be informed of the committee's actions by the Executive Director of the Geological Society of America.

ALL APPLICATIONS MUST BE SUBMITTED ON THE 1996 FORMS AND POSTMARKED BY FEBRUARY 15, 1996

CALL FOR NOMINATIONS REMINDERS

Materials and supporting information for any of the following nominations may be sent to GSA Executive Director, Geological Society of America, P.O. Box 9140, Boulder, CO 80301. For more detailed information about the nomination procedures, refer to the October 1995 issue of *GSA Today,* or call headquarters at (303) 447-2020, extension 136.

Penrose and Day Medals, and Honorary Fellowship

Nominations for 1996 Penrose and Day Medals and for Honorary Fellowship in the Society are due by **FEBRUARY 1, 1996.**

Young Scientist Award (Donath Medal)

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

For the year 1996, only those candidates born on or after January 1, 1961, are eligible for consideration. In choosing candidates for the Young Scientist Award, scientific achievement and age will be the sole criteria. Nominations for the 1996 award must include

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

Deadline for nominations for 1996 is **FEBRUARY 1, 1996.**

Officers and Councilors

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

Deadline for nominations for 1997 is **FEBRUARY 15, 1996.**

Distinguished Service Award

The GSA Distinguished Service Award was established by Council in 1988 to recognize individuals for their exceptional service to the Society. GSA Members, Fellows, Associates, or, in exceptional circumstances, GSA employees may be nominated for consideration. Any GSA member or employee may make a nomination for the award. Awardees will be selected by the Executive Committee, and all selections must be ratified by the Council. Awards may be made annually, or less frequently, at the discretion of Council. This award will be presented during the annual meeting of the Society. Deadline for nominations for 1996 is **MARCH 1, 1996.**

John C. Frye Environmental Geology Award

In cooperation with the Association of American State Geologists (AASG), GSA makes an annual award for the best paper on environmental geology published either by GSA or by one of the state geological surveys. The award is a $1000 cash prize from the endowment income of the GSA Foundation's John C. Frye Memorial Fund. The 1996 award will be presented at the autumn AASG meeting to be held during the GSA Annual Meeting in Denver.

Nominations can be made by anyone, based on the following criteria: (1) paper must be selected from GSA or state geological survey publications, (2) paper must be selected from those published during the preceding three full calendar years, (3) nomination must include a paragraph stating the pertinence of the paper.

Nominated papers must establish an environmental problem or need, provide substantive information on the basic geology or geologic process pertinent to the problem, relate the geology to the problem or need, suggest solutions or provide appropriate land use recommendations based on the geology, present the information in a manner that is understandable and directly usable by geologists, and address the environmental need or resolve the problem. It is preferred that the paper be directly applicable by informed laypersons (e.g., planners, engineers). Deadline for nominations for 1996 is **APRIL 1, 1996.**

National Awards

The deadline is **April 30, 1996,** for submitting nominations for these four awards: William T. Pecora Award, National Medal of Science, Vannevar Bush Award, Alan T. Waterman Award.

GSAF UPDATE

Robert L. Fuchs

Tax Tips for 1995

If you are looking for ways to reduce your 1995 income taxes that will be due and payable by April 15, consider the following:

- If you itemize deductions, gifts to the GSA Foundation are deductible from income. At the higher tax rates (maximum is 39.5%), the savings can be significant.
- The process is simple—just send a check to the Foundation. You may use the accompanying coupon, particularly if you have any special instructions.
- Making gifts of securities you own that have gone up in value will provide a double tax benefit—a deduction in the amount of the market value of the securities, regardless of what you paid, plus the avoidance of capital gains taxes on the difference.
- This may be the right time to consider a long-range planned gift that will give you a deduction now and provide income for life. The Foundation office has details.
- To conform to IRS regulations, make certain that you retain with your back-up papers all letters and receipts acknowledging your 1995 charitable gifts.
- Your 1995 contribution must be made in 1995. This means that the postmark on the envelope must be earlier than midnight on December 31. A check written and dated on December 31 but put into the mail on January 1 or 2 will be a contribution for 1996. ■

Five-Year Magma Copper Pledge

The Foundation has received a five-year pledge of financial support for the Second Century Fund from Magma Copper Company. In the commitment letter, the company's Executive Vice President Bradford A. Mills stated, "It is important to us that organizations such as GSA are provided with support to continue research and provide for educational opportunities in the geological forefront."

Magma Copper, one of the largest primary copper producers in the United States, produces high-quality copper cathodes and rods for sale to customers worldwide. The company operates four mines in the United States, at San Manuel, Superior, and Miami in Arizona, and at Ely, Nevada. Last year Magma acquired the Tintaya mine in southern Peru. Smelting and refining operations at San Manuel, including the world's largest flash furnace, represent nearly 25% of U.S. smelting capacity.

An aggressive explorer of low-cost orebodies worldwide, Magma prides itself on a highly skilled, motivated, and creative work force of 5000 employees, strong orientation toward growth as a low-cost producer, and operations that are conducted in an environmentally responsible manner. Second Century Fund industry Vice Chair Paul Bailly noted, "The pledge from Magma Copper is an important addition to the Industry Support Program for Earth Science. We are gratified by the confidence that Magma has placed in GSA and its scientific, educational, and outreach programs." ■

Pooled Income Fund Grows

In mid-September the assets of the GSA Foundation Pooled Income Fund exceeded $400,000 for the first time. This is attributable to additional contributions to the fund from members responding to the challenge posed by Bill Heroy and Larry Sloss. Also, the value of the assets in the fund increased by 6.9% during the first 8.5 months of 1995, which is an annualized rate of 9.6%.

For the first six months of the year, the fund paid income at the annualized rate of 6.1% on the net asset value at the beginning of 1995. Because of the tax savings generated by contributions to the fund, the net return to participants varied between 8% and 10%, the actual rate depending on each individual's personal tax situation.

The portfolio of the Pooled Income Fund includes holdings in the Warburg, Pincus Fixed Income, and Global Fixed Income Funds, the SteinRoe Income Fund, and the PIMCO Total Return Fund. ■

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Supporting The Advancement of Research

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☐ Enclosed is my contribution in the amount of $_____ for:
☐ Foundation Unrestricted ☐ GSA Unrestricted

☐ Please add my name to the Century Plus Roster (gifts of $150 or more).

☐ My gift is for the Second Century Fund. Please credit the _____ Section goal.

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Donors to the Foundation, September 1995

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Membership Goal

$1.5 million

Section Goals

Cordilleran	North-Central	Northeastern
$465,000	$170,000	$265,000
Rocky Mountain	**South-Central**	**Southeastern**
$225,000	$165,000	$210,000

SAGE REMARKS

Edward E. "Dr. Ed" Geary, Educational Programs Coordinator

Exemplary Earth Science Education Resources: Part One

During the past five years, interest in earth science education has grown rapidly. In fact, for the 1995 GSA Annual Meeting in New Orleans in November more abstracts were submitted to the education technical sessions than to any other technical program category. As interest in earth science education grows, many GSA members have expressed an interest in learning about and keeping up to date on the educational activities and resources of other organizations. The article here focuses on the programs and resources of the National Association of Geoscience Teachers.

NAGT and JGE: New Names and New Programs in Support of Geoscience Education

Lauret Savoy, *Mount Holyoke College*
Barbara Tewksbury, *Hamilton College*

The National Association of Geoscience Teachers (NAGT), one of GSA's associated societies, has recently changed its name and has developed several exciting programs to encourage high-quality teaching in the geosciences. We hope that this article will encourage you to subscribe to the *Journal of Geoscience Education* and become a member of NAGT.

What's in a name?

For many years, NAGT had been the National Association of Geology Teachers. In order to make the broad focus of the organization more explicit, the membership voted in the fall of 1995 to change "Geology" to "Geoscience" in both the association's name and the name of its journal, which is now the *Journal of Geoscience Education*.

Journal of Geoscience Education

Advances in geoscience education happen most quickly when educators build on the successes of others, rather than reinvent the wheel over and over again. Dissemination of great ideas is a critical step in the process, and the *Journal of Geoscience Education* is dedicated to seeing that great ideas reach the widest possible audience. Published five times a year, the *Journal of Geoscience Education* aims to reach teachers with the best ideas for teaching geoscience at all levels. JGE is the place to learn about creative and innovative ways to teach geoscience and is the only journal devoted to improving the quality of geoscience education from content to pedagogy.

Inside the pages of JGE, you'll find articles that range in topic from the general to the specific, from college-level to elementary school. The *Journal* publishes stimulating examples of innovation in the content of what we teach, as well as creative approaches and methods for how we teach. Recent issues have included articles on innovative strategies for teaching large classes, new approaches for teaching mineralogy, creative demonstrations for grade school classes, and techniques for integrating computers into courses. The *Journal* also has reviews of movies, videos, software, and books.

Many teachers at all levels are interested in successful strategies for incorporating more hands-on and group investigation and less lecture into their classes. The September 1995 issue of JGE is undoubtedly destined to become the resource for such ideas in the geosciences. This 150-page issue has 23 articles on techniques and approaches for group and collaborative learning in the classroom, in the field, and in research settings. Sample titles from the table of contents illustrate the wide variety of types of courses and subdisciplines addressed in the articles: Specific Strategies for Using the "Jigsaw" Technique, Changing a Course in Marine Geology from Lecture Format to a Cooperative-Learning Format, A Collaborative Approach to Petrology Field Trips, Cooperative Learning Activities in Large Entry-Level Geology Courses, and Research Groups for Undergraduate Students.

Events at the 1995 GSA Meeting

At the GSA Annual Meeting in New Orleans, NAGT sponsored or cosponsored several popular sessions focused on geoscience education. The sessions included a one-day workshop on effective teaching (cosponsored with GSA), an afternoon workshop on preparing successful grant proposals to fund curriculum innovation in the geosciences (cosponsored with NSF), a symposium on assessing teaching and learning, and two theme sessions, one on environmental geoscience across the curriculum (cosponsored with GSA's Institute for Environmental Education), and one on making connections between K–12 and university education (cosponsored with the National Earth Science Teachers Association and GSA).

At the NAGT booth in the Exhibit Hall, many people took The NAGT Challenge, where we challenged faculty members to commit to trying at least one new innovative strategy in teaching their courses during this academic year and to submit a short summary of their successes for inclusion in a report on the results of the Challenge, to be published in JGE.

Collaboration with GSA and AGU

NAGT activities at the New Orleans GSA meeting are typical of the collaborative approach that NAGT has taken in working closely over the past several years with other professional geoscience organizations interested in improving the quality of geoscience education. In addition to activities at GSA meetings, NAGT has cosponsored the AGU Chapman Conference Scrutiny of Undergraduate Education, held in September 1994, and has been a prominent participant in the CESE (Coalition for Earth Science Education) exhibit hall booth at National Science Teachers Association annual meetings.

Workshops

At both the 1994 and 1995 GSA annual meetings, NAGT and GSA have cosponsored a day-long workshop on effective teaching aimed primarily at new faculty members and graduate students interested in teaching. The workshops offered hands-on, practical sessions focused on specific strategies for effective geoscience teaching. The sessions emphasized nontraditional approaches and gave participants practical suggestions and strategies to improve student learning. Sessions during the workshop focused on approaches to course design, more effective lecturing to large classes, working in groups in large classes, moving away from lecture-based courses, and authentic assessment.

NAGT hopes to be able to continue offering intensive short courses on effective teaching over the next few years, including several one-day short courses to be held in conjunction with national and regional GSA and AGU meetings and a four-day summer workshop on redesigning introductory and upper level undergraduate geoscience courses. We hope, in addition, to be able to produce a companion Teaching Resource Book of successful and innovative strategies for teaching geoscience to undergraduates.

Distinguished Speaker Series

In 1994–1995, NAGT launched a program of Distinguished Speakers, who have made themselves available for workshops and presentations on innovative teaching in the geosciences. The ten speakers in the program were chosen not only for their abilities as speakers and workshop leaders, but also for their position at the forefront of creative approaches to teaching geoscience. Dean McManus (University of Washington), for example, is available to talk about the successes and problems of using cooperative learning in courses, and on using the World Wide Web for student projects. Marcia Bjornerud (Lawrence University) offers workshops on leaner teaching, and the inverse relationship between comprehensive coverage and student comprehension, as well as incorporating computers in the classroom. Heather Macdonald (College of William and Mary) will speak on alternatives to lectures in large introductory courses. Barbara Tewksbury (Hamilton College) is available for workshops on innovative course design. Paul Pinet (Colgate University) and Jill Schneiderman (Vassar College) could speak, respectively, on earth science and ethics, and policy in geoscience curricula. Through these and the other Distinguished Speakers, NAGT reaches a large number of college faculty, graduate students, and high school teachers and encourages them to push the envelope in educational reform.

The Distinguished Speaker's Program is supported by a generous grant from the National Science Foundation. Funding is currently available to cover travel costs for a speaker to visit your school, and the deadline for mid-year applications is December 20, 1995. If you would like information and an application for funding to bring a Distinguished Speaker to your campus, contact the speaker coordinator, Barbara Tewksbury, at btewksbu@hamilton.edu (or 315-859-4713).

Electronic Discussions

NAGT actively supported development of a new discussion list, known as Geo-ed list, on the Internet. Geo-ed list was developed and maintained by Bryan Tapp at the University of Tulsa and has provided an invaluable forum for discussion of important issues in geoscience education. In the eight months since the discussion list began, subscribers have talked back and forth electronically about issues ranging from strategies for collaborative learning to budget cuts. The list is an ideal way to float a question, conduct an informal survey, or ask for advice and receive many responses in a short period of time. Individuals wishing to join the list should contact Bryan at jbt@arbuckle.geo.utulsa.edu for instructions on how to subscribe.

WWW Home Page

NAGT has a home page under construction on the World Wide Web. By the time this article appears in print, it should be up and running. Look for us!

Subscriptions and Membership

A one-year subscription to the *Journal of Geoscience Education,* which also includes membership in NAGT, costs $25 for professionals and $15 for students. Subscription and membership forms appear inside the back cover of any issue of JGE or are available from Bob Christman (xman@henson.cc.wwu.edu or Box 5443, Bellingham, WA 98227-5443). Individual back issues of JGE are available at $8 each from the same address. Questions about NAGT programs can be addressed to NAGT President Heather Macdonald (heather@asci. wm.edu) or Vice President Barbara Tewksbury (btewksbu@hamilton.edu).

The *Journal of Geoscience Education* is a real deal and is the only journal devoted to improving geoscience education. We invite you to subscribe and to explore great ideas for great teaching! ■

INTERNATIONAL DIVISION NEWS

Pinar O. Yilmaz, Past President, International Division

1996 Officers of the International Division are President James W. Skehan, Boston College; First Vice-President Ian W. D. Dalziel, University of Texas at Austin; Second Vice-President Gabor Tari, Amoco Production Company, Houston; Secretary-Treasurer Suzanne Mahlburg Kay, Cornell University.

GSA International Division Notes Advantages of Industry Collaboration with Academia

The GSA International Division strives to establish relationships with overseas academic institutions and research centers in order to publicize their activities to GSA members. The petroleum industry has established communication and in some cases funded some of the research applicable to their exploration activities around the world. The International Division could enhance exposure of these groups in GSA and facilitate scientific interaction by forging ties between industry and academia during symposia at annual meetings and at other GSA-sponsored meetings.

The international petroleum industry is currently in the midst of a dynamic shift toward redefining the approach to exploration and production. Companies are smaller, research groups are more focused, and an increasingly large number of support activities are being outsourced. In many companies, both basic and applied research are being cut back sharply. Restructuring in the industry is coming at a time when public funding for research and training in the academic institutions is being cut. With overall long-term funding diminishing, researchers in universities and research laboratories are developing shorter term applied research projects. Industry-funded research programs, once thought to be on the fringe, are becoming more important in academic institutions.

The petroleum industry (Exxon, Shell, Mobil, Texaco, Amoco, Chevron, and others) supports academic research both at home and overseas. The industry needs to keep up with recent advances in science and technology, and can leverage its outsourced research studies for the added benefit of recruiting potential new hires. Academic institutions benefit by having access to unpublished data, facilities, and equipment, and may obtain funding for research activities.

Industry-funded research topics are as diverse as the industry itself: from hydrocarbon cracking kinetics to reservoir characterization to rock physics, as well as artificial intelligence. In general, most of these interdisciplinary projects are funded by a consortium consisting of the research institution itself, government, and one or more industry members. Members of the consortium provide guidance and direction given to the research, as well as specified products. Occasionally, foreign researchers are in the United States for consulting visits to the industry. For Exxon, some of the overseas centers involved in leveraged research include University of Nancy, France; Geological Institute of the Russian Academy of Sciences; Free University and Delft University of Technology, Netherlands; University of Reading, Petroleum Science Technical Institute, IBM UK Science Center, and Sander Geophysics, Ltd., United Kingdom; CSIRO—Canberra, Australia; KFA, Norway; and University of Calgary, Canada. This listing expands to include more countries if groups sponsored by other companies are added.

The International Division of GSA should be active in contacting these overseas centers and should attempt to include them in symposia planning for annual meetings. Travel support for key foreign researchers could be requested from the industry in a model similar to that used by the American Association of Petroleum Geologists and the Society of Economic Geologists. These organizations have forged industry-academia bonds, and similar relationships should work well for the International Division of GSA. ■

AGID Scholarship Opportunity for Field Work by International Students

The Association of Geoscientists for International Development (AGID) offers several opportunities that might be of some interest to International Division members. One is the William Greenwood Memorial Scholarship Fund. The fund was established in memory of Bill Greenwood, a Councilor of AGID at the time of his death. Twenty awards were made in 1994 to students in eight countries in Asia, Africa, and Latin America, in support of field work related to their graduate thesis projects. The awards are small, only US$100-300 each, but of great help to the recipients. One of the most rewarding aspects of Vice President Sandra Barr's work with AGID has been the letters received from these students. Reports on some of these projects have been included in the first issue of *Geoscience and Development* (formerly *AGID News*), which was published in Uruguay with help from UNESCO.

Donations to the William Greenwood Memorial Scholarship Fund are welcome, and can be sent to Sandra Barr (Dept. of Geology, Acadia University, Wolfville, N.S. B0P 1X0, Canada) by check or money order made payable to AGID. ■

New Honorary Fellows

Two eminent scientists, P. G. Cooray and Ferenc Horvath, the newly named GSA Honorary Fellows, exemplify the spirit of international cooperation that sparks progress in the geosciences.

Percival Gerald Cooray

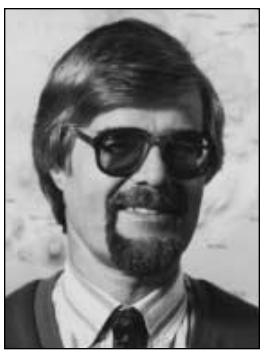
Cooray's 40 year career in geoscience has included detailed mapping of Sri Lanka and authorship of the standard reference book on the country's geology, teaching in Southeast Asia and Africa, and research on charnockites.

Cooray, born in Kuala Lumpur, Malaysia, in 1920, earned a B.A. Honors in geography, a B.Sc. in geology, and a Ph.D. in geology at the University of London, and a Diploma of Imperial College (University of London) in geology. He has taught at the University of Ceylon, the University of Ife (Nigeria), the University of Zambia, and King Abdulaziz University (Saudi Arabia); he is currently a visiting lecturer in the Department of Geology at the University of Peradeniya in Sri Lanka.

While doing research and writing on, especially, the geology and mineral resources of Sri Lanka, Cooray has also worked to further international cooperation in geoscience. He has been on the Council and served as president of the Association of Geoscientists for International Development (AGID), initiated the first Geological Congress of South Asia, served on the International Geological Correlation Program Scientific Committee, and chaired the organizing committee for the second Geological Congress of South Asia.

He has written papers and books on such diverse topics as earth slips, sand deposits, mica ages in gneiss, and geoscience and development. His book *Geoscientific Writing and Editing*, published by AGID in 1987, continues to be a best seller, and he has used it in his workshops on writing and editing in Sri Lanka, India, Pakistan, Bangladesh, Malaysia, and Zambia.

As a field mapper, scholar, and teacher, Cooray has applied his knowledge and ability to furthering societal welfare in his part of the world and fostering communication of geological knowledge to the rest of the world. ■



Ferenc (Frank) Horvath

Combining study of the European Pannonian basin, teaching, and promotion of international scientific cooperation, Frank Horvath has made significant and lasting contributions to geoscience knowledge.

Hungarian born (1944) and educated (Ph.D., Eotvos University, Budapest), Horvath teaches at Eotvos while doing research in tectonics and environmental geology and basin analysis and hydrocarbons. He was co-editor of *The Pannonian Basin—A Study in Basin Evolution* (American Association of Petroleum Geologists, 1988), still the principal multidisciplinary reference on the evolution of that basin. The book was an outgrowth of a major project between the Massachusetts Institute of Technology and Eotvos University. Previous collaborations involved Italian and British scientists studying the tectonics and geologic evolution of the Mesozoic continental margin in Europe. His international scientific activity has included participation in the International Geodynamics Project, co-chairing the International Lithosphere Program Task Force on the Origin of Sedimentary Basins, coordinating the European community project Advanced Training in Geology (Eotvos University, University of Karlsruhe, and Free University of Amsterdam), and promoting the proposed EuroProbe seismic profiling project across the Carpathian Mountains and Pannonian basin. He has applied his multidisciplinary research in regional- and prospect-scale evaluations of hydrocarbons in the Carpathian-Pannonian region.

Committed to educating geoscience students in Hungary, Horvath has paved the way for many of those students to do graduate and postdoctoral work in western Europe and the United States. He teaches practical application of the general principles and theory, bringing modern concepts to the traditional eastern European education system.

Horvath has organized numerous conferences in Hungary and elsewhere. He has served on the editorial boards of *Tectonophysics* and *Terra Nova*, and he received an award for an educational television series on earth science. He is currently on the executive council of the European Union of Geosciences.

Undeterred by political obstacles, Horvath has promoted international geological cooperation, and through his work he has fostered contacts between the Hungarian petroleum industry and the academic world in Hungary and elsewhere. ■

Honorary Fellowship

GSA Honorary Fellows, geoscientists who have distinguished themselves in geological investigations or in notable service to the Society, are nominated by Members or Fellows; five letters of support are required for each nomination. The GSA Council considers the nominations and gives final approval. Nearly all Honorary Fellows are non–North American and live and work outside of North America. Most have been elected after many years of outstanding and internationally recognized contributions to the science.

The deadline for 1996 nominations is February 1, 1996. Nomination forms and procedures are avaialble by contacting: Executive Director, Geological Society of America, P.O. Box 9140, Boulder, CO 80301, (303) 447-2020, fax 303-447-1133.

New GSA Members

The following 704 Members were elected to membership by council action during the period from April 1995 through October 1995.

Andrew P. Abban
Mark B. Abbott
Martin Acaster
Andrew B. Aceves
Kurt N. Addington
Brian R. Adkins
Rhonda M. Adkins
Gerardo J. Aguirre-Diaz
Moses L. Alcala
Kambra M. Allen
Mead A. Allison
Susan J. Altman
Carlos A. Alvarez
Dorothea Ames
Chris Y. Anani
Diana Elder Anderson
Vassilia Angelaki
Marco Antonellini
John G. Arnason
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Daniel K. Asiedu
Aida A. Awad
Nina L. Baghai
Taixu Bai
Eugene M. Bailer
Scott W. Bailey
Steven D. Balsley
Huiming Bao
Chris A. Barker
Sharon L. Barker
Robert F. Barminski, Jr.
Walter A. Barnhardt
Mark L. Barnhill
R. Keith Barnhill
Douglas Barrie
Susanne Barth
Julie K. Bartley
Colleen A. Barton
Carl P. Bastian
Jeffrey K. Bates
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New Members
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New GSA Fellows

The following 22 Members were advanced to Fellowship in November 1995.

Ina B. Alterman
Robert W. Baker
Jon C. Boothroyd
James R. Burnell, Jr.
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B. Neil Church
J. Allan Donaldson
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Eric R. Force
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Michael E. Hohn
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Ernest A. Mancini
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Donald I. Siegel
James T. Teller
P. C. Thurston
E. Bruce Watson
Frederic H. Wilson

BOOK REVIEWS

Dolomites. A Volume in Honor of Dolomieu. *International Association of Sedimentologists Special Publication 21. Edited by Bruce Purser, Maurice Tucker, and Donald Zenger. Blackwell, Oxford, UK, 1994.*

This volume is a compilation of 24 articles presented at the Dolomieu Conference on Carbonate Platforms and Dolomitization held in September 1991 at Ortisei, Italy, to celebrate the 200-year anniversary of the publication of Dolomieu's historic paper describing dolomite. Editors Purser, Tucker, and Zenger have together accumulated a vast experience and in-depth knowledge of carbonate rocks and are well suited for presenting this selection of articles on dolomites and dolomitization processes. Despite the considerable volume of papers and books on dolomite, a significant number of problems and unanswered questions on the topic remain. This volume is not a comprehensive review of the present-day knowledge of the dolomite problem; rather, the editors have chosen to present an extensive selection of what should become reference articles on key problems discussed at the Ortisei conference, with a specific emphasis on post-Paleozoic dolomitization cases.

Dolomites provides detailed examples of well-studied dolomitization models, sabkha-evaporitic-reflux dolomitization (four papers), mixing-zone and sea water dolomitization (three papers) and burial dolomitization (five papers), and also focuses on other important subjects such as dolomite reservoirs (three papers), petrology and geochemistry of dolomites (four papers), and the relations between dolomitization and organic matter (two papers). In the Introduction chapter (three papers), the editors nicely summarize and discuss dolomite research in terms of its present state, including recent progress, remaining gaps in knowledge, and future developments. The geo-historical article on the scientific and adventurous life of Déodat de Dolomieu is particularly enjoyable. On the other hand, the summary article presented at the end of the Introduction appears redundant and of little use to the reader, each article having an abstract. More useful would be an article in which the editors would have placed the dolomitization problem in a more global geological context (climate, eustasy, tectonics, stratigraphy, basin hydrogeology). This global perspective appears to be missing in this volume, where interesting specific dolomitization examples are presented case by case, without a real link between them. Some readers may regret that the puzzling problem of dedolomitization is not even mentioned in this volume.

The articles, all of high scientific standard, are well written (thus easy to read) and are illustrated by high-quality photographs, charts, and figures. There seems to be in this volume a will, especially by some authors, to really attempt to quantify dolomitization processes. Most of the articles are supported by detailed field and petrographic observations and by ample geochemical measurements of stable and Sr isotopes as well as some trace elements. If all the authors, not just

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New GSA Student Associates

The following 162 Student Associates became affiliated with the Society during the period from April 1995 through October 1995.

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John-Paul Zonneveld
Haibo Zou ■

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some, would present and discuss their analytical data in the form of tables as well as graphs, it would be much easier for the reader to evaluate their data. The case studies chosen for this volume come from a broad range of geographic locations, depositional environments, geologic ages, and tectonic settings.

Dolomites will quickly become the "bedside companion" of every carbonate geologist. Unfortunately, because it fails to present dolomite and dolomitization in a global geological perspective, this book's popularity will probably be restricted to sedimentary petrographers. Because of its organization, scope, and level of detail, the volume is an ideal tool for teaching an advanced sedimentary petrography class or a graduate seminar on the subject of carbonate petrology.

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Earth's Glacial Record. *Edited by M. Deynoux, J. M. G. Miller, E. W. Domack, N. Eyles, I. J. Fairchild, and G. M. Young. Cambridge University Press, Cambridge, UK, 1994, 266 p., $89.95.*

Earth's Glacial Record is the product of IGCP Project 260 of the same name. The book comprises 19 papers that deal with glacial sedimentology, examining familiar questions such as whether a diamictite is glacial or of some other origin, such as a gravity deposit, and also examining interesting new questions such as the significance of carbonates and stable isotopes in carbonates associated with glacial deposits. In their preface, the editors of this volume state, "Now glacial sedimentology has joined the mainstream of sedimentology" (p. xv). That glacial sedimentology has become mainstream is best demonstrated by the use of several standard references in almost every contribution to the volume. Sixteen of the 19 papers are about Late Proterozoic and late Paleozoic glacial sequences, two papers are about glacial processes, and one is about tectonics and glaciation. This last paper, which constitutes Chapter 1, demonstrates another important truth: that our improved understanding of glacial sedimentology allows us more confidence in testing hypotheses of global tectonic and climatic change for such ancient times as the Late Proterozoic.

Earth's Glacial Record is well written and very well edited. It should be read by a much wider audience than just glacial sedimentologists.

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Oshkosh, WI 54901-8649

Venus: The Geological Story. *Peter Cattermole. Johns Hopkins University Press, Baltimore, 1994, $49.95.*

This book is relevant to all geologists interested in the history of Earth and processes of global tectonism and volcanism. There are several reasons why a book about Venus should be of general geologic interest. First, Venus is a geological museum of volcanism and tectonism. Or to put it as John Guest, one of the Magellan mission scientists and a GSA Planetary Geology Division G. K. Gilbert awardee, is fond of saying, "Venus is a volcanologist's paradise and a tectonic geologist's nightmare." The beauty and variety of volcanic centers and volcanic features on Venus are such that it is impossible not to learn something new about volcanism from the study of the surface of Venus, which is otherwise unobservable on Earth, and the complexity of tectonic features on Venus, including faulting, folding, and multiphase deformation in bizarre terrains such as tessera, is such that unraveling the tectonic story of just a small area is a direct challenge to the skills of the best tectonic geologist. Second, Venus appears to have a global tectonic style that differs from Earth. It does not involve plate tectonics, for the most part, and is best described as intraplate in character, or hot-spot–style tectonism. This alone may yield clues to tectonic styles of pre–plate-tectonic Earth and certain aspects of continental and plate interior deformation. Although recent proposals relate hot spots and large-scale igneous provinces to plate motions on Earth, nearly identical patterns and clustering of hot spots occur on Venus in the absence of apparent plate motion. There may be a message here for our understanding of the geometry, mantle melting events, and convection in planets in general. Third, there is increasing evidence to support the presence of at least one "catastrophic" global tectonic and volcanic event in the history of Venus, or a brief burst of activity planet-wide that completely resurfaced it in a geologically short period of time. In the history of geology as a science, there have been frequent allusions to possible global "episodes" of tectonism, but arguable evidence. The lesson here may be that some of the possible discontinuities in tectonic style and global history of Earth may hearken to similar global "catastrophic" episodes in Earth's past as yet unresolved. In short, Venus is another experimental result in a science, terrestrial geology, notable until now for its necessary monoscopic attention to one geology.

Short of reading the original papers, this is the best text for the interested geologist to use in gaining some familiarity with Venus and some of these insights for understanding Earth.

Although *Venus: The Geological Story* may not read like a story, it is nonetheless in part a chronological story of the geological exploration of Venus. Because most of this story has unfolded in the past few years, this book is mostly about the results of the last (Magellan) mission to that planet and only partly about events and explorations leading up to that mission. Although many specialists in the study of Venus may find minor quibbles and oversimplifications in the text,

Book Reviews *continued on p. 256*

Final Announcement

SOUTH-CENTRAL SECTION, GSA
30th Annual Meeting

Austin, Texas
March 11–12, 1996

The Department of Geological Sciences at the University of Texas at Austin will host the 30th meeting of the South-Central Section. The meeting will be held on campus, during spring break week. Scientific sessions start at 8:00 a.m., Monday, March 11, and conclude at 5:00 p.m., Tuesday, March 12.

LOCATION

Austin is located where the Colorado River cuts through the Balcones escarpment, formed by the normal fault system that marks the southeastern edge of the Texas Hill Country. Austin, the 23rd largest city in the nation, has a population of 514,000, with 963,000 in the metropolitan area. Since the early 1980s, the region has had one of the fastest growing economies in the United States, with expansion driven largely by growth of high-tech industries. Thirty miles of urban hike-and-bike trails wind their way through more than 11,000 acres of park land. Austin is known by many as the "live music capital of the world," with dozens of night spots along the nine-block stretch of historic Sixth Street.

The city is located along IH-35 approximately 200 miles south of Dallas and 80 miles north of San Antonio. The airport is only a 15-minute drive from campus. Dozens of hotels and numerous fine restaurants are readily accessible by car or taxi. The average temperature in early March is 60 °F, with a 20% chance of a rain shower.

REGISTRATION

PREREGISTRATION DEADLINE: FEBRUARY 9, 1996

Anyone wishing to attend the technical sessions, exhibits, or field trips, must register for the meeting. Preregistration can be accomplished by returning the attached preregistration form with payment prior to February 9, 1996. Preregistrants will be mailed their badges and tickets. The meeting program and other materials will be available for pickup from a specially designated area at the information and registration desk.

On-Site Registration. For those who cannot preregister, on-site registration will be available Sunday, March 10, from 4:30 to 8:00 p.m; Monday, March 11, from 7:30 a.m. to 4:30 p.m.; and Tuesday, March 12, from 7:30 to 11:30 a.m. Credit cards will NOT be accepted for on-site registration.

A limited quantity of *Abstracts with Programs* for the meeting and guidebooks will be available for purchase at the information and registration desk.

REGISTRATION FEES

	Advance*	On-site
Professional—		
Member	$50	$60
Nonmember	$55	$65
Student—		
Member	$15	$25
Nonmember	$20	$30
K–12 Teachers	$15	$15
Guest or Spouse	$10	$10

Deadline is February 9, 1996.

Cancellations, Changes, and Refunds. All requests for registration additions, changes, and cancellations must be made in writing and received at the GSA Meetings Department in Boulder by February 16, 1996. Faxes will be accepted. NO REFUNDS WILL BE MADE ON CANCELLATIONS RECEIVED AFTER FEBRUARY 16, 1996. Refunds will be mailed after the meeting, and fees paid by credit card will be credited according to the card number on the preregistration form. NO refunds will be given for on-site registration and ticket sales.

STUDENT PAPER AWARDS AND TRAVEL GRANTS

Awards will be presented for the Best Oral Student Paper and Best Student Poster at the meeting. Awards will be based on quality of research and effectiveness of presentation. To be eligible, the abstract must list only student authors and must be identified clearly as a student paper.

Limited funds for support of travel expenses for students presenting a paper (oral or poster) at the meeting are available from the GSA South-Central Section. For information, contact meeting chair Mark Cloos, Department of Geological Sciences, University of Texas, Austin, TX 78712, (512) 471-4170, fax 512-471-9425, E-mail: cloos@maestro.geo.utexas.edu. Travel grant requests must be postmarked no later than February 9, 1996.

STUDENT POSTER SESSION

The Geology Division of the Council on Undergraduate Research will sponsor a student poster session to showcase senior theses and other undergraduate research projects. First authors must be undergraduate students and are responsible for the bulk of the research, preparation of the poster, and presentation of the results. For more information, contact Diane R. Smith, Department of Geosciences, Trinity University, 715 Stadium Dr., San Antonio, TX 78212-7200, (210) 736-7656, fax: 210-736-8264, E-mail: dsmith@earth.mms.trinity.edu.

TECHNICAL PROGRAM

Papers are invited for presentation at oral technical sessions, symposia, and poster sessions. Papers dealing with the geology of the South-Central region (Texas, Oklahoma, Arkansas, and surrounding areas) are especially encouraged. Except for special presentations arranged by symposia organizers, oral presentations will be limited to 17 minutes with 3 minutes for questions. Poster sessions will be set up for four hours and authors will be available for at least two hours to discuss their work. Abstracts volunteered for but not included in a symposia will be considered for regular technical sessions.

Symposia

Symposia conveners have invited a group of speakers for these sessions. Volunteered talks are also highly encouraged for these topics.

1. **NAGT Symposium—Planetary Geology in Geological Education.** James L. Carter, Programs in Geosciences, University of Texas at Dallas, Richardson, TX 75083, (214) 883-2455, fax 214-883-2537; and Donald H. Lokke, Math and Science Division, Richland College, Dallas, Texas, (214) 239-7920.
2. **Records Preserved in Carbonate Rocks: Cycles, Ocean Chemistry, Sedimentation, and Diagenesis.** Brenda Kirkland-George, Department of Geological Sciences, University of Texas, Austin, TX 78712, (512) 471-5129, fax 512-471-9425, E-mail: kirkland@maestro.geo.utexas.edu; and Jay Banner, Department of Geological Sciences, University of Texas, Austin, TX 78712, (512) 471-5016, fax 512-471-9425, E-mail: banner@maestro.geo.utexas.edu.
3. **Caribbean Tectonics.** Larry Lawver, University of Texas Institute for Geophysics, 8701 MoPac North, Austin, TX 78759, (512) 471-6156, fax 512-471-8844, E-mail: larry@utig.ig.utexas.edu.
4. **High-Resolution Analysis of Coastal Processes and Geomorphic Change.** Robert A. Morton, Texas Bureau of Economic Geology, University Station Box X, University of Texas, Austin, TX 78712, (512) 471-1534, fax 512-471-0140, E-mail: mortonr@begv.beg.utexas.edu.
5. **Fractured Aquifers and Petroleum Reservoirs.** Steve Laubach, Texas Bureau of Economic Geology, University Station Box X, University of Texas, Austin, TX 78712, (512) 471-1534, fax 512-471-0140, E-mail: laubachs@begv.beg.utexas.edu.
6. **Invertebrate Paleontology of the South-Central Region.** James Sprinkle, Department of Geological Sciences, University of Texas, Austin, TX 78712, (512) 471-4264, fax 512-471-9425.
7. **Karst Hydrogeology.** Neven Kresic, Department of Geology, Texas Christian University, Forth Worth, TX 76129, (817) 921-7506, fax 817-921-7789, E-mail: kresic@gamma.is.tcu.edu.
8. **Late Cretaceous–Early Tertiary Stratigraphy and Paleontology in Northeastern Mexico.** Richard Buffler, University of Texas Institute for Geophysics, 8701 MoPac North, Austin, TX 78759, (512) 471-0448, fax 512-471-8844, E-mail: dick@utig.ig.utexas.edu; Kris Soegaard, Programs in Geosciences, P.O. Box 830688, University of Texas at Dallas, Richardson, TX 75083, (214) 883-2415, E-mail: soegaard@utdallas.edu; and Francisco J. Vega, Inst. Geológica, UNAM, México D.F., 04510, México, E-mail: vegaver@servidor.unam.mx.
9. **Origin and Evolution of the Ouachita Embayment.** Ian Dalziel, University of Texas Institute for Geophysics, 8701 MoPac North, Austin, TX 78759, (512) 471-6156, fax 512-471-8844, E-mail: ian@utig.ig.utexas.edu.
10. **Precambrian Evolution of the Southwestern Laurentian Continent.** Calvin Barnes, Department of Geology, Texas Technological University, Lubbock, TX 79409, (806) 742-3102, fax 806-742-0100, E-mail: gical@ttacs.ttu.edu; Sharon Mosher, Department of Geological Sciences, University of Texas, Austin, TX 78712 (512) 471-4135, fax 512-471-9425, E-mail: mosher@maestro.geo. utexas.edu; and Kent C. Nielsen,

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Housing Form–
Holiday Inn—Town Lake, Austin, Texas

South-Central Section • Geological Society of America
Sunday, March 10–Tuesday, March 12

Arrival Date _____ Departure Date _____

Arrival Time _____ Via Car or Airplane (circle one)

Person Requesting Housing (type or print)

Last Name _____ First _____

Institution or Firm _____

Address or P.O. Box Number _____

City _____ State/Province _____ ZIP _____

Phone: Day ( ) _____ Home ( ) _____

Sharing room with _____

Type of room	rate per day
Single	$72
Double	$72

Smoking Nonsmoking (circle one)

- *First night's deposit or credit information must accompany reservation.*
- *Credit card deposits will be processed 14 days prior to arrival.*
- *Refund of deposit will be honored 14 days prior to arrival.*
- *Rooms may not be available for occupancy until 3 p.m. on day of arrival.*
- *Check out time is 12:00 noon.*

If your reservation is not received by February 9, 1996, availabilty cannot be guaranteed.

Telphone reservations accepted:

(512) 472-8211 fax 512-472-4636

Type of Card _____ Card Number _____

Exp. date _____ Signature _____

Send this form and remittance or credit card information to:
Reservations Department, Holiday Inn, Austin—Town Lake, 20 N. IH-35, Austin, TX 78701

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Programs in Geosciences, University of Texas, Dallas, (214) 883-2401, fax 214-883-2537, E-mail: knielsen@utdallas.edu.

11. **Principles and Practice of Hydrogeology.** John M. Sharp, Jr., Department of Geological Sciences, University of Texas, Austin, TX 78712, (512) 471-3317, fax 512-471-9425, E-mail: jsharp@maestro.geo.utexas.edu; Alan R. Dutton, Bureau of Economic Geology, Austin, (512) 471-1534, fax 512-471-0140, E-mail: duttona@begvbeg.utexas.edu; and Ridge Kaiser, R. W. Harden and Associates, 3409 Executive Center Dr., Suite 226, Austin, TX 78731, (512) 345-2379, fax 512-338-9372.

12. **Restructuring Geoscience Education for the 21st Century.** Bob Pinker, Johnson County Community College, (913) 469-3894; and Phil Kehler, Department of Geology, University of Arkansas, Little Rock, AR 72204, (501) 569-3545, fax 501-569-3271, E-mail: pkehler@ualr.edu. *Symposium cosponsored by NAGT Mid-Continent Section and GSA South-Central Section Geoscience Education Division.*

13. **The Ronald K. DeFord Symposium on the Stratigraphy and Structure of Trans-Pecos Texas.** Donald F. Reasor, Department of Geology, University of Texas at Arlington, Box 19049, Arlington, TX 76019-0049, (817) 273-2987; Page Twiss, Department of Geology, Kansas State University, Manhattan, (913) 532-6724, fax 913-532-5159; and James Underwood, Department of Geology, Kansas State University, Manhattan.

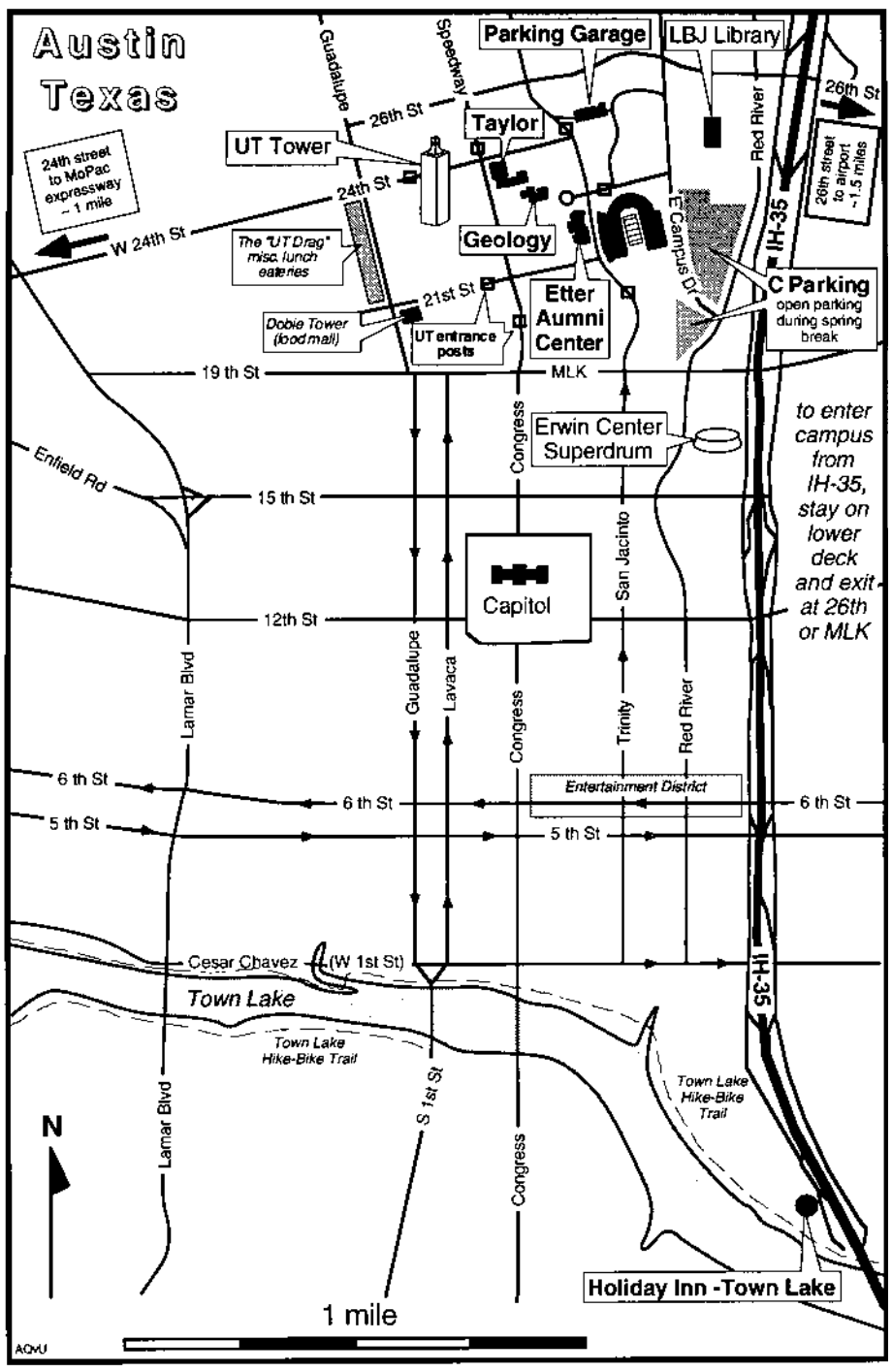
14. **Tertiary Tectonics of the South-Central Region.** Randy Marrett, Department of Geological Sciences, University of Texas, Austin, TX 78712, (512) 471-4885, fax 512-471-9425, E-mail: marrett@maestro.geo.utexas.edu.

15. **Unsaturated Zone Hydrology.** Bridget Scanlon, Texas Bureau of Economic Geology, University Station Box X, University of Texas, Austin, TX 78712, (512) 471-1534, fax 512-471-0140, E-mail: scanlonb@begv.beg.utexas.edu.

16. **Vertebrate Paleontology of the South-Central Region.** Ernie Lundelius, Department of Geological Sciences, University of Texas, Austin, TX 78712, (512) 471-6088, fax 512-471-9425, E-mail: erniel@maestro.geo.utexas.edu; and Tim Rowe, Department of Geological Sciences, University of Texas, Austin, TX 78712, (512) 471-1725, fax 512-471-9425, E-mail: rowe@maestro.geo.utexas.edu.

17. **Quaternary Geology and Paleoenvironments.** Tom Gustavson, Texas Bureau of Economic Geology, University Station Box X, University of Texas, Austin, TX 78712, (512) 471-1534, fax 512-471-0140, E-mail: gustavsont@begv.beg.utexas.edu; and Steve Hall, Department of Geography, University of Texas, Austin, TX 78712, (512) 471-5116.

18. **Biological Tools for Water Quality and Hydrologic Assessment.** C. Evan Hornig, J. Bruce Moring, and Lynne Fahlquist, Water Resources Division, U. S. Geological Survey, 8011 Cameron Road, Austin, TX 78754-3898, (512) 873-3008, fax 512-873-3090, E-mail: lfahlqst@servdtxast.cr.usgs.gov.



POSTER SESSIONS

Three half-day poster sessions are planned. We encourage poster contributions because they permit extended discussion. Please indicate your preferences for a poster session on the GSA abstract form.

WORKSHOPS

Steve Laubach will hold a premeeting, one-day workshop on "New Methods to Quantify Fracture Attributes in Deeply Buried Clastic Rocks." For more information, contact Steve at the Texas Bureau of Economic Geology, University Station Box X, University of Texas, Austin, TX 78712, (512) 471-1534, fax 512-471-0140, E-mail: laubachs@begv.beg.utexas.edu.

Tim Rowe will hold a premeeting, one-day workshop on "Computer Multimedia in Paleontology." This workshop will demonstrate recently developed multimedia applications for both research and education in paleontology, including The Age of Dinosaurs CD-ROM and Thrinaxodon: Digital Atlas of the Skull CD-ROM. It will then present a step-by-step overview of how to build your own CD-ROM, including digitizing techniques, multimedia authoring systems, and CD-ROM pre-mastering. For more information, contact Tim at the Department of Geological Sciences, University of Texas, Austin, TX 78712, (512) 471-1725, fax 512-471-9425, E-mail: rowe@maestro.geo.utexas.edu.

FIELD TRIPS

All trips start and end in Austin. Trip fees include all transportation during the trip, including transportation to and from Austin, and a guidebook. Other included costs are noted by B—breakfast, L—lunch, D—dinner, and ON—overnight lodging. Please contact the trip leaders for additional information.

Premeeting Trips

Trip 1. **Precambrian Geology of the Eastern Llano Uplift, Central Texas.** Saturday, March 9, and Sunday, March 10. Sharon Mosher (512) 471-4135, fax 512-471-9425, E-mail: mosher@maestro.geo.utexas.edu; Robert C. Roback, Daniel S. Barker, and Rob Reed, Department of Geological Sciences, University of Texas, Austin, TX 78712; Joe Reese, Idaho State University; and Diane Smith, Trinity University. Cost: $150 (2 ON, 2 B, 2 L, 2D). The trip will leave Austin on Friday evening (March 8) at 5:00 p.m. and will return late afternoon Sunday (March 10).

This two-day trip to the Middle Proterozoic Llano Uplift will highlight results from recent geochronological and structural research which has defined a polydeformed, highly transposed supracrustal sequence situated between a lesser deformed tonalitic to dioritic island-arc terrane and a polydeformed granitic gneiss terrane and from recent work on the late syn- to post-tectonic granites.

Trip 2. **Quaternary Alluvial Deposits of the Colorado River, Texas Gulf Coastal Plain.** Saturday, March 9, and Sunday, March 10. Mike Blum, Department of Geology, University of Nebraska—Lincoln, P.O. Box 880340, Lincoln, NE 68508, (402) 472-7872, fax 402-472-4917, E-mail: mblum@unl.edu. Maximum: 20. Cost: $110 (1 ON, 2 L).

This two-day trip will examine Quaternary alluvial deposits of the Colorado River, a major source for sediment input into the Gulf of Mexico basin. The first day will focus on late Pleistocene and Holocene deposits, and the second on middle to late Pleistocene Beaumont strata. Topics to be discussed include allostratigraphic and chronostratigraphic frameworks, facies, paleosols, and the roles of climate change vs. glacio-eustasy in development of alluvial successions.

Trip 3. **Cretaceous Cyclic Platform Carbonates of Central Texas.** Sunday, March 10. Brenda Kirkland-George and Jay L. Banner, Department of Geological Sciences, University of Texas, Austin, TX 78712, (512) 471-5129 (Kirkland), (512) 471-5016 (Banner), fax 512-471-9425, E-mail: kirkland@maestro.geo.utexas. edu; banner@maestro.geo.utexas.edu. Cost: $30. (1 L).

This one-day field excursion will examine the stratigraphy and depositional environments of cyclic, shallow-water platform carbonates of Albian-Aptian age in central Texas. Vertical sequences through tidal flat, lagoonal, and shelf deposits that formed on the margin of the ancestral Gulf of Mexico will be studied in riverbed, quarry, roadcut, and front-yard exposures. Features of the localities to be visited include: hardground surfaces, a rudist biostrome, teepee(?) structures, porosity development in strata that comprise a regional aquifer, and contrasting styles of parasequence cyclicity and dolomitization across a sequence boundary.

Trip 4. **Edwards Aquifer, Central Texas.** Sunday, March 10. John M. Sharp, Jr., Department of Geological Sciences, University of Texas, Austin, TX 78712, (512) 471-3317, fax 512-471-9425, E-mail: jsharp@maestro.geo.utexas.edu; and Nico Hauwert, Barton Springs/Edwards Aquifer Underground Water Conservation District. Cost: $45 (1 L).

This one-day trip will show the discharge area (Barton Springs), recharge features, and important hydrostratigraphic features of the Edwards aquifer in the Austin area. Special consideration will be given to the effects of urbanization (including sedimentation), the spring system biota, estimation of recharge, and problems of land-use planning. This trip will also examine several characteristic stratigraphic sections.

Postmeeting Trips

Trip 5. **Late Cretaceous–Early Tertiary Stratigraphy and Paleontology of Northeast Mexico.** Wednesday, March 13 to Saturday, March 16. Francisco Vega Vera, Universidad Nacional Autónoma de México, E-mail: vegver@servidor.dgsca.unam. mx; Katherine Giles, New Mexico State University, kgiles@nmsu.edu; and Kristian Soegaard, Department of Natural Sciences and Math, University of Texas at Dallas, Richardson, TX 75083, (214) 883-2415, E-mail: soegaard@utdallas.edu. Trip leaves from Austin International Airport on March 13 (morning) and returns March 16 (evening). Maximum: 16. Cost: $785 (includes round-trip airfare from Austin, Texas to Monterrey, Nuevo Leon, Mexico), (3 ON). Proof of U.S. residency required for clearing customs in Mexico.

The La Popa and Parras basins, located between Saltillo, Monclova, and Monterrey in northeastern Mexico, form a complex foreland system to the thrust belt of the Sierra Madre Oriental. On this field trip to excellent exposures within these basins, we will examine lithostratigraphy, biostratigraphy, chronostratigraphy, and structural relations within the uppermost

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Cretaceous to Eocene Difunta Group. One day will be devoted to lithostratigraphy and sequence stratigraphy of fluviodeltaic and shallow-marine siliciclastic sedimentary rocks in the Parras basin. Two days will be spent studying paleontology and biostratigraphy of several K-T and Paleocene-Eocene boundary sections in the northern Parras and La Popa basins. In the La Popa basin, we will examine the structure and stratigraphic relations of diapir-related growth strata which provide evidence for timing of both halokinesis and thrust tectonism, as well as controls on carbonate deposition in this otherwise siliciclastic dominated foreland. The overall objective of the field trip is to present an integrated stratigraphic correlation between the Parras and La Popa basins which in turn sets the stage for new interpretations of tectonic setting and timing of deformation in the Sierra Madre Oriental fold-and-thrust belt and adjacent foreland.

PROJECTION EQUIPMENT

All slides must be 2″ × 2″ and fit a standard 35 mm carousel tray. If possible, please bring your own loaded carousel trays. Two 35 mm slide projectors and two screens will be available for each oral technical session. Overhead projectors will not be available. A speaker ready room equipped with projectors will be available.

ACCOMMODATIONS

A block of 100 rooms has been reserved at a special rate for meeting participants and their guests at the Holiday Inn—Town Lake. This hotel, located on the shore of scenic Town Lake southeast of downtown Austin, is approximately 2.5 miles south of the site of the meeting and 4 miles from the airport. The Sixth Street entertainment district and Town Lake Hike-and-Bike trail are nearby. Please use the attached housing form to obtain the special rate of $72 per day for a single or double room at this hotel.

There are numerous other motels in Austin at which meeting attendees may arrange their own accommodations. Establishments near and north of campus along the IH-35 corridor include: Rodeway Inn—University, 2900 N. IH-35, (512) 477-6395; Days Inn—University, 3105 N. IH-35, (512) 478-1631; Motel 6—Airport, 5330 N. IH-35, (512)467-9111; Ramada Limited—Airport, 5526 N. IH-35, (512) 451-7001; Drury Inn—Austin North, 6511 N. IH-35, (512) 467-9500.

PARKING AND MEALS

During spring break, there is open parking in the student C lots east and south of the football stadium. Do NOT park in faculty F or staff A lots on Monday or Tuesday, because all places are reserved for cars with appropriate stickers. Ticketing of unauthorized cars by UT police is likely.

More than a dozen eating establishments should be open for lunch in a food court on the second floor of Dobie Tower on the corner of 21st and Guadalupe streets, located a 10–15 minute walk from the site of the meeting. In addition, there are a variety of restaurants along Guadalupe Street, better known as the "UT Drag."

GUEST PROGRAM

No formal guest program has been arranged. The 350-acre main campus of the University of Texas has numerous cultural facilities including the two Archer M. Huntington Art Galleries (located in the Art Building and the Harry Ransom Center), the Lyndon B. Johnson Presidential Library and Museum, and the Texas Memorial Museum. There is no admission charge to any of these facilities, which are located a short walk from the conference site. The Texas Capitol Complex, Governors' Mansion, French Legation, Treaty Oak, George Washington Carver Museum, Laguna Gloria Art Museum, O. Henry Museum, Austin Children's Museum, Austin Nature Center, Barton Springs Pool, Zilker Botanical Gardens, and the 10-mile Town Lake Greenbelt are all a short drive from campus. The Austin Convention and Visitors Bureau and the Historic Landmark Commission sponsor a two-hour walking tour of downtown Austin. Guided tours are also given at the newly renovated and expanded Texas Capitol. In the evening, the Sixth Street entertainment district offers a wide variety of live music and restaurants.

SPECIAL EVENTS

WELCOMING RECEPTION. A welcoming reception will be held on Sunday, March 10, from 7:00 to 9:00 p.m. at the Lila B. Etter Alumni Center, located on San Jacinto Boulevard across the street from the football stadium. Registration materials can be picked up at this event.

SPECIAL LECTURE. "Viewing the Earth from the Space Shuttle," W. R. Muehlberger, University of Texas at Austin, will present a special one-hour slide-filled lecture titled "Viewing the Earth from the Space Shuttle" at 5:00 p.m., Monday, March 11. Muehlberger was the chief geologist for the Apollo 17 lunar landing and has taught geology to all space shuttle astronauts. This lecture is open to the general public and should be of interest to all science teachers and many non-geologists. The lecture will be followed by the Texas Barbecue (tickets must be purchased in advance) at the Lila B. Etter Alumni Center.

TEXAS BARBECUE. A catered barbecue will be held in the Lila B. Etter Alumni Center building from 6:30 to 8:30 p.m. on Monday, March 11, immediately following the special lecture by W. R. Muehlberger. A cash bar will be open; tickets for the dinner must be purchased in advance. ■

Preregistration Form

GSA South-Central Section

Preregistration deadline is February 9, 1996.

Austin, Texas • March 11–12, 1996

Please print clearly • THIS AREA IS FOR YOUR BADGE

Name as it should appear on your badge (last name first)

Employer/University Affiliation

City | State or Country

Please inform us by February 16 of any special considerations that you or your guest require.

☐ I will need special considerations. Please call me.

Circle member affiliation (to qualify for registration member discount*):

(A) GSA Member #_____

(B) NAGT (C) PS (D) PANDER SOC.

(E) SEPM (F) SVP

Mailing Address (use two lines if necessary)

City | State | ZIP Code | Country (if other than USA)

GUEST INFORMATION • Please print clearly • This area is for badge

Name as it should appear on your guest's badge | City/State or Country

PREREGISTRATION *Required for participating in all activities.*

		Rate	Qty	Amount
Professional Member* (circle affiliation above)	(01)	$50 ☐	1	$ _____
Professional Nonmember	(03)	$55 ☐	1	$ _____
Student Member* (circle affiliation above)	(05)	$15 ☐	1	$ _____
Student Nonmember	(07)	$20 ☐	1	$ _____
K–12 Professional	(42)	$15 ☐	1	$ _____
Guest (per guest listed above)	(09)	$10 ☐	____	$ _____

*Member fee applies to any Professional or Student Member of GSA or Associated Societies listed above. Discount does not apply to guest registrants.

SPECIAL EVENTS

Annual Banquet Texas Barbecue	March 11	(20) $ 20	____	$ _____

FIELD TRIPS

1. Precambrian Geology, Eastern Llano Uplift, Central Texas	March 9–10	(101) $150	1	$ _____
2. Quaternary Alluvial Deposits, Colorado River, Texas Gulf Coastal Plain	March 9–10	(102) $110	1	$ _____
3. Cretaceous Cyclic Platform Carbonates, Central Texas	March 10	(103) $ 30	1	$ _____
4. Edwards Aquifer, Central Texas	March 10	(104) $ 45	1	$ _____
5. Late Creatceous–Early Tertiary Stratigraphy and Paleontology, NE Mexico	March 13–16	(105) $785	1	$ _____

TOTAL FEES ..... **$** _____

Remit in U.S. funds payable to:
1996 GSA South-Central Section Meeting
(All preregistrations must be prepaid. Purchase Orders not accepted.)

Payment by (check one): ☐ Check ☐ American Express ☐ VISA ☐ MasterCard

Card Number

Signature | Expires

MAIL TO: **GSA SOUTH-CENTRAL SECTION MEETING, P.O. BOX 9140, BOULDER, CO 80301**

FOR OFFICE USE

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Final Announcement

NORTHEASTERN SECTION, GSA
31st Annual Meeting

Buffalo, New York
March 21–23, 1996

The Deptartment of Geology, University at Buffalo (SUNY) together with the Buffalo Museum of Science and the SUNY Colleges at Buffalo and Fredonia will host the 1996 meeting of the Northeastern Section of the Geological Society of America at the Hyatt Regency Buffalo. Meeting in conjunction with the GSA Northeastern Section will be the Eastern Section of SEPM, Northeastern Section of the Paleontological Society, Eastern and New England Sections of the National Association of Geology Teachers, Sigma Gamma Epsilon, and the Association for Women Geoscientists. The meeting will start at 8:00 a.m. Thursday, March 21, and end at 12:00 noon, Saturday, March 23. Field trips and short courses will be held on Wednesday, March 20, and Saturday afternoon, March 23.

REGISTRATION

Registration is required for all who participate in any event at the meeting, including technical sessions, symposia, short courses, field trips, exhibits, and planned social events.

PREREGISTRATION DEADLINE: FEBRUARY 26, 1996

Advance registration is encouraged to aid the local committees in making final plans for the meeting. A preregistration discount is available to those who register using the form provided in this announcement. Advance registration is required for field trips and short courses. Return the completed registration form with full payment by check or money order in U.S. currency payable to: UB Foundation, 314 Crofts Hall, University at Buffalo, Buffalo, NY 14260-7015. Credit cards are also accepted; see preregistration form. For registration information, telephone (716) 645-3869.

Register one professional or student per form. Copy the form for your records. Requests for registration changes, cancellations, and refunds must be made in writing and received before February 26, 1996. Faxes will be accepted. NO refunds will be made on cancellation notices received after the preregistration deadline. A 10% service charge will be deducted for cancellation of registration.

On-Site Registration

For those who cannot preregister, on-site registration will be available on the mezzanine level, Hyatt Regency Buffalo*:
Wednesday, March 20, 5:00–9:00 p.m.
Thursday, March 21, 7:00 a.m.–noon
Friday, March 22, 7:00 a.m.–noon
Saturday, March 23, 7:00 a.m.–noon

The Northeastern Section of GSA is only able to accept credit cards for preregistration or on-site registration by charging a 7½% service fee.

A limited number of *Abstracts with Programs* for the meeting will be available for purchase at the information/registration desk.

*For remote sensing short course participants only, registration will be 7:00–10:30 a.m. at the Natural Sciences and Mathematics Complex, SUNY at Buffalo.

LOCATION

The Hyatt Regency Buffalo is a 16-story French Renaissance landmark with an attached contemporary glass atrium in the heart of downtown Buffalo. It is located on beautiful Lake Erie near the head of the Niagara River; scenic Niagara Falls is only 20 minutes north of Buffalo. Toronto is two hours to the northwest. Buffalo is served by I-90 and the QEW in Canada. These connect with I-190 or Route 33 leading to the downtown area. The Greater Buffalo International Airport is only 10 minutes northeast of downtown Buffalo via ITA shuttle (which leaves every hour on the hour) or taxi. Daytime average temperatures during March range from 30–47 °F; any combination of rain, snow, sleet, and sunshine are to be expected.

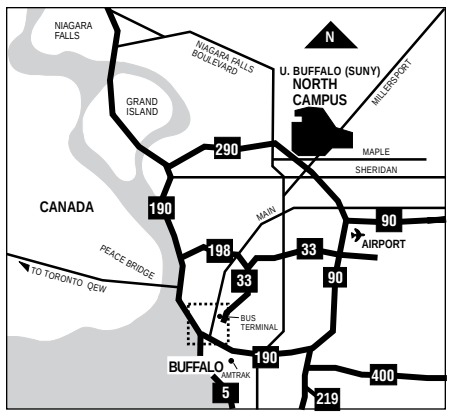
TECHNICAL PROGRAM

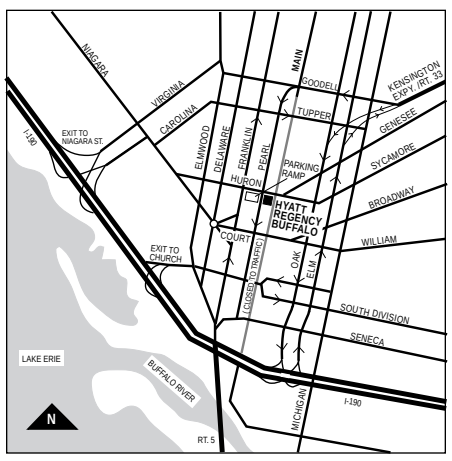
The technical sessions (oral and poster), symposia, and theme sessions will begin on Thursday, March 21, and end at noon on Saturday, March 23. Oral and poster sessions will be held in the Hyatt Regency Buffalo. General questions on equipment or format of sessions should be addressed to symposium coordinator and co–General Chair Robert Jacobi, Department of Geology, SUNY at Buffalo, 876 Natural Sciences Complex (NSM), Buffalo, NY 14260, (716) 645-6800, ext. 2468.

Oral general technical and theme sessions will include 15 minutes for presentation and 5 minutes for discussion. Two 35 mm carousel projectors and two screens will be provided for each oral session. All slides must fit into standard carousel trays. (Authors are encouraged to bring their slides already loaded into the circular trays.) Overhead projectors will be available on request. A speaker-ready room will be available for previewing slides and to supply additional carousel trays when necessary.

Poster sessions will allow at least three hours of display time, two of them specified when authors must be present. Two 4′ × 8′ tackboards will be provided. Electrical outlets or furniture for poster sessions must be specifically requested.

In addition to the general technical sessions dealing with all disciplines of geology and related fields such as water resources, hydrology, and environmental science, the following oral symposia and theme sessions, as well as special poster sessions, are planned for the Buffalo meeting.





Symposia

1. **Neotectonics of the Eastern and Central Great Lakes Region.** J. Wallach, Atomic Energy Control Board, Box 1046, Ottawa, Ontario K1P 5S9, Canada, (613) 995-2509.
2. **Toward a New Generation of Seismic Hazard Maps and Engineering Implications for North America**. K. Jacob, Lamont-Doherty Earth Observatory, Palisades, NY 10964, (914) 365-8440, jacob@lamont.ldgo.columbia.edu; A. Dargush, NCEER, SUNY at Buffalo, 107 Red Jacket Quad, Buffalo, NY 14261, (716) 645-3391, E-mail: nceer@ubvms.cc.buffalo.edu.
3. **Economic Mineral Deposits.** W. Kelly, New York State Geological Survey, Room 3140 CEC, Albany, NY 12230, (518) 474-7559, wkelly@museum.nysed.gov; R. Altamura, Dept. Geosciences, Pennsylvania State University, University Park, PA 16802, (814) 863-1665, E-mail: boba@gaia.essc.psu.edu.
4. **From Sandstone to Chaos: Processes in Sedimentology.** A Symposium in Honor of Gerald V. Middleton on his Retirement, 1996. R. Cheel, Dept. Geological Sciences, Brock University, St. Catherines, Ontario, L2S 3A1, Canada, (905) 688-5550, ext. 3512, E-mail: rcheel@craton.geol.brocku.ca.
5. **New 1:100,000 Bedrock Geology Map of Vermont: Progress and Preliminary Maps.** *See Special Poster Sessions.*
6. **Taconic Convergence: Orogen, Foreland Basin, and Cratonic Interactions.** C. Mitchell and R. Jacobi, Dept. Geology, SUNY at Buffalo, 876 NSM, Buffalo, NY 14260, (716) 645-6800, ext. 3991, E-mail: glgchuck@ ubvms.cc.buffalo.edu.
7. **Geochemistry and Tectonics in the Northern Appalachians.** R. Coish, Dept. Geology, Middlebury College, Middlebury, VT 05753, (802) 388-3711, ext. 5423, E-mail: coish@middlebury.edu.
8. **Metamorphism and Tectonics in the Northern Appalachians.** R. Tracy, Dept. Geological Sciences, 4044 Derring Hall, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, (703) 231-5980, E-mail: rtracy@vtvm.cc.vt.edu; R. Wintsch, Dept. Geological Sciences, Indiana University, Bloomington, IN 47405, (812) 855-4018, E-mail: wintsch@juliet.usc.indiana.edu.

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REGISTRATION FEES

	Advance*		On site	
	Full Meeting	One day	Full Meeting	One day
Professional—Member	$60	$35	$75	$45
Professional—Nonmember	$75	$40	$90	$50
Student—Member	$20	$20	$25	$25
Student—Nonmember	$30	$30	$35	$35
K–12 Earth Science Teachers	$30	$20	$40	$25
Guest/Spouse	$15	$15	$15	$15

Deadline is February 26, 1996.

Housing Form–
Hyatt Regency Buffalo, Buffalo, New York

Northeastern Section, Geological Society of America
Wednesday, March 20–Saturday, March 23, 1996

Arrival Date _____ Departure Date _____

Arrival Time _____ ☐ Car ☐ Airplane (flight #) _____

Person Requesting Housing (type or print)

Last Name _____ First _____

Institution or Firm _____

Address or P.O. Box Number _____

City _____ State/Province _____ ZIP _____

Phone: Day _____ Home _____

Sharing room with _____ Arrive date _____ Depart date _____

Rates per room (rates include 13% New York occupancy/state sales tax). **Indicate choice**

Type of Room	Per Day	Type of Room	Per Day
☐ Single	$85.00	☐ Triple	$89.00
☐ Double	$87.00	☐ Quad	$92.00

☐ King Bed
☐ Two Double Beds
☐ Smoking
☐ Nonsmoking

Preference (based on availability)

First night's deposit or credit information must accompany reservation. Credit card deposits will be processed 14 days prior to arrival. Refund of deposit will be honored 14 days prior to arrival. Rooms may not be available for occupancy until 3:00 p.m. on day of arrival. Check out time is 12:00 noon. If your reservation is not received by February 20, 1996, availabilty cannot be guaranteed.

Telphone reservations accepted:
(716) 856-1234 Toll-free (800) 233-1234 Fax: 716-856-6734

Type of card _____ Card number _____

Exp. date _____ Signature _____

Send this form and remittance or credit card information to:
Reservations Department, Hyatt Regency Buffalo, 2 Fountain Plaza, Buffalo, NY 14202

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9. **Bioevents and Sequence Stratigraphy**. (Sponsored by SEPM.) C. Brett, Dept. Geological Sciences, University of Rochester, 227 Hutchinson Hall, Rochester, NY 14624, (716) 275-2408, E-mail: cebh@db1.cc.rochester.edu.
10. **Faunal Succession and Speciation: The Role of Evolutionary and Ecological Replacement in Species Turnover.** (Sponsored by the Northeastern Section of the Paleontological Society.) C. Mitchell, Dept. Geology, SUNY at Buffalo, 876 NSM, Buffalo, NY 14260, (716) 645-6800, ext. 3991, E-mail: glgchuck@ubvms.cc.buffalo.edu.
11. **GIS, Geologic Maps and Public Policy.** R. Fakundiny, NYS Geological Survey, NYS Museum, 3136 Cultural Education Center, Albany, NY 12230, (518) 474-5816, E-mail: rfakundi@museum.nysed.gov.
12. **Hydrogeologic Aspects of Site Characterization and Remediation.** J. Fountain and C. Renshaw, Dept. Geology, SUNY at Buffalo, 876 NSM, Buffalo, NY 14260, (716) 645-6800, ext. 3996, E-mail: fountain@acsu.buffalo.edu.
13. **Fracture and Fault Characterization: Innovative Techniques and Interpretation.** R. Jacobi and J. Fountain, Dept. Geology, SUNY at Buffalo, 876 NSM, Buffalo, NY 14260, (716) 645-6800, ext. 2468, E-mail: fountain@acsu.buffalo.edu.
14. **Great Lakes Geological and Environmental Issues.** (Sponsored by the Institute for Environmental Education.) J. Singer, Dept. Earth Sciences and Science Education, SUNY College at Buffalo, 1300 Elmwood Avenue, Buffalo, NY 14222, (716) 878-4724, E-mail: singerjk@snybufaa.cs.snybuf.edu.
15. **Early Through Middle Wisconsin Glacial Records in the Great Lakes–Eastern North America Region.** R. Young, Dept. Geological Sciences, SUNY College at Geneseo, Geneseo, NY 14454, (716) 245-5296, young@uno.cc.geneseo.edu; P. Calkin, Dept. Geology, SUNY at Buffalo, 876 NSM, Buffalo, NY 14260, (716) 645-6800 ext. 3985, E-mail: glgparkr@ubvms.cc.buffalo.edu.

THEME SESSIONS

The following theme sessions with conveners will be held if sufficient relevant papers are submitted.

1. **Glacial Meltwater: Subglacial, Ice Marginal, and Glacial Lakes.** P. Karrow, Dept. Earth Sciences and Quaternary Sciences Institute, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada, (519) 885-1211, ext. 3731, pfkarrow@sciborg.uwaterloo.ca; P. Calkin, Dept. Geology, SUNY at Buffalo, 876 NSM, Buffalo, NY 14260, (716) 645-6800, ext. 3985, glgparkr@ubvms.cc.buffalo.edu.
2. **Appalachian and Michigan Basin Black Shales**. J. Over, Dept. Geological Sciences, SUNY College at Geneseo, Geneseo, NY 14454, (716) 245-5294, over@uno.cc.geneseo.edu.
3. **Undergraduate Research.** *See Special Poster Sessions*.

SPECIAL POSTER SESSIONS

1. **New 1:100,000 Bedrock Geology Map of Vermont: Progress and Preliminary Maps.** (Symposium.) N. Ratcliffe, U.S. Geological Survey, 926 National Center, Reston, VA 22092, (703) 648-6939; Rolfe S. Stanley, Dept. Geology, University of Vermont, Burlington, VT 05401.
2. **Undergraduate Research.** (Sponsored by the Geology Division, Council on Undergraduate Research.) (Theme session.) Student(s) must be listed as the author and have been the major preparer of the poster. Papers must also have been designated for this theme session on abstract forms. Lawrence L. Malinconico, Dept. Geology, Lafayette College, Easton, PA 18042, (610) 250-5193, malincol@lafayette.edu; Robert M. Cassie, Dept. Earth Sciences, SUNY College at Brockport, Brockport, NY 14420-2936, (716) 395-5716, rcassie@weather.brockport.edu.

STUDENT AWARDS AND TRAVEL ASSISTANCE

Awards will be given for the best oral paper and best poster session presented by students. Although the faculty mentor may appear as the junior author, a major part of the paper or poster session must represent work by the single student author. NOTE: Papers considered for this award will be only those designated as student author on the abstract form.

The Northeastern Section of GSA will award travel grants to students who give papers (oral or poster) of which the student is the presenter and author or co-author, at the meeting. In addition, the Northeastern Section will award student research grants to undergraduate students in 1996. Applications for travel assistance and guidelines for student research grants may be obtained from Kenneth N. Weaver, Secretary-Treasurer, Northeastern Section, GSA, c/o Maryland Geological Survey, 2300 St. Paul St., Baltimore, MD 21281-5210, (410) 554-5532, fax 410-554-5502.

K–12 TEACHER WORKSHOP

A Saturday morning (7 a.m. to 12 noon, March 23, 1996) workshop for K–12 in-service and preservice teachers has been organized as part of the 1996 GSA Northeastern Section meeting. The workshop will begin with a full breakfast, followed by breakouts for grades K–6 and 7–12. Teachers, whether you just want a refresher or have little or no geology background, this workshop is for you. Come and enjoy what promises to be an educational and fun-filled morning.

Some planned activities include the following.

Breakfast Discussion: A geology-style breakfast! (If you are not sure what this is, come and see.) The breakfast provides an opportunity for geology teachers to become better acquainted with one another and to share concerns about the state of geology teaching in our schools.

Geology Extravaganza: Geology kits, supplies, and teaching aids will be put on display and demonstrated for you. Make-and-take opportunities.

Newest & Latest: An opportunity to learn new concepts in geology (for example, are you aware of the newest Niagara Falls stratigraphy?).

Share Plan: An opportunity to present and share with others a lesson, activity, or field trip that has worked or has not worked in your class. To help us plan this activity, a short abstract (less than 50 words) would be appreciated by March 1, 1996. Please send your abstract to: Stephen Vernette, Earth Science and Science Education, Buffalo State College, 1300 Elmwood Ave., Buffalo, NY 14222.

The workshop will end by noon on Saturday, allowing participants to register for the afternoon field trips. For further information and/or to submit an abstract (see above), contact Stephen Vernette, vermetsj@snybufaa.cs.snybuf.edu. Cost: $5; includes breakfast and materials. Preregistration for the meeting is required (registration fee plus workshop cost).

SHORT COURSES

Two short courses will be offered, one full-day course on Wednesday, before the meeting and one on Saturday afternoon after the technical sessions are over. Preregistration is required for both of these courses. The short courses may be canceled if enrollment is low. Interested participants should contact James Ellis or John Fountain at the addresses listed below for further information. Enroll early!

1. Practical Remote Sensing for Geology. James Ellis, Supervisor, Remote Sensing Services, Chevron Overseas Petroleum, P.O. Box 5046, San Ramon, CA 94583, (510) 842-3672, jael@chevron.com. Participant limit: 20. Wednesday, March 20, 8:00 a.m. to 5:00 p.m. at Natural Science and Mathematics Complex, University at Buffalo, Amherst, New York. Registrants will be contacted with location map and details. Cost: $85 for students; $130 for professionals; includes box lunch and an extensive set of course materials (see below).

This full day course covers (1) overview of fundamentals, (2) evaluation of satellite and airborne sensors, (3) acquisition and integration of images, digital elevation models, and maps, (4) image-processing techniques, and (5) interpretation of images for geology, logistics, and environmental features. Case histories will be presented from Papua New Guinea, Yemen, Kazakhstan, Nigeria, and Colombia that demonstrate the potential and limitations of remote sensing. How to successfully use remote sensing in relatively well mapped North America and integrate remote sensing with GPS, CAD, GIS, and field work will also be covered. This course is for students and professionals with a geologic background; some knowledge of computers is helpful but not necessary. A bound ~100-page text will be accompanied by an exercise folder with ~20 color image copies and partly to fully annotated overlays for interpretation purposes.

2. Contaminant Hydrogeology in Fractured Bedrock. Bernard Keuper, Dept. Civil Engineering, Queens University; Kent Norakowski, National Water Research Institute, Burlington, Ontario; Carl Renshaw and Robert Jacobi, Dept. Geology, SUNY at Buffalo. Contact: John Fountain, Dept. Geology, 876 NSM, SUNY at Buffalo, Buffalo, NY 14260, (716) 645-6800, ext. 3996, fountain@acsu.buffalo.edu. No participant limit. Saturday, March 23, 1:00 to 6:00 p.m., Hyatt Regency. Cost: $35 for students, $70 for professionals.

Fractures can dramatically affect the transport and remediation of contaminated aquifers. This course will acquaint you with basic principles and current research on the hydrology of fractured rock systems. Particular emphasis will be given to the current understanding of transport and remediation of contaminants in the subsurface, including dense nonaqueous phase liquids (DNAPLs). Current understanding of the geometry of fracture systems as well as innovative techniques for characterizing this geometry will also be covered. A manual with course notes will be provided. The course is intended for professionals—geologists, hydrologists, engineering geologists, and environmental scientists—as well as students who have a basic understanding of hydrogeology and some knowledge of subsurface contaminant transport. See program for room assignment in Hyatt. Preregistration is required.

FIELD TRIPS

Two half-day field trips are planned for Saturday afternoon, March 23. These trips begin and end at the Hyatt Regency Hotel in Buffalo. Please address specific questions to the individual field trip leaders indicated. March weather is unpredictable; participants should dress warmly, and boots will be appropriate. However, no strenuous walking will be involved. Trips will be canceled only in the most inclement weather. Preregistration is required, but a few spaces may be available at the time of on-site registration. If a field trip must be canceled because of weather or insufficient enrollment, a refund will be issued after the meeting.

1. Stratigraphy and Quaternary Geology of the Niagara Falls and Gorge. Carlton Brett, Dept. Geological Sciences, Hutchinson Hall, University of Rochester, Rochester, NY 14624, (716) 275-2408, cebh@db1.cc.rochester.edu; Parker Calkin, Dept. Geology, SUNY at Buffalo, 876 NSM, Buffalo, NY 14260-3050, (716) 645-6800, ext. 3985, E-mail: glgparkr@ubvms.cc.buffalo.edu. Participant limit: 40. Saturday, March 23, 12:30 to 6:00 p.m. Cost: $25; includes box lunch, guidebook, and transportation.

This field trip will provide an overview of bedrock stratigraphy and glacial and surficial geology of Niagara County, New York. It will feature stops along the Niagara Gorge (New York side), from Niagara Falls, northward to Lewiston at the Niagara Escarpment. Additional stops in eastern Niagara County in the area of Lockport will illustrate comparative aspects of bedrock stratigraphy and glacial features related to the development of Lake Tonawanda and succeeding glacial Lake Iroquois. The Niagara Gorge is the classic section for the North American Silurian Series and is beautifully exposed in the walls of the gorge. There and at other outcrops, we will focus on sequence stratigraphy and the relation of sequence boundaries and flooding surfaces to patterns of sedimentation and biotic change. Surficial aspects of the trip will focus on the history of gorge cutting and ongoing processes at Niagara Falls itself.

The trip will provide ample opportunity for photography of the spectacular geologic features of Niagara Falls and some collecting of fossils, lithologies, and mineral specimens. Waterproof boots and warm clothes are a must.

2. Environmental Geology of the Buffalo Niagara Area. (Sponsored by SEPM.) Robert V. Demicco, Dept. Geological Sciences and Environmental Studies, SUNY at Binghamton, Binghamton, NY 13902-6000, (607) 777-2264, demicco@bingsuns.cc.binghamton.edu; Kelly C. Cloyd, NYS Dept. of Environmental Conservation, Region 8 Office, Avon, NY 14414, (716) 226-2466. Participant limit: 20. Saturday, March 23, 1:00 to 5:00 p.m. Cost: $10 for student members of SEPM or GSA, $15 for other students and for secondary school teachers, and $25 for professionals; includes transportation and guidebook.

This trip will focus on how the glacial and preglacial stratigraphy of the area controls the shallow ground-water flow systems. Anthropomorphic effects on the ground-water flow systems will be examined. Sites to be visited include the Buffalo Road Industrial Area and, if time permits, the Love Canal site. This trip is intended primarily for students and secondary school teachers.

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Northeastern *continued from p. 254*

EXHIBITS

Exhibit space will be available in the same hall (Grand Ballroom C–G) as the poster sessions at the Hyatt Regency. Refreshments will be continuously available for exhibit visitors. Booths, which are 8′ × 10′, framed by pipe and drape and containing table and chairs, will be available for exhibitors during the entire meeting, from 8:00 a.m., Thursday, March 21, to noon, Saturday, March 23. Reduced rates are available for book sellers and educational or nonprofit groups. For further information and space reservations, contact Rossman Giese, Exhibits Coordinator, Dept. Geology, SUNY at Buffalo, 876 NSM, Buffalo, NY 14260, (716) 645-6800, ext. 3008, E-mail: glgclay@ubvms.cc.buffalo.edu.

GUEST ACTIVITIES

The Buffalo area offers a wide range of activities that may be of interest to guests, including Niagara Falls and associated attractions. For example, within the city is the internationally known Albright-Knox Art Gallery, the Naval and Servicemen's Park, and the Buffalo Museum of Science (see Special Events). Short drives allow access to old Erie Canal sights, the shores of Lakes Erie and Ontario, or the Letchworth Gorge. Brochures, maps, and a knowledgable volunteer will be available at the NE-GSA registration desk to assist guests with sightseeing plans.

ACCOMMODATIONS

A large block of rooms has been reserved for meeting participants and their guests at the Hyatt Regency Hotel. The Hyatt has provided reasonable room rates, and we urge participants to take advantage of the offer. A parking ramp is located directly across from the hotel and inexpensive, special long-term parking is available nearby. For conference planning purposes and to ensure the guaranteed room rates, it is imperative that you reserve your room(s) before **February 20, 1996**. If you make telephone reservations, it is important that you state you are attending the Northeastern Section GSA meeting. **Mail the housing form directly to the hotel**.

SPECIAL EVENTS

GSA Northeastern Section Management Board Meeting, Wednesday, March 20, 4:30 to 6:30 p.m., Hyatt Regency, Ellicott Room.

Welcoming Reception, Wednesday, March 20, 6:30 to 10:00 p.m., Hyatt Regency Grand Ballroom. Liquid refreshments and snacks will be served. A cash bar will be available for mixed drinks.

NAGT Eastern and New England Sections Business Meeting and Luncheon, Thursday, March 21, 12 noon to 1:15 p.m. Cost: $15; preregistration is required. See program for room assignment.

Paleontological Society, Northeastern Section Luncheon, Thursday, March 21, 12:00 noon to 1:30 p.m., directly following the Paleontological Society symposium "Faunal Succession and Speciation: The Role of Evolutionary and Ecological Replacement in Species Turnover." Cost:$15. Preregistration is required. See program for room assignment.

SEPM Eastern Section Business Meeting and Reception, Thursday, March 21, immediately following the last talk of the SEPM symposium, "Bioevents and Sequence Stratigraphy: Paleozoic Examples from Eastern North America." The president-elect of SEPM, John Armentrout, Mobil Oil (Dallas, Texas) will deliver an address following the business meeting. Refreshments will be served. The meeting is open to all SEPM members. See program for room assignment.

Annual GSA Northeastern Section Reception and Banquet, Thursday, March 21, 6:30 to 9:00 p.m., Hyatt Regency Grand Ballroom A-B. The social time (with cash bar) will begin at 6:30 p.m.; dinner will be at 7:00 p.m. We will be serenaded by the music of the Newton Street Irregulars, led by geologist Richard Gilman of Fredonia. GSA President Eldridge M. Moores, University of California, Davis, will speak on "Ophiolites, SWEAT , and the Appalachian-Cordilleran Connection." This talk will explore the possible correlations between the east and west coasts called up by the general idea of the SouthWest U.S.–East Antarctic connection during the late Precambrian. The doors will be opened following the banquet in order that the address of President Moores may be heard by all. Banquet cost: Professional—$26 or $27, Student—$15 or $16; see preregistration form. Preregistration is required.

5K Fun Run, Friday morning, March 22, 6:30 to 7:30 a.m., Buffalo waterfront. For those who need or like to run or jog, this will be a chance to get some noncompetitive exercise during the meeting. We will meet at 6:15–6:30 a.m. in the Hyatt lobby and proceed by van to the Buffalo and Erie County Naval and Serviceman's Park. The 5K route begins and ends near the adjacent Vietnam Veterans monument. Light refreshments will be provided for participants after the run. Please indicate interest on the preregistration form. Sweats, hat, and gloves may be appropriate. A no-cost event.

Association for Women Geoscientist Breakfast, Friday, March 22, 6:45 to 8:30 a.m. Cost:$12. Preregistration is required. See program for room listing.

ADDITIONAL INFORMATION

The preregistration form and full payment must be received by the preregistration deadline of February 26, 1996. All forms received after this date, regardless of when postmarked, will be held for on-site processing. We suggest that you copy the completed form for your records. An accompanying guest is defined as a non–earth scientist, spouse, or friend (of a professional or student). Guests may attend social functions but not technical sessions. Students must show a current student ID to obtain student rates. Students not having a current student ID when picking up the registration kit or registering on-site will be charged the professional fee. Those who will attend only a short course or field trip must pay at least the one-day registration fee. Badges must be worn for all activities. Registration fees do not include provisions for insurance of participants against personal accidents, sickness, theft, or property damage. ■

Preregistration Form

GSA Northeastern Section

Preregistration deadline is February 26, 1996.

Buffalo, New York • March 21–23, 1996

Please print clearly. Copy for your records.

Name (last) _____ (first name/nickname as it should appear on badge) _____

Employer/University (affiliation as it should appear on badge) _____

Employer/University mailing address for Employer/University above _____

City _____ State _____ ZIP Code _____

Country (other than USA) _____ ( ) Business Phone _____ ( ) Fax _____ ( ) Home Phone _____

Spouse/Guest Name (last) _____ (first name/nickname as it should appear on badge) _____

City/State _____ Country _____

Please inform us by March 3 of any special considerations that you or your guest require.

☐ I will need special considerations. Please call me.

Circle member affiliation (to qualify for registration member discount*):

(A) GSA Member #_____
(B) NAGT
(C) PS
(D) SEPM
(E) AWG
(F) SGE

REGISTRATION	By February 26 Full Meeting	By February 26 One Day	On Site Full Meeting	On Site One Day	Amount
Professional Member	$60 ☐	$35 ☐	$75 ☐	$45 ☐	$_____
Professional Nonmember	$75 ☐	$40 ☐	$90 ☐	$50 ☐	$_____
Student Member	$20 ☐	$20 ☐	$25 ☐	$25 ☐	$_____
Student Nonmember	$30 ☐	$30 ☐	$35 ☐	$35 ☐	$_____
K–12 Professional	$30 ☐	$20 ☐	$40 ☐	$25 ☐	$_____
Guest/Spouse	$15 ☐	$15 ☐	$15 ☐	$15 ☐	$_____

WORKSHOP				
K–12 Teacher Workshop, Saturday, March 23			$ 5	$_____
SHORT COURSES				
1. Practical Remote Sensing for Geology, Wednesday, March 20		Professional	$130	$_____
		Student	$ 85	$_____
2. Contaminant Hydrology in Fractured Bedrock, Saturday, March 23		Professional	$ 70	$_____
		Student	$ 35	$_____
FIELD TRIPS				
1. Silurian Stratigraphy and Quaterary Geology of the Niagara Area, Saturday, March 23			$ 25	$_____
2. Environmental Geology of the Buffalo Area, Saturday, March 23		Professional	$ 25	$_____
		Student GSA or SEPM Member	$ 10	$_____
		Other Students and K–12 Teachers	$ 15	$_____
SPECIAL EVENTS				
Welcoming Reception, Wednesday, March 20			FREE	I will participate ☐
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Paleontological Society Northeastern Section Luncheon, Thursday, March 21			$ 15	$_____
Annual Northeastern Section GSA Reception and Banquet	Prime Rib	Professional	$ 27	$_____
March 21	Cornish Game Hen	Professional	$ 26	$_____
(Speaker: 1996 GSA President Eldridge M. Moores)	Prime Rib	Student	$ 16	$_____
	Cornish Game Hen	Student	$ 15	$_____
5K Noncompetitive Fun Run, Friday, March 22			FREE	I will participate ☐
Association for Women Geoscientists Breakfast, Friday, March 22			$ 12	$_____
Sigma Gamma Epsilon Luncheon, Friday, March 22			$ 15	$_____
Reception and Supper, Buffalo Museum of Science, Friday, March 22			$ 15	$_____

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ducted slabs could delaminate and form a mineralogical phase denser than the ambient lower mantle. Lighter elements could be settling up and out of the outer core as a more iron-rich inner core freezes at an inner core boundary eutectic point, increasing the outer core percentages of lighter elements. All of these mechanisms have been proposed, but it is not clear which of them, if any, actually occurs.

Chemical variations will cause P and S seismic-velocity variations that are distinct from thermal effects, as shown for the major lower-mantle constituents, perovskite and magnesiowüstite. Figure 8, from Wysession et al. (1992), uses a third-order Birch-Murnaghan equation of state to show the amount of change in temperature, silicate/oxide ratio, and iron/magnesium ratio required to change the P and S velocities in D″ by several percent. This means that seismic observations of P and S velocities varying out of tandem within D″, as was observed for diffracted wave profiles beneath the northern Pacific, may tell us when thermal or chemical effects are dominant. If current tomographic models of D″, such as the S model of Su et al. (1994) and the P model of Pulliam et al. (1993), are combined, they provide a map of the Poisson ratio in D″ that varies from 0.295 to 0.310 (5%). Neither our seismic data nor our thermoelastic constants are quite good enough yet to take a map of D″ Poisson ratios resulting from these models and convert them into temperature and compositional variations, but it is the direction in which we are moving.

Variations in CMB topography are also a kind of lateral chemical variation. The asphericity of the CMB has been detected seismically at both very high and very low wavelengths, as well as through length-of-day variations. Actual determination of CMB topography is very difficult to measure because of trade-offs with velocity heterogeneities, but it is vitally coupled to dynamic CMB processes. The CMB will be depressed beneath regions of lower mantle downwelling because of the isostatic weight of the colder rock as well as the dynamic force of the convection. However, we would also expect the CMB to be depressed beneath regions of compositionally denser mantle dregs. A possible scenario is that the CMB topography undergoes a cyclic transition during the cycle of mantle mass transport. During the initial stages of the birth of a mantle plume, the increased temperature will cause an elevated CMB, but as the plume develops, denser mantle aggregates will be swept laterally to the site of the plume, causing a depression of the CMB. In other words, the convective cycle may cause a temporal transition in CMB topography similar to that modeled by Gurnis (1992) for long-wavelength surface topography during the history of lithospheric subduction.

The electrical conductivity for lowermost mantle phases may vary by 11 orders of magnitude (Jeanloz, 1990). This is important because determinations of core flow using temporal variations in Earth's magnetic field (e.g., Bloxham, 1993) assume that the mantle behaves as a perfect insulator. Because the mantle flows a million times slower than the outer core, D″ structure can also have lasting effects on core convection in more direct ways. CMB topography can serve to channel core flow, like air over mountains, or lateral D″ thermal variations can regionally vary the heat flux out of the core, constraining core convection patterns.

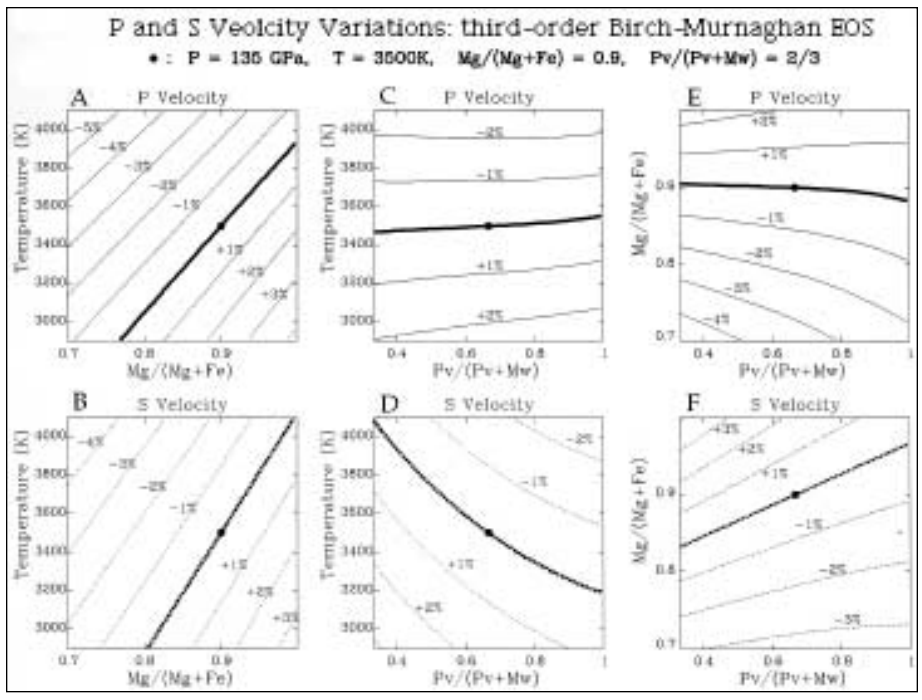

Figure 8. The percentage changes in P and S velocities for rock at the base of the mantle as a result of changes in three parameters: temperature, silicate/oxide ratio, and iron/magnesium ratio. Calculations are done using a third-order Birch-Murnaghan equation of state (EOS) for the iron and magnesium end-members of perovskite and magnesiowüstite, using the best available thermoelastic parameters (from Wysession et al., 1992). The starting material is a pyrolite-type composition at 135 GPa and 3500 K. Note that the P and S velocities do not change in the same way for the different thermal and chemical changes, implying that we may eventually be able to use not only the P and S velocities in D″ but also their relative variations to identify their dominant geophysical causes.

Mineralogical Phase Changes.

The third form of explanation for observed seismic variations is that of pressure-driven changes in the mineralogical assemblages that are present. If there are either thermal or chemical variations across D″, this could cause vertical topography on a mineralogical phase boundary, presuming one were present. A possible candidate would be the breakdown of the silicate $(Mg,Fe)SiO_3$ (perovskite) into the oxides (Mg,Fe)O (magnesiowüstite) and SiO_2 (stishovite) (Stixrude and Bukowinski, 1990). Although the phase relations at CMB temperatures and pressures are still poorly constrained, such a phase change would provide the best explanation for the sharp velocity increase seen at the top of D″ in many radial velocity models like Figure 5. It is also possible that high-pressure phases of stripped oceanic eclogitic crust, which would be denser, yet seismically faster, could accumulate at the base of the mantle and provide a chemical basis for the D″ reflector (Christensen and Hofmann, 1994). Both of these mechanisms are shown through thermochemical modeling to be able to provide the necessary 3% seismic velocity jump (Wysession, 1995b). It is unlikely that an inverted temperature change, such as for descended cold rock that has spread out and ponded at the CMB, would have the very steep gradient that is observed seismically.

If such a phase transition does occur, we can also speculate as to the effects of composition and tempera-

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overall, Cattermole does a commendable job of summarizing what has been learned. Because it was written so early after publication of the initial results, most of the presented materials are derived from the initial (Saunders and Pettengill, 1991; Saunders, 1992) publications devoted to summary results of the Magellan mission. As such, it is mostly a digested version of those reference works with related bits and pieces and balancing arguments thrown in. However, that is not necessarily bad; after reading it, I found that my grasp of some of the issues and subtopics of secondary interest to me, which I had skimmed in the original references, was somewhat clarified and expanded. However, this book is not "watered-down" science for popular consumption; it rates as a reference book. One wishes that the results of many large-scale scientific studies could have a similar synthesis done in such an easily readable format by one synthesizing author familiar with the science, as Cattermole appears to be.

In addition to the summary of the recent geological story, there are also nicely done summaries of the related atmospheric characteristics, which anyone who uses the term "greenhouse effect" in discussions of environmental science may wish to review. The brief summary of the geometry and overall methods of the synthetic aperture radar imaging technique may be useful to the uninitiated, but one could wish for more details and a discussion of influence of surface properties (roughness and reflectivity) on images and altimetry determinations, especially because that influence serves as a hook for learning about an important remote-sensing technique used in terrestrial environmental studies. Although there is a substantial list of references, relevant references such as Ford et al. (1993) and more recent summaries and data releases are not listed. A discussion of some of the subsidiary image products such as stereo radar image data and digital terrain models would be desirable. At the time the book was written, only preliminary results were in on Magellan-derived gravity data, but there is still room for more summary discussion about the global gravity field, its interpretations, and particularly some of its implications for regional geologic characteristics.

Several matters of production detract from the book. Because much in this book derives from what was largely an imaging mission, the dimensions of the pages are relatively small for image reproduction; the many images and maps that fill the text could have been better presented in a larger format book. Perhaps because of the format, the overall reproduction of the global altimetry and image maps is poor, although the inclusion of several color plates is a welcomed, if fuzzy, addition. Many of the black and white images are too dark and lack contrast. Even though a significant fraction of the Magellan image data are radar dark, it is possible to reproduce the image data in better contrast. Several distracting errors also occur: Figures 3.7, 3.8, and 9.25 are printed upside down (but in fairness, this seems difficult even for some science journals to get right), a number of typographical errors occur in some of the figure captions, at least one map is misattributed, and some symbols are mentioned in captions that do not appear in the figures. The text is generally well written, understandable at the advanced undergraduate and graduate level. However, because of the particular time period during which this text was written, the occasional switch from present to future tense in referring to mission events ensured that the text would sound out of date before it actually made it into print. These are minor distractions, however, not condemnations.

If the geology of Venus is a story, then the "moral" of the story is still being determined. The moral would seem to have something to do with the large-scale effects of subtle differences in starting conditions and environment on subsequent development of two otherwise similar planetary bodies (Earth and Venus), but it is also about some large-scale similarities over which environment has little influence. Perhaps the moral may have been best summarized in the title of a presentation by the mission project scientist Steve Saunders: "Venus and Earth: Twins Separated at Birth." Behavioral scientists found out long ago the value of that experiment. Now we geologists have our chance at a similar experiment.

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Geomorphology of Desert Environments. *Edited by Athol D. Abrahams and Anthony J. Parsons. Chapman & Hall, London, 1994, 674 p., $146.95.*

Desert environments, encompassing about 30% of Earth's land surface, are increasingly being subjected to urban and industrial development. Many of these developed areas have

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ture. The seismic observations of Kendall and Shearer (1994) and Revenaugh and Jordan (1991) suggest that a correlation may exist between regions of shallow D″, as defined by the height of the discontinuous velocity increase, and fast seismic velocities, as determined from tomographic models. Fast velocities mean colder temperatures, suggesting that the phase transformation would be endothermic. Just as with the 660 km discontinuity, colder temperatures would depress the phase boundary; however, mineral physics experiments suggest that this transformation would occur at higher pressures (greater depths) if the rock were enriched in magnesium relative to iron, so the phase transition could also be exothermic if rock were significantly depleted in iron relative to its surroundings. Advances in mineral physics will eventually solve this question of the possibility of a D″ phase transition and the form it would take.

FUTURE DIRECTIONS

The only real fact that can be gleaned from the previous section is that the questions still outnumber the answers. Several very good scenarios have been identified, but much more work needs to be done to discern among them. The future directions for seismology in mapping the CMB and lowermost mantle include efforts in using new phases, developing new techniques, and obtaining new data sets.

An example of using new phases is the utilization of differential Pdiff and PKP phases (which refract through the core) for looking at long-wavelength P velocities in the lowermost mantle (Wysession, 1994). By cross-correlating the Pdiff phases (data and synthetic) and PKP phases separately, we are able to determine the delay of Pdiff relative to PKP and isolate any anomalous behavior of Pdiff during its long path around the CMB. The CMB Fresnel zones of the long-distance Pdiff waves are very large, but the superposition of these cover all parts of the CMB, and an over-determined inversion can be done for the long-wavelength D″ P velocities. Because of the geographical limitations of available earthquakes and seismometers, utilizing all phases that interact with the CMB will help fill in the many gaps that exist in our geographical coverage of the lowermost mantle.

We also need to be constantly developing new techniques to increase our ability to interpret existing seismic data. As an example, Koper and Wysession (1995) have developed a genetic algorithm for simultaneously determining radial velocity structure at both the CMB and inner core boundary using the AB, BC, and DF branches of PKP arrivals. The PKP branches are our best seismic tools for examining the P velocity structure of the core, but difficulties arise because the DF and BCdiff branches interact with both the inner and outer core boundaries. The genetic algorithm is a powerful technique for identifying the different kinds of possible structures at both boundaries that would simultaneously satisfy all of the observed PKP arrivals. These investigations use high-quality seismic array data to examine regional parts of the core, as well as the set of ISC PKP times, to determine a global core model.

An important contribution from seismologists is obtaining new data sets that can be made available to future researchers who will answer the questions that currently puzzle us. In January and February 1995 my colleagues and I, together with Timothy Clarke (University of Illinois) and Karen Fischer (Brown University), installed 18 broad-band seismometers in a straight line, connecting stations CCM (Missouri) and HRV (Massachusetts). This Missouri-to-Massachusetts deployment (MOMA), which will run for one year, is designed to investigate several aspects of deep Earth geology, including core and CMB velocities, the structure of subducting slabs, and the velocity structure of the upper mantle and crust beneath North America. The 20 stations span 16° in the distance range of about 100°–130° from the world's most seismically active regions in the western Pacific, and are therefore ideally set to examine the CMB by means of core-diffracted waves. In fact, as is seen in Figure 9, the northeastern United States is one of two geographical regions that are within the 95°–135° distance range from more large earthquakes than any another parts of the world (the second is southern Africa). A problem of the seismic data set today is that while seismic stations are spaced to cover the globe evenly (although they are limited to mostly continents and islands), this results in a large distance between stations and creates an aliasing problem in our ability to image Earth's interior structure. Regionally dense temporary seismic deployments like MOMA, made possible by using instruments borrowed from IRIS (Incorporated Research Institutions for Seismology), help provide high-resolution windows into the planet. One of the MOMA sites, installed in March 1995 near Lake Newton in eastern Illinois, is shown in Figure 10.

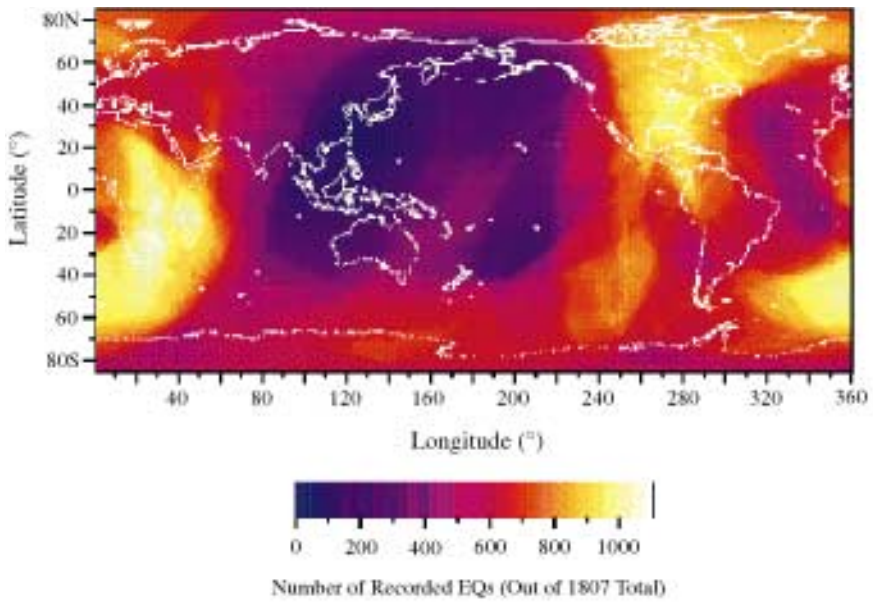

Figure 9. A map showing the number of earthquakes (EQs; mb >5.7) during a ten-year period (1983–1992), which occurred within a distance of 95°–135° from any given location (out of a total of 1807). This distance range is required for examining the CMB using core-diffracted Pdiff and Sdiff waves. The Missouri-to-Massachusetts (MOMA) array of portable broad-band seismometers, which will consist of 18 stations linearly connecting CCM and HRV and will be recording until March 1996, is ideally suited to record core-grazing and diffracting waves from the seismogenic western Pacific regions. Such temporary arrays, funded through the PASSCAL program of IRIS (Incorporated Research Institutions for Seismology), greatly help in providing new seismic data that fill in the aliasing gaps between permanent seismometers.

Figure 10. Ghassan Al-Eqabi (left) and Patrick Shore (right) completing installation of one of the MOMA (Missouri-to-Massachusetts) portable-array broad-band seismometers near Lake Newton, Illinois.

The most important aspect of the future of seismology in imaging the CMB and lowermost mantle is the continued communication between seismologists and scientists from other fields. SEDI (Studies of Earth's Deep Interior) organizations exist nationally within the American Geophysical Union and the National Science Foundation, and internationally as well. These provide many opportunities for seismologists to share both observations and insights. Input from these interactions gives us an understanding of what the important questions are and where to concentrate our efforts. The recent successes in understanding the CMB have come about through interdisciplinary cooperation and will continue to happen in this way.

ACKNOWLEDGMENTS

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The Department of Geological Sciences at the University of Maine, Orono, Maine, will be filling a tenure-track position in hydrogeochemistry in the Fall of 1996 at the Assistant or Associate Professor level.

Teaching and research responsibilities will be approximately equal. The selected person will be expected to develop and deliver on a yearly basis an introductory senior/graduate level course in hydrogeology, a course in hydrogeochemical modeling, and a third course.

The successful candidate will be expected to develop (1) an externally funded research program with some emphasis on groundwater problems in Maine and (2) strong working relationships with appropriate personnel at the University of Southern Maine and the Maine Geological Survey. In addition, we enourage linkages with other people/organizations and more wide-ranging interest in hydrogeochemical problems. Research should focus on the chemical dynamic aspects of subsurface water-rock/mineral interaction, chemical evolution of water along flow paths and evolution of plumes of chemicals/pollutants, and hydrogeologic controls on groundwater chemistry.

This position will initially be funded by a grant from the U.S. Department of Energy (EPSCoR Program) and the Maine Science and Technology Foundation. After expiration of the grant, the position will be funded by the College of Sciences, University of Maine. The broad goal of the grant is to develop a state-wide collaborative groundwater resource group in cooperation with the University of Southern Maine and the Maine Geological Survey. This group is designed to provide research and educational expertise in near-surface geophysics, structural controls on groundwater flow, and hydrogeochemistry.

The Department of Geological Sciences faculty, programs, and research resources are described on the WWW (http://iceage.umeqs.maine.edu/geology/home.htm). A new building is under construction to house the Department along with the administrative offices of the Institute for Quaternary Studies. Occupancy is expected in early Spring of 1997.

Interested candidates should, by the time of hiring, have the Ph.D. or equivalent in Geology or a closely related field. Inquiries about the position may be addressed to Stephen A. Norton, Chair and Professor of Geological Sciences, Department of Geological Sciences, 5711 Boardmann Hall, University of Maine, Orono, Maine 04469-5711. E-mail: norton@maine.maine.edu. Phone: (207) 581-2156. FAX 207-581-2202. Applications should include a curriculum vitae, a statement of research interests and philosophy of teaching, and names, addressess, and phone numbers of three referees. Review of the position will start December 29, 1995 and continue until the position is filled.

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COLBY COLLEGE, a highly selective liberal arts institution with a tradition of excellence in the sciences, seeks a talented individual to join an active science faculty in a one-year position as Visiting Assistant Professor of Geology for the 1996-97 academic year; the department hopes to conduct a national search for a tenure-track position in these fields the following year. The ideal candidate for this position will be an outstanding teacher who is able to teach undergraduate courses in invertebrate paleontology, structural geology, stratigraphy and sedimentology (as individual courses or combined), as well as an introductory course for non-majors. Applicants should have Ph.D. in hand by September 1, 1996, but outstanding ABD candidates will also be considered. To apply, send letter of application, complete resume, official copies of transcripts showing all college-level work, and names and addresses of at least three persons willing to provide letters of recommendation; at least one person serving as reference should be able to comment knowledgeably on the applicant's teaching skills in a classroom setting. Complete application should be sent in time to arrive no later than February 1, 1996, and be addressed to: Chair of Search Committee, Department of Geology, Colby College, 5804 Mayflower Hill Drive, Waterville, ME 04901-8858. Colby is an AA/EO employer and especially encourages applications from women and minorities.

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The Department of Geology, University of Illinois at Urbana-Champaign, invites applications for a full-time, tenure-track position beginning in the Fall semester of the 1996 academic year. We seek an outstanding candidate in an area of physical, chemical, or microbiological hydrgeology. The candidate is expected to develop a strong research program in his or her field of specialization, and to participate in all aspects of teaching and advising at the undergraduate levels. We will fill this position at the Assistant Professor level. Salary will be commensurate with qualifications. An earned Ph.D. degree is required.

The Hydrogeology Program is supported within the department by a variety of analytical and computational facilities. The National Center for Supercom-

GSA ANNUAL MEETINGS

1996

Denver, Colorado • October 28–31
Colorado Convention Center
Marriott City Center

General Chairs:
Gregory S. Holden *and* ***Kenneth E. Kolm***
Colorado School of Mines

Technical Program Chairs:
John D. Humphrey *and* ***John E. Warme***
Colorado School of Mines
Dept. of Geology & Geological Engineering
Golden, CO 80401
(303) 273-3819, fax 303-273-3859
E-mail: jhumphre@mines.edu

Field Trip Chairs:
Charles L. Pillmore, *(303) 236-1240 and*
Ren A. Thompson, *(303) 236-0929*
U.S. Geological Survey, MS 913, P.O. Box 25046
Denver Federal Center, Denver, CO 80225

Theme Session Proposal Deadline is January 3, 1996.
See November *GSA Today* for theme invitation *or* the World Wide Web for invitation and proposal form. The World Wide Web address is: **http://www.aescon.com/geosociety/index.html.** Theme proposal information appears under the header for the Denver Meeting.

EARTH SYSTEM SUMMIT Denver

1997

Salt Lake City, Utah • October 20–23
Salt Palace Convention Center, Little America

General Chair: ***M. Lee Allison,*** *Utah Geological Survey*

Technical Program Chair: ***John Bartley,*** *University of Utah*

Call for Field Trip Proposals: We are interested in proposals for single-day and multi-day field trips beginning or ending in Salt Lake City, and dealing with all aspects of the geosciences. Please contact the field trip chairs listed below.

Paul Link
Department of Geology
Idaho State University
Pocatello, ID 83209-8072
(208) 236-3365
fax 208-236-4414
E-mail: linkpaul@isu.edu

Bart Kowallis
Department of Geology
Brigham Young University
Provo, UT 84602-4646
(801) 378-3918
fax 801-378-2265
E-mail: bjk@geology.byu.edu

Field trip guides will be published jointly by Brigham Young University Geology Studies and the Utah Geological Survey. Review drafts of field guides will be due March 15, 1997.

For general information on any meeting call the GSA Meetings Department
1-800-472-1988 or (303) 447-2020, ext. 133
E-mail: meetings@geosociety.org

GSA SECTION MEETINGS — 1996

SOUTH-CENTRAL SECTION, *March 11–12, 1996.* University of Texas, Austin, Texas. Information: Mark Cloos, Department of Geological Sciences, University of Texas, Austin, TX 78712, (512) 471-4170, fax 512-471-9425, Email: cloos@maestro.geo.utexas.edu. *Abstracts Deadline: December 7; Preregistration Deadline: February 6, 1996.*

SOUTHEASTERN SECTION, *March 14–15, 1996.* Ramada Plaza Hotel, Jackson, Mississippi. Information: Darrel Schmitz, Department of Geosciences, P.O. Box 5448, Mississippi State University, Mississippi State, MS 39762, (601) 325-2904; or Charles Swann, Mississippi Mineral Resources Institute, 220 Old Chemistry Bldg., University, MS 38677, (601) 232-7320, E-mail: cts@mmri.olemiss.edu. *Preregistration Deadline: February 6, 1996.*

NORTHEASTERN SECTION, *March 21–23, 1996.* Hyatt Regency, Buffalo, New York. Information: Parker E. Caulkin, Department of Geology, SUNY at Buffalo, 876 NSM, Buffalo, NY 14260, (716) 645-6800, ext. 3985, fax 716-645-3999, or *preferably by E-mail:* glgparkr@ubvms.cc.buffalo.edu. *Preregistration Deadline: February 26, 1996.*

ROCKY MOUNTAIN SECTION, *April 18–19, 1996.* Rapid City Civic Center, Rapid City, South Dakota. Submit completed abstracts to: Alvis L. Lisenbee, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 East St. Joseph St., Rapid City, SD 57701-3995, (605) 394-2463. *Abstract Deadline: January 5, 1996.*

CORDILLERAN SECTION, *April 22–24, 1996.* Red Lion Hotel at Lloyd Center, Portland, Oregon. Submit completed abstracts to: Richard Thoms, Department of Geology, Portland State University, P.O. Box 751, Portland, OR 97207-0751, (503) 725-3379. *Abstract Deadline: December 28, 1995.*

NORTH-CENTRAL SECTION, *May 2–3, 1996.* Iowa State University, Ames, Iowa. Submit completed abstracts to: Kenneth E. Windom, Department of Geological and Atmospheric Sciences, Iowa State University, 253 Science I Building, Ames, IA 50011-3210, (515) 294-2430, E-mail: kewindom@iastate.edu. *Abstract Deadline: January 17, 1996.*

Student Travel Grants

The GSA Foundation will award matching grants up to a total of $3500 each to the six GSA Sections. The money, when combined with equal funds from the Sections, will be used to assist GSA Student Associates traveling to the 1996 GSA Annual Meeting in Denver in October and to the 1996 Section meetings. Contact your Section Secretary for application procedures.

Cordilleran	Bruce A. Blackerby	(209) 278-2955
Rocky Mountain	Kenneth E. Kolm	(303) 273-3932
North-Central	George R. Hallberg	(319) 335-4500
South-Central	Rena M. Bonem	(817) 755-2361
Northeastern	Kenneth N. Weaver	(410) 554-5532
Southeastern	Harold H. Stowell	(205) 348-5098

GSA Thanks the 1995 Annual Meeting Sponsors

For the New Orleans Annual Meeting, the following exhibitors generously donated funds to support the meeting. GSA is most appreciative of this support and thanks these companies.

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Dept. of Geology and Geophysics
WORTH PUBLISHERS

puting Applications and the research facilities of the Illinois State Water and Geological Surveys are on campus, and an office of the U.S. Geological Survey is nearby. The university has established and long-standing programs in groundwater hydrology within Civil Enginering and Agronomy Departments, as well as the Department of Geology.

For equal consideration, an interested individual should send his or her curriculum vita, list of publications, statement of research and teaching interests, and the names and addresses of at least three references by December 15, 1995 to Professor Craig Bethke, Search Committee Chariman, Department of Geology, University of Illinois, 1301 West Green Street, Urbana, Illinois 61801 (Tel: 217-333-3369). Women and minority candidates are encouraged to apply.

University of Illinois is an equal opportunity/affirmative action employer.

SOUTHERN ILLINOIS UNIVERSITY AT CARBONDALE

The Department of Geology at Southern Illinois University at Carbondale invites applications for a tenure-track assistant professorship in environmental geology/geomorphology starting August 16, 1996. Applicants must hold the Ph.D. degree and must have demonstrated teaching ability and existence of, or potential for developing, an externally funded research program of high quality. Experience in fluvial geomorphology, climate change research, and the applications of GIS, image analysis, and remote sensing is preferred.

Applicants should submit a CV, statement of teaching and research interests, and names and addresses of four referees by 1 January to Dr. Michael A. Kruge, Search Committee, Department of Geology, Southern Illinois University at Carbondale, Carbondale, IL 62901-4324; (618) 453-3351; fax: (618) 453-7393; e-mail: kruge@qm.c-geo.siu.edu.

Southern Illinois University at Carbondale is an equal opportunity/affirmative action employer.

EARTH SCIENCES PROGRAM
ENVIRONMENTAL GEOLOGY / HYDROGEOLOGY

Simon Fraser University is expanding its Earth Sciences program. We are seeking to fill a tenure-track position at the assistant professor level in one of the two following areas:

Environmental Geology. The ideal candidate would be a geologist with advanced work in geotechnical engineering or environmental geology. The candidate will play a central role in the development of the environmental geology teaching and research program.

Hydrogeology. The successful candidate will combine a field oriented approach to groundwater evaluation with use of modelling techniques. The Ph.D. is required at the time of appointment and the successful candidate will be eligible, preferably, for professional registration (PGeo, PEng). This appointment will commence in September 1996.

The successful candidate must have a commitment to both undergraduate and graduate education as well as to developing a funded research program. In accordance with Canadian Immigration this advertisement is directed to Canadian citizens and Permanent Residents. Simon Fraser University is committed to the principle of equity in employment and offers equal employments opportunities to qualified applicants.

Applicants should send a curriculum vitae, a letter describing current and near-term research interests and copies of appropriate reprints. Please provide an E-mail address or Fax number, and the names of at least three referees by January 31, 1996 to: Dr. Michael C. Roberts, Director, Earth Sciences Program, Faculty of Science, Simon Fraser University, Burnaby, BC V5A 1S6. Phone (604) 291-3723; Fax (604) 291-5841;

STABLE ISOTOPE GEOCHEMISTRY

The Department of Geology, University of Florida, will hire a permanent full-time "Assistant in Geochemistry" to manage the stable isotope mass spectrometry laboratory beginning on or after Jan. 1, 1996. Duties will include preparing geologic and archaeological samples (H_2O, CO_2, PO_4, SiO_4, and organic fractions) for stable isotopic ratio analysis ($^{18}O/^{16}O$, $^{13}C/^{12}C$, and $^{15}N/^{14}N$); operating and maintaining the gaseous-source mass spectrometer (VG Isogas PRISM Series II) and associated preparation lines; training and supervising graduate stduents; and participating in collaborative research with other faculty. Candidates should have a Ph.D. or equivalent degree, and experience with extraction techniques and operation of a gaseous-source mass spectrometer. The position is non-tenure accruing, but is supported 100% by state funds. Send letter of interest, resume, and the names of 3 references by December 15, 1995, to Dr. David A. Hodell, Dept. of Geology, 1112 Turlington Hall, Gainesville, FL 32611. The University of Florida is an equal opportunity-affirmative action employer.

UNIVERSITY OF SOUTHERN CALIFORNIA
MARINE STRATIGRAPHY/SEDIMENTATION; PALEOSEISMOLOGY

The Department of Earth Sciences, University of Southern California, is accepting applications for a faculty position in either or both of the following fields of specialization: 1) marine stratigraphy/sedimentology; and 2) paleoseismology The tenure-track appointment(s) will be at the Assistant Professor level, beginning in September, 1996.

Applications including curriculum vitae, a statement of teaching and research interests, and the names of three references should be sent directly to: Professor Charles Sammis, Chair, Dept. of Earth Sciences, University of Southern California, Los Angeles, CA 90089-0740. The deadline for applications is February 1, 1996.

USC is an equal opportunity/affirmative action employer. The University is proudly pluralistic and firmly committed to providing equal opportunity for outstanding men and women of every race, creed, and background.

YOUNGSTOWN STATE UNIVERSITY

Tenure-track position at assistant or associate rank. Duties include: serving as Director of the Center for Environmental Studies, teaching environmental courses, research and community outreach. Available Fall 1996. Ph.D. required. Nine month salary; $32,000-$44,000. Additional summer salary is available. Applicants should send a resume, transcripts, and names of three references to: Dr. Lauren Schroeder, Center for Environmental Studies, Youngstown State University, Youngstown, OH 44555. Review of applications will begin 12/18/95 and will continue until the position is filled. YSU is an Affirmative Action/Equal Opportunity employer, minorities and women and especially encouraged to apply.

ENVIRONMENTAL GEOLOGIST/OCEANOGRAPHER

Earth Sciences at Southern Connecticut State University anticipates a tenure-track Assistant/Associate Professor position beginning August 1996. Responsibilities: Teach Marine Science, Hydrology, Engineering Geology and Marine Geology for majors; Introductory Oceanography for non-majors. Qualifications: Ph.D. or be in final stages of completion of the degree. Send letter of application, complete resume and 3 letters of recommendation by December 15, 1995 to: John W. Drobnyk, Chairman, Earth Science Department, SCSU, 501 Crescent Street, New Haven, CT 06515. AA/EOE.

Opportunities for Students

Graduate Fellowship or assistantship in geophysics/seismology at the University of Kansas. Awardee will participate in research in earthquake, exploration, or near-surface seismology. Total award of $20,000 for one year, with flexibility about form of remuneration. Subsequent funding contingent on satisfactory progress toward the Ph.D. Contact Don Seeples, Ross Black, or Geoff Abers, Department of Geology, The University of Kansas, 120 Lindley Hall, Lawrence, Kansas 66045, (913)864-4974; fax: 913-864-5276.

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

These awards are from funds endowed by Orrin K. Earl, Jr., and by the Texaco Philanthropic Foundation. Each fellowship carries an annual stipend of $34,000 and offers a research expense fund of $1,000 per year and one-way travel to Pasadena. The duration of each appointment will normally be for two years, contingent upon good progress in the first year, and beginning with the 1996-97 academic year. Fellows are eligible to participate in Caltech's health and dental program.

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

Application forms may be obtained by writing to Prof. E. M. Stolper, Chairman, Division of Geological and Planetary Sciences, Mail Code 170-25, California Institute of Technology, Pasadena, California 91125 (email:stover@arms.gps.caltech.edu).

Completed applications with references should arrive at Caltech by Monday, January 15, 1996.

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

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

Vincent C. Kelley and Leon T. Silver Graduate Fellowship

Department of Earth and Planetary Sciences
The University of New Mexico

The Department of Earth and Planetary Sciences at the University of New Mexico invites applications for the Vincent C. Kelley and Leon T. Silver Graduate Fellowship. The fellowship will be awarded on the basis of scholastic record and academic promise. The fellowship will provide a generous living stipend of $1400/mo. for 9 to 12 months, and up to $3000/yr. for travel and research expenses. The Caswell Silver Foundation will pay all tuition and university fees. The award is initially made for one year but is renewable for one additional year for fellows in the masters program and two additional years for those in the Ph.D. program. Preference will be given to, but not restricted to, applicants for the Ph.D. program.

An application for admission to the UNM Graduate Program, transcripts, Graduate Record Examination scores (general and geology), three letters of recommendation, and a brief statement of research goals are required for consideration for the fellowship. Application materials may be obtained from:

Barry S. Kues
Chair
Department of Earth and Planetary Sciences
University of New Mexico
Albuquerque, NM 87131

The deadline for applications is January 31, 1996 for the Fall Semester of 1996

Book Reviews *continued from p. 256*

encountered environmental hazards including debris flows, flash flooding, and dune encroachment, to mention only a few. Famine and poverty associated with desertification has also received considerable public attention. Therefore, it is not surprising that the study of geomorphic processes and the evolution of hyperarid, arid, and semiarid terrains has exploded since the 1970s. Nonetheless, it can be easily argued that as a separate subdiscipline, the geomorphology of deserts is still in its infancy, and only a handful of texts, most geared toward the beginning student of dry-land regions, are readily available.

Geomorphology of Desert Environments is a collection of 26 well-written review papers by 22 authors, all of whom have had extensive experience in the geomorphic analysis of hyperarid, arid, and/or semiarid terrains. Contrary to what is implied by the book's title, the emphasis is on "geomorphic processes and their effects in desert areas" and not on the unique topography exhibited by desert regions of the world. In fact, the book is subdivided according to various processes that function in deserts or subenvironments within deserts. These include weathering (four chapters), hillslopes (four chapters), rivers (two chapters), piedmonts (two chapters), lake basins (two chapters), and aeolian surfaces (three chapters). In addition, seven chapters are devoted to the effects of paleoclimate on modern landscape morphology, or the use of geomorphic data in the reconstruction of past climatic conditions.

Clearly, this book covers a wide range of topics, and at 674 pages the authors have, to varying degrees, examined their particular subject area in considerable depth. In addition, an extensive bibliography is associated with most discussions, allowing the reader ready access to the original studies mentioned in the text. As acknowledged by the editors, however, 14 of the 22 authors are based in North America; thus, there is a slight bias toward research conducted in the southwestern United States. Moreover, the papers were written primarily between 1988 and 1992, and as a result, some of the reported research is dated. In spite of these minor shortcomings, there is little doubt that the book provides an excellent, and perhaps unique, reference on desert geomorphology for those who currently possess a basic understanding of geomorphic processes, or Quaternary geology. In fact, it could be successfully argued that it would make an excellent text for a graduate-level course on the geomorphology of desert lands, except for its exorbitant price and its associated strain on student finances. Nonetheless, I strongly recommend the book to professionals actively involved in the analysis of desert regions or, for that matter, the examination of geomorphic processes operating in any climatic regime.

Jerry R. Miller
Desert Research Institute
Reno, Nevada 89506

Erosion and Sedimentation.
Pierre Y. Julien. Cambridge University Press, New York, 1995, 280 p., $54.95.

This book is a concise summary of the Newtonian mechanics of fluids and sedimentary particles. The emphasis is on physical properties, fundamental principles, and engineering applications. The text covers fluids, particles, and their interactions in a systematic and rigorous manner. It is well organized, with symbols and units clearly defined; the text is easy to read, and has very few typos.

As a sedimentary geologist, primarily interested in interpreting the stratigraphic record, I was disappointed to find no applications to the study of sedimentary rocks. Engineers, geomorphologists, and hydrologists will find this book to be more useful than will sedimentary geologists, although the latter will find it a concise presentation of Newtonian mechanics.

The book is nicely produced, with abundant exercises and problems throughout the text, including several examples of practical solutions to engineering problems. It is equally useful as a textbook, a review book, or a reference book. It is densely packed with information.

Raymond V. Ingersoll
University of California
Los Angeles, CA 90095-1567 ■

Coal Division Offers Medlin Award

The Coal Geology Division of the Geological Society of America announces the availability of the Antoinette Lierman Medlin Scholarship in Coal Geology for the 1996–1997 academic year. The scholarships provide full-time students who are involved in research in coal geology (origin, occurrence, geologic characteristics, or economic implications of coal and associated rocks) with financial support for their project for one year.

Scholarship funding can be used for field or laboratory expenses, sample analyses, instrumentation, supplies, or other expenses essential to the successful completion of the research project. Approximately $1500 will be available for the 1996–1997 scholarship award. In addition, the recipient of the scholarship may be provided with a stipend of up to $500 to present results of the research at the 1997 GSA Annual Meeting. For the academic year 1996–1997, the Coal Geology Division is also offering a field study award of $500.

Proposals for the scholarship and the field study award will be evaluated by a panel of coal geoscientists. Applicants may apply for the scholarship award, the field study award, or both; however, only one award will be made to a successful applicant.

Interested students should submit five copies of the following: (1) a covering letter indicating which award(s) is (are) sought; (2) a concise statement of objectives and methods, and a statement of how the scholarship funds will be used to enhance the project. The proposal would be no more than five (5) double-spaced pages in length, including references; (3) a letter of recommendation from the student's immediate advisor which includes a statement of financial need and the amount and nature of other available funding for the research project.

Send the material to: **Peter D. Warwick**, Chairman, A. Lierman Medlin Scholarship Committee, Branch of Coal Geology, U.S. Geological Survey, MS 956 National Center, Reston, VA 22092, Phone: (703) 648-6469, E-mail: pwarwick@ncrds.usgs.gov.

The proposal and letter of recommendation must arrive no later than **February 15, 1996.** Applicants will be notified of the Scholarship Committee's decision by April 1, 1996.

The scholarship was established as a memorial to Antoinette "Toni" Medlin who, for many years dedicated her efforts toward the advancement of coal geoscience and to the encouragement of students in coal geology. Monies for the scholarships are derived from the annual interest income from the scholarship fund.

Pardee Coterie Open to New Members

The GSA Foundation has formed the Pardee Coterie to recognize those who have made planned gifts that will support GSA and its programs. Members of the Pardee Coterie and spouses meet informally once each year, generally at the annual meeting, to discuss topics of current interest to scientists and supporters of geology. The group is named after Joseph T. Pardee, whose bequest established a major GSA endowment to support education and scientific work.

Those who have made planned gifts to the Society or Foundation such as the Pooled Income Fund, charitable remainder trusts, insurance, or gift annuities are eligible for the Pardee Coterie. Others who have designated GSA in their wills or are contemplating planned gifts, to the Pooled Income Fund for example, are asked to advise the Foundation of this by calling or mailing the accompanying coupon. Pardee Coterie membership is extended to all planned donors.

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