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GSA TODAY

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INSIDE

- Geosphere Alliance Committee, p. 100
- Call for Committee Service, p. 102
- Book Reviews, p. 106

Chasing the Paleomonsoon over China: Its Magnetic Proxy Record

Subir K. Banerjee, *Institute for Rock Magnetism, Department of Geology and Geophysics, University of Minnesota, Minneapolis, MN 55455*

ABSTRACT

Magnetic susceptibility enhancements in Chinese paleosols compared to the underlying loess horizons can be explained by pedogenesis. In regions where variations in mineralogic composition and grain size are not large, the magnetic enhancement can serve as a proxy for paleomonsoon precipitation. Soil magnetization and current rainfall over many sites, plotted against each other, do provide a linear relation, a climofunction. When such climofunctions are used for old paleosols and loess, we can obtain relative variations in paleomonsoon precipitation that are comparable to general circulation model (GCM) estimates for these time periods.

A trench cut into the loess section near Xining, Qinghai Province, China. Xining is currently cooler and drier than Xifeng because Xining lies in the monsoon rain shadow to the west of the Liupan Mountains. However, magnetic parameters show that the climate at Xifeng and Xining was similar during both the early Holocene and last interglacial, about 9 and 120 ka, respectively. *Photo by Christopher Hunt.*

A vertical cut into the loess section near Xifeng, Gansu Province, China. Xifeng, which lies to the east of the Liupan Mountains, is currently warmer and wetter than sites to the west, as revealed by the vegetation and the magnetic properties of the youngest layers. *Photo by Christopher Hunt.*

INTRODUCTION

Climate change and the effects of climate change on society are interesting topics in their own right. Our concerns about them have taken on a much more urgent note, however, with the realization that increased emissions of greenhouse gases and the resultant induced warming may bring about a more rapid tempo of climate change than has been common in the past. Recent numerical modeling of the effects of global warming, using atmospheric general circulation models (GCMs) have shown that large grain-producing areas of China and India could become arid and unproductive as a result of such global change.

Oxygen isotope ($\delta^{18}O$) records from the shells of marine foraminifera have yielded relative global ice volume data and, hence, measures of global temperature. We have learned, for example, that the last interglacial (stage 5 in the SPECMAP oxygen isotope stratigraphy; Imbrie et al., 1984) lasted from about 128 to 75 ka, and was much warmer than the present interglacial (stage 1) that began 10 ka ago. If we could obtain reliable, high-resolution (spatial and temporal) records of summer monsoon activities in China for stages 5 and 1, their intercomparison could help teach us what to expect if the world approached stage 5 conditions of climate in the future. Also, the recently discovered sharp instabilities in climate obtained from Greenland ice cores could be compared with continental paleomonsoon records.

The alternating loess and paleosol layers (total thickness ~100 to 300 m) dissected by the Yellow River (Huang He) in central China extend over an area of 500,000 km^2 (see Fig. 1). They constitute a 2.6-m.y.-old archive of high-quality paleoclimatic proxies waiting to be deciphered by modern techniques, even though geologists for more than a century have used conventional approaches such as pollen records and clay/silt ratios to extract a coarse-resolution paleoclimate record. The successful extraction of a magnetic reversal stratigraphy from Chinese loess by Heller and Liu (1984, 1986) has allowed the dating of the numerous peaks in magnetic susceptibility (χ). These peaks had been known to coincide with the warmer interglacials and interstadials when the paleosol layers had formed.

THE ROCK MAGNETIC RECORD

The loess deposits of China represent eolian dust from the deserts of the north and northwest lifted by the winter northwesterlies and deposited on the loess plateau (Pye and Zhou, 1989). During glacial times, however, the input was much higher than during interglacial times. Except for the difference in color between buff-brown loess (glacial) and darker brown paleosols (interglacial), it has been difficult to study quantitatively the relative degrees of climatic change (or the precise ages of specific horizons of this uniform body) by the existing sedimentological and other methods. Magnetostratigraphic dating by Heller and Liu (1984, 1986) allowed the correlation of loess χ profiles from multiple sites. High sensitivity of the various rock magnetic parameters to climate change (through a change in the concentration, composition, and grain-size of the magnetic minerals) has provided a high-resolution climatic proxy record. The magnetic minerals responsible are magnetite, maghemite, and hematite; the first two are much more strongly magnetic and thus contribute greatly to the susceptibility signal. However, without a widely-accepted model for the changes in magnitude of all the many magnetic parameters that have been measured up to now, we are still waiting to interpret completely the finer scale details of the magnetic signatures.

Kukla et al. (1988) compared the detailed χ-record of two sections at

China *continued on p. 94*

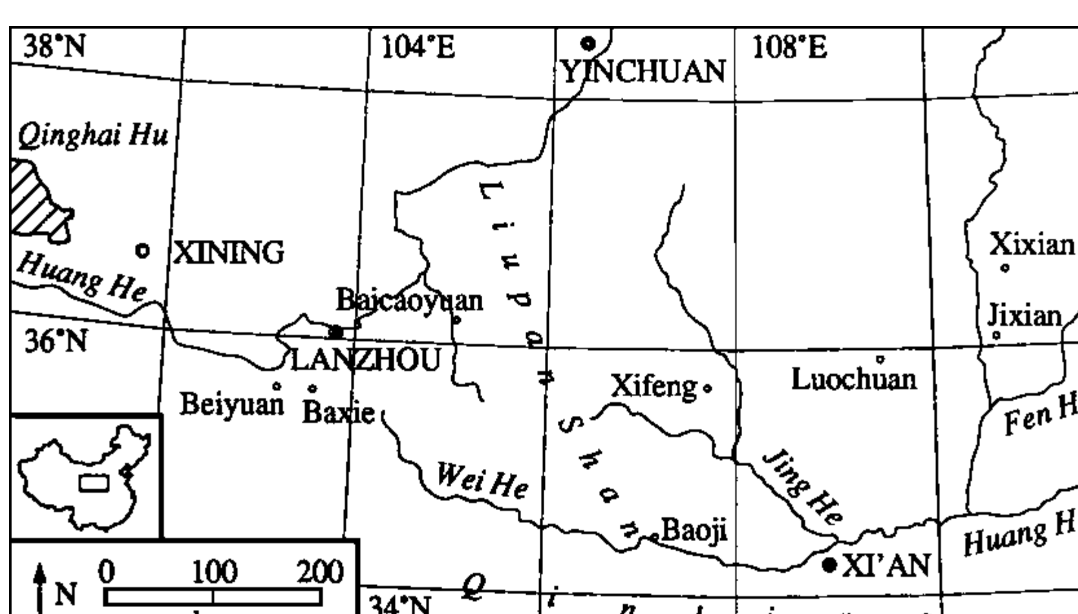

Figure 1. A map of the loess plateau (~500,000 km^2) of China, located north of the Qinling mountains. Open circles mark sampling sites (e.g., Xifeng).

Note: With apologies to Alexander Frater, author of the eminently readable *Chasing the Monsoon* (Holt and Co., 1992).

IN THIS ISSUE

Chasing the Paleomonsoon over China: Its Magnetic Proxy Record 93
About People 94
In Memoriam 94
Correction 94
GSA on the Web 94
Forum 97
Geosphere Alliance Committee Seeks Input and Action 100
GSAF Update 101
Call for GSA Committee Service 102
Earth Scientists and Forest Health Policy 103
Assessing Environmental Change 104
Letter to the Editor 104
Field Cooking Contest 105
Book Reviews 106
Book Nook 108
1995 GeoVentures 109
GSA Meetings 110
Classifieds 111
Calendar 111

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China *continued from p. 93*

Xifeng and Luochuan with the $\delta^{18}O$ stratigraphy from SPECMAP, which represents the worldwide average changes in global ice volume measured through the variations in oxygen isotopes ^{18}O and ^{16}O in marine foraminifera. The choice of the sites may have been fortuitous, but even without the benefit of formal statistics it is clear that there is excellent correlation between the χ and $\delta^{18}O$ records (Fig. 2). Many of the details of the peaks in the magnetic parameter can be compared with similar details in the oxygen isotope stratigraphy. Because Xifeng and Luochuan are about 160 km apart, Kukla et al. (1988) concluded that the magnetic variations could not be due to pedogenesis. The preferred model of Kukla et al. called for a relative weakening of χ in the loess layers and a strengthening in the paleosol layers, as a result of variable concentration of a global "rain" of strongly magnetic magnetite in a low-magnetic-susceptibility eolian dust (loess) prevalent during glacial times. During interglacial times, when soils formed slowly and dust arrival diminished, the magnetite rain from the troposphere was concentrated, thus presenting a relatively large magnetic susceptibility to the observer. As proof, Kukla et al. (1988) presented a model in which the average magnetic susceptibility was multiplied by the thickness of the sediment column above the sample to produce a plot of magnetic mineral accumulation against inferred geologic age. It was observed that both Xifeng and Luochuan had the same magnetic accumulation rate for the past 800 ka.

Zhou et al. (1990) and Maher and Thompson (1991) showed that when the paleosol and loess samples are studied in detail for their grain-size-dependent rock magnetic parameters, it becomes clear that the paleosol layers are distinguished from loess layers by concentration, mineralogy, and a much different (and much smaller) grain-size of the magnetic carriers. The data presented by Zhou et al. (1990) are shown in Figure 3. Both groups of authors thought that the evidence points, at least partially, to a pedogenic magnetic

China *continued on p. 95*

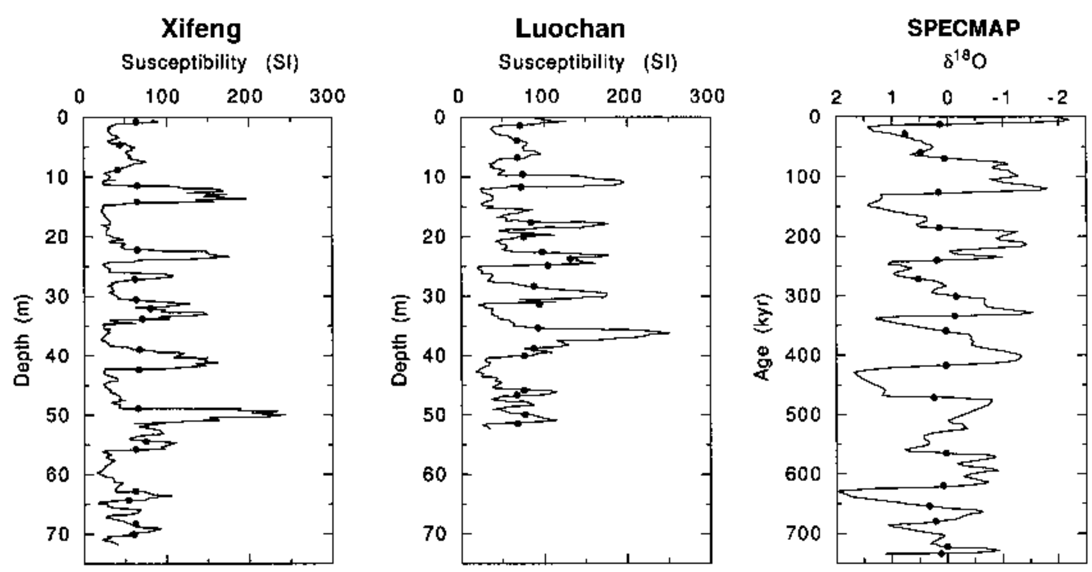

Figure 2. Kukla et al.'s (1988) comparison of the χ depth series from Zifeng and Luochuan with the SPECMAP time series of globally averaged $\delta^{18}O$. Because $\delta^{18}O$ values provide global ice volume data, they indirectly provide data on global temperature fluctuations which coincide in character with the χ depth series, providing the first comparable scale comparison between oceanic and continental climates.

About People

GSA Member **Raymond E. Beiersdorfer,** Youngstown (Ohio) State University, was recently awarded the 1995 Gustav Ohaus-NSTA (National Science Teachers Association) Award for Innovations in College Level Science Teaching.

GSA Member **Timothy R. Carr,** Kansas Geological Survey, Lawrence, has been appointed a co-director of the University of Kansas Energy Research Center.

Fellow **Richard Gray,** GAI Consultants, Inc., Monroeville, Pennsylvania, was elected president of the Association of Engineering Geologists.

Fellow **Morris W. Leighton,** chief emeritus of the Illinois State Geological Survey, Champaign, has received the Gaylord Donnelly-Nature of Illinois Foundation Award, for recognition of significant science and conservation efforts in Illinois.

The American Association for the Advancement of Science awarded its 1994 Philip Hauge Abelson Prize to GSA Fellow **Frank Press,** Carnegie Institution of Washington. The award honors sustained exceptional contributions to advancing science or a career distinguished both for achievement and notable services to the scientific community.

The Maryland Geological Survey in Baltimore renamed its office building the **Kenneth N. Weaver** Building in honor of GSA Fellow Kenneth N. Weaver's 29 years of service as director and state geologist. Weaver also received the John Wesley Powell Award for Citizen's Achievement from the U.S. Geological Survey.

The Meritorious Service Award, the second highest award given by the U.S. Department of the Interior, honored these U.S. Geological Survey employees and GSA members: Fellow **Charles W. Naeser,** Reston, Virginia; Fellow **Robert N. Oldale,** Woods Hole, Massachusetts; Member **Charles L. Rice,** Reston, Virginia; member **John F. Slack,** Reston, Virginia; and member **Bruce R. Wardlaw,** Reston, Virginia. ■

In Memoriam

Sturges Bailey
Madison, Wisconsin
November 30, 1994

Russell C. Cutter
Ft. Lauderdale, Florida
September 26, 1994

Richard M. Foose
Amherst, Massachusetts
November 26, 1994

Mack Gipson, Jr.
Columbia, South Carolina
March 10, 1995

Karl A. Naert
Ontario, Canada
September 28, 1994

Marshall Schalk
Northampton, Massachusetts
February 21, 1995

C. Bertrand Schultz
Papillion, Nebraska
March 7, 1995

Reginald C. Sprigg
Port August, South Australia
February 12, 1994

Sherman A. Wengerd
Alburquerque, New Mexico
January 28, 1995

CORRECTION

In *GSA Today,* v. 5, no. 3, p. 46 (March 1995), Francis S. Birch was inadvertently listed among the deceased members. This was an error. We apologize to Francis S. Birch and his family and friends.

GSA ON THE WEB

What's new on the GSA home page on the World Wide Web? If you haven't yet connected to the Web, the Universal Resource Locator (URL) is **http://www.aescon.com/geosociety/index.html.**

For current information on the 1995 Annual Meeting in New Orleans, go to **Meetings** and choose **1995 Annual Meeting.** This area contains a listing of Symposia and Theme Sessions and has information about Field Trips, Continuing Education, Exhibits, Travel, and Lodging.

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.

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China *continued from p. 94*

enhancement through the formation of ultrafine (superparamagnetic and single domain, $d \sim 0.1$ µm or smaller) magnetite. Later, Maher and Thompson (1992a) attributed all χ-variation to pedogenesis, as had been done earlier by An et al. (1991), and used a statistical sequence-slotting method to correlate susceptibility features with the SPECMAP $\delta^{18}O$ stratigraphy. Verosub et al. (1993) have also argued that *all* of the susceptibility enhancements above the loess background signal are due to pedogenesis. Pedogenesis may be driven by variations in summer monsoons, which may be the global climate change signal, as indicated by the similarity with $\delta^{18}O$ data from ocean sediments. However, in the absence of an independent high-resolution chronology for the χ stratigraphy, such correlations do not constitute an a priori proof of the pedogenic hypothesis.

To test the model of Kukla et al. (1988), Hovan et al. (1989) and Clemens and Prell (1992) tried to correlate directly the loess stratigraphy with the record of eolian silica flux in the northwest Pacific and the Arabian Sea, respectively (and claimed success). However, Maher and Thompson (1992b) thought that such a correlation between magnetic susceptibility, which is a concentration-dependent parameter, should not be attempted with mass eolian accumulation rate, which is a rate-dependent parameter. They emphasized that although both were ultimately responsive to climate change, the susceptibility record in the Chinese loess plateau was more a record of pedogenesis and thus indirectly a record of the east Asian monsoon intensity during summer at these sites. Pye and Zhou (1989) also compared the ages of the maxima in wind-blown deposits in the Pacific Ocean and in the Chinese loess plateau and concluded that they are neither coeval nor caused by the same wind system.

In my opinion, both of the proposed models (a pure accumulation model that primarily causes χ minima by dilution and a pure pedogenic model causing χ maxima by pedogenic enhancement) are perhaps two idealized end members. In reality, both the loess and the paleosol layers must have varying amounts of magnetic contribution due partly to detrital input and partly to pedogenesis. Unfortunately, two recent attempts to resolve this problem (Beer et al., 1993; Verosub et al., 1993) have not produced conclusive answers, but they deserve our careful attention.

Beer et al. (1993) measured the depositional input of ^{10}Be in a loess profile (S_0-L_2, or isotopic stages 1–6) from Luochuan and claimed that the ^{10}Be flux in the 0–130 ka interval can be fitted to a constant, and global, atmospheric flux (F_A) and a time-varying contribution due to a dust flux (F_D) from the desert delivered by the winter northwesterlies. By further assuming that part of the magnetic susceptibility flux (the depositional, low-χ part, or F'_D) is linearly proportional to the ^{10}Be dust flux ($F'_D = \alpha F_D$), Beer et al. (1993) and their colleagues Heller et al. (1993) claimed that the rest of the susceptibility signal is pedogenically produced. However, the hypothesis of constant F_A has major weaknesses, as Beer et al. and Heller et al. themselves have pointed out, and it also militates against their own experimental data, sometimes by as much as 50% (see Fig. 4 of Beer et al., 1993). The result is a derived pedogenic χ component that is likely to be inaccurate by up to 50%.

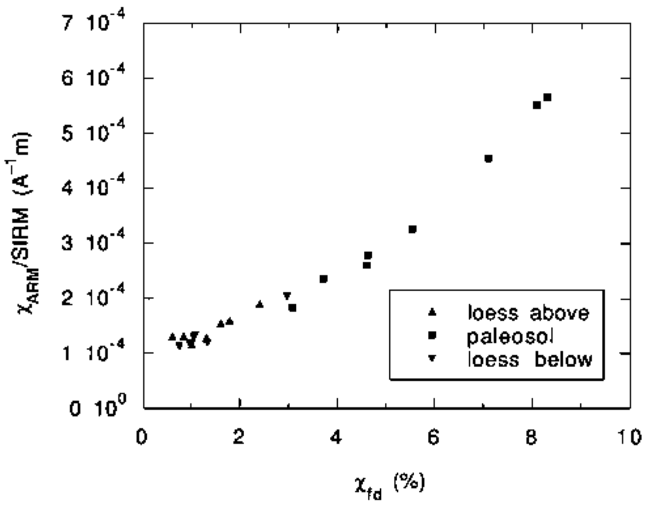

Figure 3. Zhou et al.'s (1990) measurements of susceptibility of anhysteretic remanent magnetization (χ_{ARM}) vs. frequency dependence of low field susceptibility (χ). χ_{ARM} has been normalized by saturation isothermal remanent magnetization to remove any concentration dependence. The ratio χ_{ARM}/SIRM increases with decreasing grain-size of magnetite. χ_{fd} is the percentage change in χ when measured at 400 and 4000 Hz and is very sensitive to the presence of magnetite grains near the superparamagnetic size threshold around 30 nm. The data show that paleosol horizons contain many grains at or below 30 nm size.

The second attempt was made by Verosub et al. (1993), who attributed the pedogenic component of χ to that part of the magnetic signal which is lost when a soil sample or a loess sample is treated with CBD (citrate-bicarbonate-dithionite; Mehra and Jackson, 1960) solution. CBD treatment removes very fine grained iron oxides, e.g., magnetite and maghemite, which make a major contribution to χ and whose origin can be attributed to pedogenesis (Fine and Singer, 1989). But here, too, the situation is murky (Liu et al., 1994a; Hunt et al., 1995), and it may be that CBD reduction of χ can also be due partly to removal of some detrital magnetite-maghemite. Even if the true pedogenic χ enhancement can be isolated and then attributed to summer rainfall variations (for a critical discussion of this hypothesis, see the next section), a question remains as to whether the appropriate cause is regional (~1000 km) or local (~100 km) rainfall variations. In order to answer this question, we took recourse (Banerjee et al., 1993) to low-temperature magnetic measurements of a pair of sites, ~300 km apart, that are on the rainy and arid sides, respectively, of a rain shadow: the roughly northwest-southeast-trending Liupan Mountains in the southwestern part of the loess plateau. Because the summer monsoon at these two sites, Baicaoyuan (arid) and Xifeng (humid), is mostly from the east, the soils at Xifeng are more highly developed and those at Baicaoyuan to the west are less so.

Characteristic thermal decay curves of saturation isothermal remanent magnetization (σ_{rs}) of a soil sample (S_0; glacial stage 1) and a sample from the underlying loess layer (L_1; glacial stage 2) are shown in Figure 4. In both cases the high-field (2.5 tesla) induced magnetization (σ_i) from all grain-size fractions is the same and varies in a similar manner with temperature change, suggesting that the same magnetic phase was present in both loess and paleosol. However, when σ_{rs} is created by a 2.5 T field at 15 K and warmed in zero field, the decay curves are very different for the two layers. In the case of the loess, there is a characteristic transition or "step" at about 100 K which is related to the low-temperature magnetic transition (Verwey transition) of coarser grained ($d > 30$ nm) magnetite. In the case of the soil sample, the Verwey transition is only barely visible, most of the σ_{rs} data showing the decay due to thermal "unblocking" of σ_{rs} of very small or "superparamagnetic" grains of magnetite or maghemite. By extrapolating the nearly linear part of σ_{rs} decay displayed by SP grains (0 nm $< d <$ 30 nm) backward to 0 K, we can graphically separate the SP fraction (SP/total) in the sample. Following Maher and Thompson (1992a), SP grains that are so small are most likely to be produced by pedogenesis. The larger grains, then, could be construed as detrital, having been deposited by the winter northwesterlies from the deserts.

Comparing variation in SP/total grains between Baicaoyuan (300 mm/yr rainfall) and Xifeng (500 mm/yr) (Fig. 4), we see that the more arid site, Baicaoyuan, has an SP/total stratigraphy that is closer to what is expected from the $\delta^{18}O$ record of glacial-interglacial climate change. In Xifeng the fluctuations are much more muted, perhaps because of the higher rainfall producing a much stronger local pedogenic signal. The difference in SP/total signal between the corresponding layers (L, S, etc.) of the two profiles allows extraction of the local monsoon intensity variation between these two sites. In addition, an apparent anomaly emerges whereby the SP/total ratio for both sites during the early Holocene (5–10 ka) seems to be the same. If the magnetic data are correct, there could be at least two interpretations. One, because the Liupan Mountains follow a south-southeast to north-northwest trend, the two sites would have received similar summer monsoon rainfalls if the summer monsoon was more southerly during the early Holocene. Alternatively, we should allow that the rainfall in the western part of the Chinese loess plateau could have been under the influence of a strong southerly Indian monsoon in the early Holocene. Kutzbach et al. (1993) used atmospheric GCMs to predict that the early extremely strong south Asian monsoon of Holocene time could have broken through to the western loess plateau.

CONVERTING MAGNETIC SUSCEPTIBILITY TO PALEORAINFALL

It is now widely accepted that the enhancement in susceptibility of paleosols relative to that of the loess horizons is due to pedogenic formation of very small ($d < 30$ nm) magnetite and/or maghemite grains. An et al. (1991), Liu et al. (1994b), and Maher et al. (1994) have further suggested that such formation is directly related to paleorainfall, especially during the summer. Such a hypothesis requires that the unaltered loess over the region under consideration has uniform mineralogy and grain size. The first proviso is easier to prove than the second. Over an ~1200 km northwest to southeast range in the loess plateau, the grains do tend to decrease in size. We do not, however, know how critical this variation is to loess pedogenesis. An added complication is the lack of precise high-resolution ages beyond ~60 ka. In spite of these difficulties, preliminary attempts have been made based on empirical correlations ("climofunctions") between modern (or slightly older) soils and current rainfall over a very large part of the loess plateau. The first attempt was by Heller et al. (1993), who used ^{10}Be data to separate the strictly pedogenic components of observed χ at Luochuan (see previous section). By using a calibration constant c (where χ = c · current rainfall, with χ from the Holocene layer [S_0]),

China *continued on p. 96*

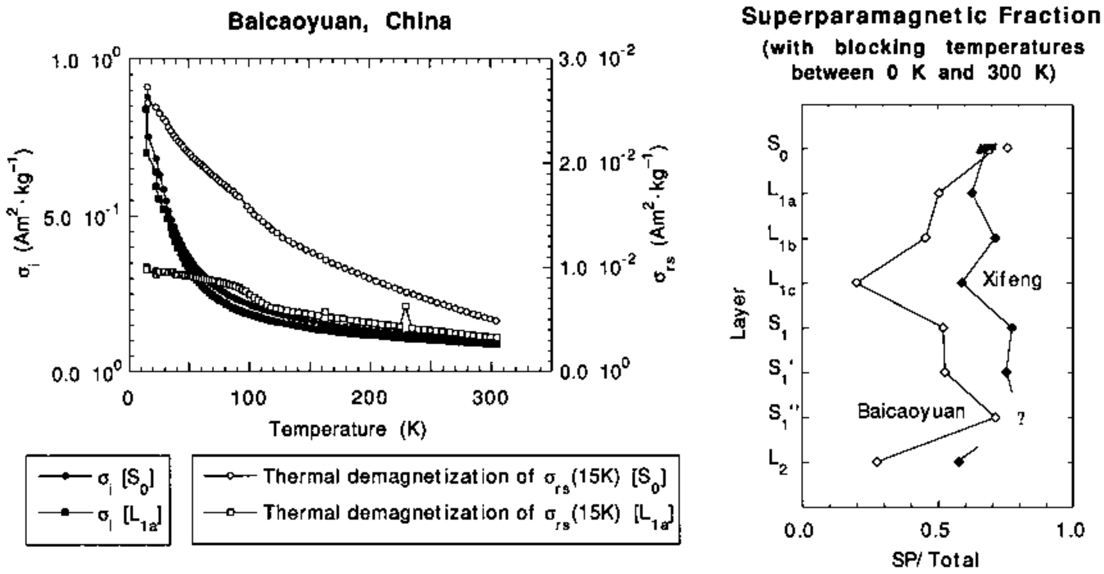

Figure 4. Left: Temperature dependence of induced magnetization (σ_i) and saturation isothermal remanent magnetization (σ_{rs}) of a representative paleosol sample (S_0) and the underlying loess (L_{1a}) from Baicaoyuan. The similarity of $\sigma_i(T)$ curves suggests a similar magnetic mineral composition, and the dissimilarity of $\sigma_{rs}(T)$ curves suggests differences in the grain size distribution. Right: SP/total, the relative fractions of superparamagnetic grains ($d < 30$ nm), plotted against depth for arid Baicaoyuan and the more humid Xifeng sites. The SP fraction causes the nearly linear decay of σ_{rs} between ~100 and 300 K in the plot at the left. Total SP fraction is extracted from the σ_{rs} intercept when the straight line (~100 to 300 K) is extrapolated to 0 K. SP/total represents pedogenically produced very small (i.e., superparamagnetic) magnetite grains. (After Banerjee et al., 1993).

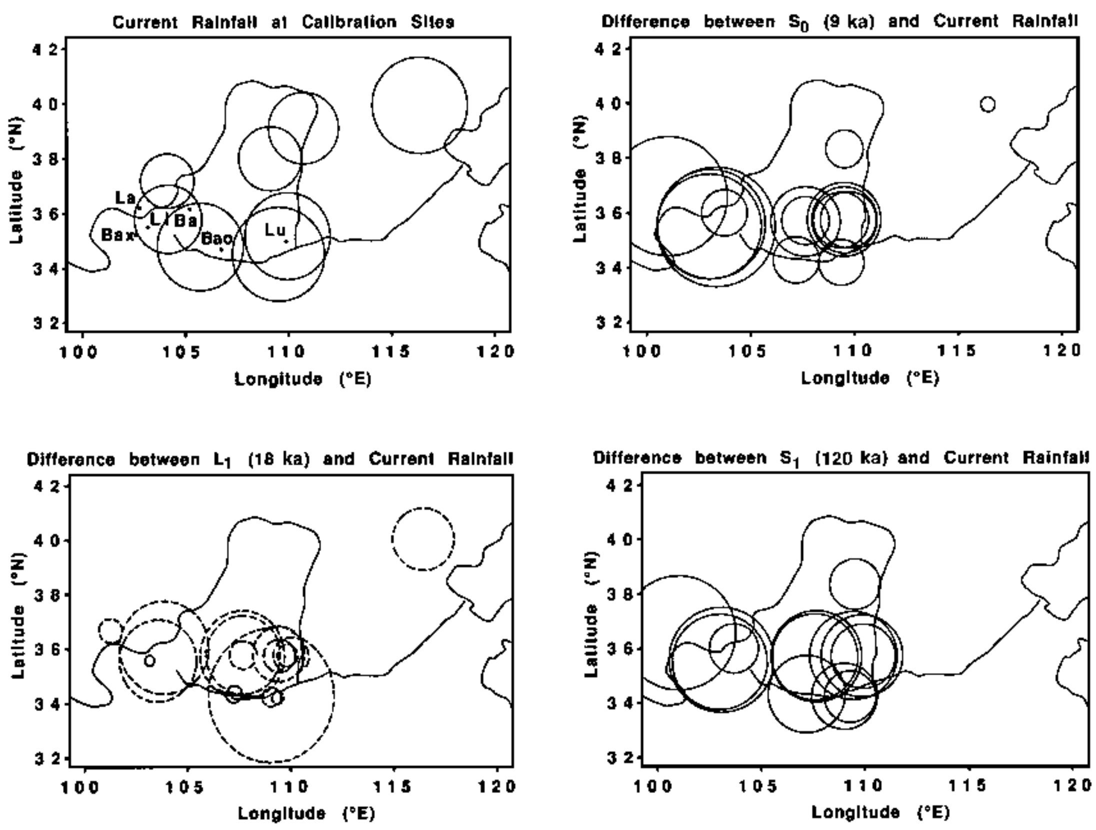

Figure 5. Top left: Calculated rainfall difference between the present and periods when specific soil or loess horizons formed on the loess plateau, China. The diameters of the circles are proportional to current rainfall in mm/yr at different sites of the loess plateau. Bax = Baxie, La = Lanzhou, Li = Linxia, Bai = Baocaiyuan, Bao = Baoji, Lu = Luochuan. In difference representations, solid circles represent excess rainfall, and dashed circles indicate less rainfall than at present. For details of conversion to paleorainfall from magnetic susceptibility enhancement, see text. Data courtesy of Maher et al. (1994).

China *continued from p. 95*

and by utilizing the average χ values for S_0 (5–10 ka), L_1 (18–75 ka) and S_1 (75–130 ka), they obtained average paleorainfall values of 600 mm/yr, 310 mm/yr, and 540 mm/yr, respectively. The S_0 soil was used for calibration because Heller et al. believe current rainfall and early Holocene rainfall to be similar. It is immediately obvious, and odd, that while the $\delta^{18}O$ value for the time interval associated with S_1 is known to be larger than S_0, the above procedure yields an S_1 rainfall that is smaller than that of S_0. Heller et al. also had to assume that the magnetic susceptibility of each layer, including S_1, had approached a steady-state value, which is contrary to what Singer et al. (1992) found, even for soils as old as 1 m.y., in California. Ongoing research by TenPas et al. (1994) may shed further light on this problem.

In the second attempt, Liu et al. (1994b), instead of using the χ measurement, used the approach of low-temperature magnetic measurement, σ_{rs} vs. T, of Banerjee et al. (1993) to determine first the variation in pedogenic fraction or SP/total with time at Xifeng from closely spaced samples over the time period 0–130 ka. They then computed a constant of proportionality between the SP fraction and precipitation by plotting the present-day precipitation against SP fraction of the early Holocene (S_0) soil at six sites within the loess plateau. The early Holocene soil was used instead of a modern soil because Liu et al. could not be sure that the modern soil was totally free from anthropogenic disturbances (farming, grazing). The correlation between present-day precipitation and the SP fraction of this horizon (S_0) for the six sites was found to have a correlation coefficient of 0.95. Liu et al. (1994b) then used the slope of this plot to convert the SP fraction to paleoprecipitation for the single high-resolution profile they had obtained at Xifeng. The paleoprecipitation curve thus obtained has a close similarity with the SPECMAP $\delta^{18}O$ record. For example, Liu et al. found that at Xifeng during glacial isotope stages 2 (L_{1a}), 4 (L_{1c}), and 6 (L_2), precipitation was about 200 mm/yr—i.e., 350 mm/yr less than today, whereas during the last interglacial, stage 6 (S_1), the precipitation was about 650 mm/yr—i.e., 100 mm/yr more than today. Unlike Heller et al. (1993), Liu et al. found that rainfall in stage 5 was higher than in stage 1, as would be expected from the SPECMAP data.

A vertical cut into the deposits near Jixian, Shanxi Province, China. The upper darker soil has formed since the last glaciers retreated about 11 ka. The lighter materal in the lower half is the loess that was deposited during the height of the last glacial period, between about 11 and 23 ka. Magnetic properties vary with degree of soil development, and they can be used as paleoclimate proxies. *Photo by Peter Solheid.*

Maher et al. (1994) gave what I perceive to be an improved approach to calculating paleorainfall. Following Singer et al. (1992), Maher et al. first determined the *increase* in susceptibility between the B (weathered soil) and C (parent material) horizons at 36 modern soil sites located in eight different areas of the loess plateau. This relative enhancement was then correlated with the average rainfall between 1951 and 1980 in a regression analysis to establish a climofunction coefficient. Like Heller et al. (1993) and Liu et al. (1994b), Maher et al. assumed that residence of only a few thousand years is enough for the magnetic susceptibility of the B horizon to have achieved a steady state. Therefore, they converted susceptibility enhancement to paleorainfall using the same coefficient for all the horizons. Base level χ value for the C horizon was approximated by the older, least weathered L_9 horizon.

For the last glacial (L_1) at 18 ka (dashed-line circles in Fig. 5) paleoprecipitation was less than at present at all of the sites, and the maximum decrease was 266 mm/yr. In contrast, both during S_0 (isotope stage 1) and S_1 (isotope stage 5), the rainfall was much greater than today, and the largest values during both periods (>200 mm/yr) were obtained from the western side of the loess plateau. During the early Holocene, the rainfall on the western side was much higher (+60%) not only compared to today but even compared to the early Holocene on the eastern side of the loess plateau. This compares well with the observations of Banerjee et al. (1993; Fig. 4), that the currently more arid western site, Baicaoyuan, was at least as humid as the eastern site, Xifeng, in the early Holocene. Maher et al. (1994) found that their calibration climofunction appears to compare well with similar functions for modern soils in other warm, temperate regions today such as Morocco, Sudan, and California. However, they also admitted that during glacial times the measured susceptibility values are low and a 25% error in the loess susceptibility measurement could easily produce an error of 47% in the glacial-stage rainfall reconstruction. The reader should remember that for the purpose of this reconstruction, it has been assumed that all of the susceptibility enhancement is due to pedogenesis, which in turn is controlled by the summer monsoon. However, if it proves to be possible in future to separate the influences on magnetic susceptibility due either to the dilution effect mentioned earlier (Kukla et al., 1988) or to decalcification and collapse of soil layers (Heller and Liu, 1986), then the true pedogenic component can be determined, and only that should be reflective of paleoprecipitation.

SUMMARY

Although it is not yet known precisely how much of the susceptibility signal or SP/total fraction in the paleosol horizons (interglacial times) is strictly due to pedogenesis, and therefore strongly reflective of summer monsoon, it has been possible to make a first approximation at calculating paleorainfall and hence paleomonsoon intensity variations from magnetic data alone. Overall, the paleoproxy records (pollen, lake-level data) and climate model simulations for the loess plateau as a whole (Winkler and Wang, 1993) support the general increase and decrease of paleoprecipitation (0–130 ka) derived by the magnetic proxy method of Maher et al. (1994). However, both the study by Banerjee et al. (1993) and the study by Maher et al. (1994) point to an interesting regional event at 5–10 ka. Rainfall over current values in the western part (now arid) of the Chinese loess plateau was then quite high (+215 mm/yr) and comparable to the eastern part. However, this result should be compared with a much larger increase (+900 mm/yr) predicted by the atmospheric GCM approach for this area (Winkler and Wang, 1993). Improvements in spatial resolution and incorporation of additional model parameters (such as aerosol concentration variation) in GCMs and, equally important, parallel advances in extracting true pedogenic components from the magnetic parameters may lead to a proper resolution of this difference. Such improved paleomonsoon time series from magnetic proxies for the Chinese loess plateau may one day provide the only high-quality continental analogs of paleoclimate time series and may lead us to high-resolution spatial and temporal determination of comparative paleorainfall variations on continents to gain an understanding of both global climate change and its regional responses.

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China *continued on p. 97*

FORUM

Bruce F. Molnia

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

Crucial Environmental Issues: Fear and Loathing at the Leading Edge—

A Sample of the 1994 Institute for Environmental Education Annual Environmental Forum

PERSPECTIVE 1:
Introduction

Bruce F. Molnia, Forum Editor

Mindful of its charge to promote the "application of geology to the wise use of Earth," the GSA Institute for Environmental Education, at the Seattle 1994 Annual Meeting, sponsored a forum concerned with disposal sites for low-level radioactive waste, ground-water contamination, reliable earthquake prediction, seismic hazard mitigation, and the causes and rates of species decline. Each is an issue that can lead to an inflamed and fearful public and which creates both problems and opportunities for geological scientists. Forum presentations examined these issues from a number of perspectives, including how geoscientists can help improve the quality of the debate and the decisions that affect site selection. Many serious questions about the cost and effectiveness of proposed solutions to these issues face the geoscientist-engineer and the public. The following three perspectives are samples of presentations from the IEE Forum.

PERSPECTIVE 2:
Endangered Species, Ecosystem Management, and the Geological Sciences

David R. Montgomery, University of Washington, Seattle

One of the great social issues of the coming millennium will be reconciling the needs and desires of a burgeoning human population with the health and integrity of ecological systems. Even now this is an urgent problem, as current extinction rates resulting from human activity approximate those recorded during the mass extinctions at the close of the Paleozoic and Mesozoic eras. The present extinction event occurs in great part because society considers the needs of other species only when they become threatened or endangered. Developing alternative approaches requires geological expertise, because of the fundamental influence of geologic processes on the structure and dynamics of many ecosystems.

An exponential increase in human population together with technological innovations have accelerated landscape alteration to the extent that humans are the dominant geomorphic agent throughout the world today. For millennia the domination of nature has been the operative paradigm of many civilizations. In serving this mission science has sought to mold landscapes to human desires or expectations, with neither attention to nor knowledge of long-term consequences. Now, our recognition of the human interdependence on and symbiosis with a complex web of ecological processes has led to political momentum for reversing historical trends of environmental degradation. The emerging philosophy of ecosystem management aims to maintain the integrity of ecological systems while deriving a sustainable level of benefits for human populations. If contemporary human societies are to adopt this approach, land management decisions must be based on an understanding of landscape-scale spatial and temporal variations in habitat-forming processes.

The Pacific salmon illustrate why such an approach is essential for preserving threatened and endangered species. This traditional symbol of the Pacific Northwest is poised for listing under the Endangered Species Act over most of its range in the lower 48 states. The continuing decline of most currently listed species illustrates that we need a more comprehensive approach if we are to reverse historical trends in salmon abundance. The plight of the salmon is not a new problem; it is a recurrent story involving processes that have been recognized for many years. In spite of increased understanding of human influences on aquatic ecosystems, we are well on the way to repeating in the Pacific Northwest the historic extirpations of wild salmon that sequentially occurred in England, the eastern seaboard of the United States, and many parts of California. The primary, widely recognized causes for declining salmon populations are overfishing, dam construction, and habitat degradation. Each cause undoubtedly contributes to the plight of the salmon, yet the interests responsible for these effects have bickered for decades about assigning culpability for declining salmon runs. Without becoming mired in this unconstructive approach, geologists can contribute crucial expertise on habitat issues.

Ecosystem-oriented land management is founded on how geologic processes create, shape, and eliminate habitat and how human actions influence these processes. Over geologic time, processes such as uplift, climate change, and volcanism influence regional habitat characteristics, control the frequency and extent of events that extirpate populations, and govern long-term environmental change. Over historic time, spatial and temporal variability of stream discharge and bed scour affect salmon and how they use channel habitat. At the finest spatial and temporal scales, intrusion of sand and silt into spawning gravel influences embryo development during incubation in stream beds. Land management that maintains salmon abundance requires incorporating ecosystem dynamics across the full temporal and spatial range of processes that govern the amount, type, and quality of salmon habitat.

Adapting our actions to reduce negative human impacts on ecological systems requires defining mechanistic links between management activity and ecosystem response. Unfortunately, much of the work on human impacts to aquatic ecosystems has relied on convenient surrogate measures, such as the percentage of a basin area over which timber has been harvested. Geologists need to help rethink and redesign our watershed assessment, research, and monitoring methods to establish underlying cause-and-effect relations. In addition, we need to be able to do this in a spatially explicit context in order to use this information to support decision making for particular places. Furthermore, society must tailor land-use decisions to the capability of the landscape to sustain human activity; this tailoring requires that scientific assessment precede planning and that management involve an adaptive, multi-scale approach based on ecologically relevant planning units. Watershed analysis procedures, such as those adopted by the State of Washington and under development for federal lands, provide a framework for using landscape-specific analyses of geomorphological, hydrological, and biological processes to guide ecosystem management.

Societal pressure to move toward ecosystem management thus holds significant opportunities and challenges for the geological sciences. There is an urgent need for interdisciplinary research with ecologists, engineers, and planners on how geologic processes influence biological communities; on how to design habitat restoration schemes; and on how to incorporate the spatial and temporal variability inherent to geomorphic processes into land-use decisions. Equally important for the future of many university geology departments is that ecosystem management requires people trained to read and interpret the landscape. If the geological community accepts the

Forum *continued on p. 98*

China *continued from p. 96*

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Forum *continued from p. 97*

challenge of contributing to such an approach, it will foster expansion of emerging job opportunities for graduates trained in a wide range of surface processes.

Watershed analysis can provide us with more and better information, but whether possession of such knowledge reverses historical trends in salmon abundance depends on land management priorities. Better information will not ensure better decisions, although it should more readily reveal conflicting objectives and enhance evaluation of the consequences of proposed actions. No one knows for sure whether adopting ecosystem management will prove to be more than a political smoke screen for continuing traditional patterns of resource exploitation and depletion. Addressing the underlying issues, however, will force decisions that historically have been made either implicitly or by default to be framed as explicit choices. In the process, this will create opportunities for furthering our understanding of how natural landscapes and ecosystems are structured and influenced by geologic processes. Until we decide to manage our land and natural resources in accordance with landscape-forming processes, we will continue driving species to extinction and shackle future generations with our legacy of a degraded environment.

Short-Course Series

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PERSPECTIVE 3:

The Low-Level Radioactive Waste Situation: Storage or Disposal?

Fred A. Donath, GSA Institute for Environmental Education

Fear is an important, but strong, emotion that often evokes irrational response. The fear of radioactivity can have that effect, but education and understanding can help to dispel fear. Confusion within the public between low-level and high-level radioactive waste, public perception of risk, and disagreement among experts, along with misleading and self-serving statements of special interests, can all contribute to strong public reaction over disposition of low-level radioactive waste. Such reaction can hamper efforts to locate a geologically acceptable environment in which to put the waste, and this can create situations that constitute even greater public risk.

Low-level radioactive waste is legally defined as what it is not—it is not the highly radioactive spent fuel rods from nuclear reactors, wastes from nuclear weapons production, nor waste from mining and processing uranium ore. Low-level waste can generally be characterized as discarded items contaminated by a small amount of radioactivity—typically paper, plastics, glass, clothing, discarded equipment and tools, and absorbed or solidified liquids.

Low-level radwaste is generated in the production of electricity, in the manufacturing of pharmaceuticals and other products, in medical diagnosis and treatment, and in university and private research. In general, low-level waste is material that has become contaminated by radioactive material used in these activities. Nuclear power plants account for about 63% of low-level waste by volume, but 94% by radioactivity. Approximately 16% by volume and 5% by activity comes from industrial processes, 16% by volume but only 0.03% by activity comes from medical practice, and 5% by volume and only 0.4% by activity comes from scientific research.

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Some confusion, and cause for concern, perhaps stems from reference to large amounts of radioactive waste from nuclear power plants. The low-level waste from nuclear power plants consists primarily of filters and filtration sludges, irradiated metals, and trash—not highly radioactive fuel components. Confusion undoubtedly also comes from equating the *volume* of waste with magnitude of the hazard, because the problem is often discussed in terms of total volume (e.g., thousands of cubic feet) rather than activity level (i.e., quantity and concentration *per unit volume*).

Low-level waste is classified as A, B, or C waste, on the basis of the hazard posed by the waste and its characteristics, such as half-life and activity level. For states like California and New York, Class A waste might constitute 95%–97% of the volume and 3% of the activity, Class B a couple of percent of the volume and another 3% of the activity, and Class C, the most hazardous of low-level wastes, only about 1% of the volume but 94% of the activity.

Views expressed by persons commenting outside their education and experience, although perhaps representing legitimate concerns, can create confusion, if not outright controversy. Unfortunately, such situations can develop even among members of the geosciences—e.g., the differing perspectives and expertise of a structural geologist and a hydrogeologist. Also, some individuals and groups have hidden agendas, and they will use their expertise to influence the outcome of a decision process. Of course, there are those who are opposed to anything nuclear—whether nuclear weapons, nuclear power, … or a nuclear family.

THE SITUATION

Because significant volumes of low-level waste already exist and additional volumes will accumulate with time, the pertinent question is not "Do we need disposal sites for low-level waste?" but "Where can we safely locate disposal sites for low-level waste?" Unfortunately, this straightforward question divides lay and scientific communities alike.

Originally, the federal government was responsible for the disposal of all radioactive waste, and six disposal facilities were available for low-level waste. Between 1975 and 1978 three of these facilities—in Illinois, Kentucky, and New York—were closed, and only those in Washington, South Carolina, and Nevada remained open. Of those remaining open, the Beatty (Nevada) site closed at the end of 1992, Hanford (Washington) no longer accepts waste generated outside the Northwest or Rocky Mountain Compacts, and Barnwell (South Carolina) has recently stopped accepting out-of-compact waste. Irrespective of future activities, the truism is that low-level radwaste already exists—and in significant quantities. Thus, new—and safe—disposal sites are needed now.

The 1980 federal Low-Level Radioactive Waste Policy Act charged each state with managing all low-level radwaste generated within its borders, except for federal low-level waste. The Act stated, further, that low-level radwaste is most safely and efficiently managed on a *regional* basis. The 1985 Low-Level Radioactive Waste Policy Amendments Act created incentives and penalties to encourage progress in developing new facilities, and encouraged the formation of regional *compacts* among states to provide for shared disposal facilities. "Compact" refers to the arrangement by two or more states to collectively regulate under provisions of the Act, and an "Agreement State" is one that has been given authority to regulate low-level radwaste disposal under an agreement entered into with the U.S. Nuclear Regulatory Commission.

At present, ten state compacts exist and five states remain unaffiliated. But, to date, only four disposal sites—in Nebraska, North Carolina, California, and Texas—have been selected, and significant controversy surrounds at least one of those.

STORAGE vs. DISPOSAL

The term "storage" implies temporary placement, pending a more permanent solution. At present, considerable volumes of low-level waste are being stored on site—in basements, sheds, and in other poorly controlled environments. "Disposal" is defined in the Low-Level Radioactive Waste Policy Act as the *permanent isolation* of low-level radwaste, in accord with U.S. Nuclear Regulatory Commission (NRC) requirements, or those of any Agreement State in which such isolation occurs.

The Low-Level Radioactive Waste Policy Amendments Act required NRC (1) to identify *alternative disposal methods* to shallow land burial, and (2) to provide *technical information and requirements* with regard to site suitability, site design, facility operation, disposal site closure, and environmental monitoring to meet performance objectives established by NRC.

Above-ground disposal methods for low-level waste include above-grade vault with earth mounding, being considered by the Appalachian (Pennsylvania) Compact, and above-grade vault without earth mounding. Below-ground disposal methods include enhanced shallow land burial, being considered by the Southwestern (California) Compact; below-grade concrete vault; below-ground concrete canisters, being considered by Texas; vertical shaft mine disposal; drift mine disposal; and augered hole disposal.

NRC sets the performance objectives for the disposal of low-level radioactive waste and requires that they be met. These are:

1. Protection of general population from releases (<25 mrem whole body annual);
2. Protection of individuals from inadvertent intrusion;
3. Protection of individuals during operations, and;
4. Stability of disposal site after closure.

In addition, technical requirements for land disposal facilities are given. Site suitability requirements include:

1. Site capable of being characterized, modeled, analyzed, and monitored;
2. Impacts of natural resource exploitation on performance objectives be considered;
3. Runoff and possible erosion or flooding be minimized;
4. Depth to water table be sufficient to avoid infiltration (note that

Forum *continued on p. 99*

Forum *continued from p. 98*

below-water-table disposal can be used if it can be conclusively shown that molecular diffusion is the predominant means of radionuclide transport and that performance objectives can be met);

5. Areas of tectonism, volcanism, or surface processes that could affect ability to meet performance objectives be avoided.

The disposal of radioactive waste has an aspect that sets it apart from other toxic wastes—that radionuclides decay with time. Whereas arsenic and other compounds are continuously hazardous over time, the activity of radionuclides decreases as a function of their half-lives. A period of ten half-lives decreases the activity to one-thousandth its initial value, and a period of 20 half-lives decreases the activity to one-millionth its initial value. Thus, the activity of an isotope with a half-life of about 30 years diminishes to negligible levels after 300 years and becomes innocuous after 600 years. The probability of exposure, and hence the risk, from radionuclides with relatively short half-lives is reduced to extremely low levels when containment periods or transport times separately or collectively isolate those radionuclides for ten to 20 half-lives.

Class A wastes are the least hazardous and typically have low activity and short half-lives; they present a potential hazard to public health and safety on the order of 100 years. Class B wastes typically have short half-lives but higher activity; they also present a potential hazard to public health and safety on the order of 100 years. Class C wastes have relatively longer half-lives and present a potential hazard to public health and safety on the order of 300–500 years. Beyond 500 years, disposed low-level waste presents a very limited hazard, even to persons who might inadvertently come into contact with the waste. It should be obvious that *containing* the waste for a period of several hundred years would solve the problem.

ASSESSMENT OF RISK

The basic concept of risk is very simple—risk is the product of the *probability* of an event occurring and the *consequences* if that event were to occur ($R = P \times C$). The risk of death to an individual as a result of a crash of a scheduled airline flight is very low because the probability of a crash is very low, even though the consequences are a likely fatality if that were to happen. The *acceptability* of risk is a matter for the individual, or in societal issues, for the public, to decide. In order to make reasoned decisions, however, it's important to understand this basic concept of risk—that risk involves more than just the possible (health) consequences. The other key element in risk concerns *probability.* Who evaluates these two aspects is important.

If a human organ is exposed to a significant or sufficient dose of radiation, the *consequences* could be very serious. However, the risk to the individual is high only if there is reasonable *probability* of that exposure occurring. The *consequences* of a radiation exposure are clearly a matter for the medical community to evaluate.

For exposures related to the disposal of low-level radwaste, the *probability* of exposure is a function of both release from containment and transport from the disposal site following a release. The probability of release is dependent on the nature of containment (waste form, containers, engineered barriers), and this aspect is best evaluated by scientists and engineers from outside the medical and the geological communities. Transport from the disposal site depends upon the geology. In selecting and assessing possibly suitable sites for low-level radioactive waste, one must consider the performance of the containment system, the performance of the existing geologic system, and the probable future performance of the geologic system—taking into consideration evolutionary change and potentially disruptive events. Clearly, the performance of the existing geologic system and the probability of change to that system are matters for geoscientists to address.

LOW-LEVEL RADIOACTIVE WASTE RELEASE AND TRANSPORT

Radionuclides placed in either a storage or disposal environment can come into contact with humans only if the radionuclides are released from that environment and transported, or if humans should intrude the facility. The predominant scenario for transport to humans involves ground water. Possible disturbance to the natural system caused by excavation, waste facility emplacement, and the presence thereafter of the waste facility must be considered. Moreover, depending on the disposal option selected, maintenance, monitoring, and/or adequate marking of the facility must be such as to ensure its integrity over the period of required isolation.

Careful evaluation of the geologic setting and its geologic history should reduce to negligible levels the probability of disruption by erosion, faulting, volcanism, or other natural processes. Similarly, careful evaluation of the geographic setting and proper monitoring and marking of the facility should reduce to negligible levels the probability of inadvertent disruption by human activity. Thus, the only feasible means of transporting radionuclides from a disposal facility, if they are released from containment, is by ground-water transport.

The potential hazard thus depends primarily upon the amount and rate of supply of radionuclides to ground water, the pathways and rate of ground-water movement, and the degree of geochemical retardation imposed by the geologic media. The configuration and composition of the geologic units, the distribution of heterogeneities within them, the presence of fractures or faults, and the hydraulic potentials present in the geologic setting dictate the pathways, flow rates, and geochemical interactions that determine transport times—*and thus the probability of exposure.* Characterization of the subsurface, involving the determination and evaluation of these controlling factors, and the analysis of ground-water flow and transport is, of course, the purview of the geoscientist—indeed, these activities would involve several subdisciplines of the geosciences.

THE SOLUTION?!

Study after study has shown that people resent most strongly those risks, real or imagined, that have been thrust upon them; they are far more tolerant of risks that they assume voluntarily. Moreover, their attitudes are based on what they read or see in the media, rather than on experience. Unfortunately, most media coverage of risk is not about "hazard," but about "outrage." The media are in the "outrage" business—about people and emotions. The media pay most attention to issues and situations that most frighten their readers and viewers. Anything about science must be "definite" to make page one—"high probability" is not good enough.

In an effort to attract readers and viewers, and to educate the public, the media often overplay risks of dubious legitimacy. Studies show that many of the alleged hazards are misstated, overstated, or nonexistent. The media have long served as an early warning system to alert people to certain risks. However, if media coverage is unbalanced, it makes reporters responsible for any inappropriate reactions of its readers and viewers. We, as geoscientists, have a responsibility *to help educate the media* so as to achieve *balanced* coverage.

To make rational choices among low-level radioactive waste storage and disposal options, the public needs to understand (1) that *risk* is the product of the *probability* of an exposure occurring and the *consequences* if that exposure were to occur, and (2) that the *probability* of radiation exposure to humans depends upon the release and transport processes and pathways. Probability is a key element in risk, and the geoscientist is concerned with the probability aspect of risk because transport in the subsurface of any released radionuclides dictates the probability of exposure.

We also need to communicate to the public that science is *an approximation of reality* at any given point in time, subject to constant revision. Areas of uncertainty are always likely to be present, but one can place limits on those areas—and thus "bound the problem." By emphasizing these key points, the debate for low-level waste issues can be focused on *relevant* aspects.

It's not popular to talk about economics when talking about health risks, but one has to be realistic with regard to expectations. There are trade-offs, and these must be addressed. Everyone would prefer "zero risk," but that simply is not feasible. Attempting to achieve zero risk would lead to bankruptcy. A more constructive approach is to present various alternatives along with a cost/benefit analysis that shows the costs of obtaining certain defined benefits. An enlightened public can then voluntarily choose a solution, rather than having one thrust upon them.

It is clear that risk issues no longer involve just science and medicine; politics and economics come into consideration as well. A recent California report intended to guide decision making by the state Environmental Protection Agency defines risk as "the likelihood of harmful effects, including human disease or death, damage to ecosystems, property losses, and *anxiety about the future.*" It will be a challenge, indeed, to integrate value judgments into risk assessment. It thus makes it all the more imperative that we, as geoscientists, attempt to clarify the other elements in risk assessment so that the debate can be focused on the *relevant* aspects.

CALL FOR NOMINATIONS

To reward and encourage **teaching excellence** in beginning professors of earth science at the college level, the Geological Society of America announces:

THE FOURTH ANNUAL

Biggs Award

For Excellence In Earth Science Teaching For Beginning Professors

ELIGIBILITY: All earth science instructors and faculty at 2- and 4-year colleges who have been teaching full time for 10 years or less. (Part-time teaching is not counted in the 10 years.)

AWARD AMOUNT: An award of $500 is made possible as a result of support from the Donald and Carolyn Biggs Fund.

NOMINATION PROCEDURE: For nomination forms write to Edward E. Geary, Coordinator for Educational Programs, Geological Society of America, P.O. Box 9140, Boulder, CO 80301.

DEADLINE: Nominations and support materials for the 1995 Biggs Earth Science Teaching Award must be **received by June 30, 1995.**

PERSPECTIVE 4:
Why Geologists Should Care about the Ward Valley Low-Level Radioactive Waste Disposal Site

William W. Otterson, Director, University of California, San Diego CONNECT; Spokesperson, National Association of Cancer Patients; Member, Southwest Compact Low-Level Radioactive Waste Commission

Some geologists are contributing to a serious threat to medical research and treatment. They are doing this by raising speculative objections to the State of California's decision to license a disposal site for low-level radioactive waste in Ward Valley. Opponents of nuclear power, who believe that nuclear power can be ended if utilities have no place to dispose of radioactive wastes, have used this geological speculation in court, in the political arena, and in the media, to bring a halt to the 14-year process of properly locating a low-level radioactive waste disposal site. Why will the failure to open the Ward Valley site in a timely fashion damage medical research and therapy? What should geologists do about it?

Radioimmunoassay, autoradiography, and other methods that use radioisotopes are among medical research-

Forum *continued on p. 104*

Geosphere Alliance Committee Seeks Input and Action from GSA Members

INTRODUCTION

David A. Stephenson, GSA President

Over the past year, GSA has discovered that its outreach endeavors (and similar endeavors by other scientific organizations) have not been effective in educating one very vital element of the public—state and federal legislators. In the past six months, the geological profession has been the target of unprecedented scrutiny—more so than any of the other sciences. The value of geology to society has been questioned at all governmental levels, but especially by the U.S. Congress. Of issue is not just funding for geological research, but the existence of selected geological agencies and the recognition of geologists (vs. engineers) as the appropriate authorities in soil and ground-water contamination issues.

The response by our colleagues to this dilemma has been effective. As a result, some of the *intranational* crisis has been somewhat alleviated. Simultaneously, however, the geological community is being alerted, in the article below by past GSA President E-an Zen, that we should increase our focus on *global* activities, especially as related to the interface between the scientific communities and nonscientific issues. Zen describes the results of a recent interdisciplinary meeting organized by the American Academy of Arts and Sciences and the Union of Concerned Scientists. This meeting was called for the purpose of airing concerns over critical issues facing our common future as inhabitants of this planet. Topics discussed ranged from atmospheric issues (climatic changes, ozone depletion) to socioeconomic issues (population growth and its impact on waning resources).

Zen, speaking for GSA's Geosphere Alliance Committee, suggests that for geologists to become involved with global issues is not simply an opportunity but a civic and professional responsibility. His call to "think globally" is an urging of GSA's membership to participate in any and all situations involving the earth and its resources. Future discussions by various GSA outreach participants will explore what we as a Society and as individuals can do to interface with interdisciplinary, intranational, and international thinkers and doers.

In the past, calls for comments in this publication have produced an underwhelming response. Perhaps something in E-an Zen's message will encourage many of you to contact Zen, Executive Director Don Davidson, or me (care of GSA headquarters). Let us know (1) if you support GSA's outreach activities, and if so (2) what issue(s) should be targeted. As geologists, we have been trained to evaluate Earth and its past and present condition. It is reasonable that this knowledge and understanding can be of fundamental value in anticipating future conditions and participating in decisions regarding use of global resources.

MESSAGE TO GSA MEMBERS

E-an Zen, Interim Chairman, Geosphere Alliance Committee

With the world population estimated to grow from the current 5.9 billion to 12 billion by 2150 (median projection by the World Bank and the Population Council) and with concurrent increasing per capita resource consumption, what will this world be like in another 100 years? Is there anything we as responsible human beings can do to ensure that it will remain a viable habitat for living forms, including our great-grandchildren?

A group of thoughtful and concerned people, mainly social scientists, have been exploring the concept of "sustainable growth [or development]" (defined with delicious ambiguity as "[meeting] the needs and aspirations of the present without compromising the ability to meet those of the future"; World Commission on Environment and Development, 1987, p. 40) as the goal toward which human societies ought to strive. This concept has not received much in-depth examination by physical scientists; some dismissed it offhand as an oxymoron. But dismissal is not an alternative solution to this urgent problem; serious discussion is called for. What elements within the general concept of sustainability are essential for the future of the world as a habitat? What alternative plan of action can we propose, if "sustainable growth" is just the Holy Grail—more an ideal than a credible program for action? What can we, as geologists trained to know Earth resources and to understand the responses of Earth to human intervention, contribute to this discussion?

During GSA's 1990 awards ceremony in Dallas, both Penrose Medalist Norman Newell and Day Medalist Bill Fyfe, when they accepted their awards, spoke urgently about our collective responsibility to preserve Earth as a habitat for future generations, to contain runaway population growth, and to strive for equity between the "haves" and "have-nots" of the world societies. Their comments hit a responsive chord; my first action as GSA president was to call upon a small group of our members to explore what GSA can do about these enormous interrelated challenges. Bill Fyfe was the chairman of this Geosphere Alliance Committee; other members were Fred Donath, Bill Fisher, Bob Hatcher, Sue Kieffer, and Ray Price. Later, Gordon Gastil, Digby McLaren, and I were added. This committee is to "think globally" and complement the work of the Institute of Environmental Education, the "act locally" arm, and the Committee on Geology and Public Policy, which acts at the legislative level. Bill Fyfe resigned as chairman last fall, and the GSA Council asked me to be the interim chairman. We are looking at our task anew, with no holds barred.

Fortuitously, GSA was invited to participate in a multisociety conference in January of this year, jointly convened by the American Academy of Arts and Sciences and by the Union of Concerned Scientists, on the subjects of identifying critical issues that face the world and defining how and what professional scientific societies can do to make a difference. President David Stephenson asked me to accompany him on behalf of GSA, but at the last moment he had to cancel. As it turned out, I was the only geologist at the meeting because the delegate from AGU was also unable to attend.

The composition of the meeting was a good cross section of the professional scientific societies. Two days of spirited and open discussion concluded with the consensus that, yes, the overarching problems of world population growth, resource consumption, and environmental rescue do demand the active involvement of the scientific groups; yes, there are signs of progress and hope amidst all the doom and gloom, but we as scientists must do better to search out the opportunities and act on them in the best *pro bono* sense; and yes, we need to improve our mutual communication and collaboration, as well as to involve other disciplines and decision and opinion makers in future gatherings of this kind.

This conference was most timely, because its purpose coincided precisely with that of our Geosphere Alliance Committee. Encouraged by the consensus of the January conference, I am asking the Council to allow us to change our name to "Critical Issues Committee," both to bring the name into line with the other groups and to bring our purpose into clearer focus.

I ask for your input on the endeavors of this committee. What sort of activity is most important for us to undertake? Who should be invited, now or at a later stage, to be members of the committee?

Let me share with you briefly my own thoughts along these lines. I think the committee would profit by including a few representatives from fields that our deliberations impinge upon—ecology and economics, for example—so as to both broaden our perspective and promote synergism. I propose that we emphasize our responsibilities as global citizens, both in terms of equity between the developing nations and the developed nations and in terms of shielding to some extent our descendants from having to face a world depleted in natural resources. We must, in short, do our part in preserving future options (one of the less tangible but real nonrenewable resources), an ability for future generations to make wise choices for themselves. Perhaps this is the practical sense of sustainability—not in growth, but in choices.

To be able to make wise choices requires that some material base be in place. What is a minimum base for such sustainability to be possible? We all can give examples of materials: water, minerals, fossil fuels, forests, ecological niches, and lifeforms. As an example, soil, essential for agriculture, is being depleted at an estimated rate of 0.7% per year, which comes to a loss of about 30% of the world's total soil bank in considerably less than a century's time. If that prospect is unacceptable, what can we do to arrest the disaster?

There is a tremendous disparity between our own per capita resource consumption and environmental pollution and those in the developing nations. If just the four most populous nations (excluding the United States) as of 1989, China, India, Indonesia, and Brazil, attain a standard of living one-fourth that of the United States in 1989, then, according to the indices I chose for comparison (see Zen, 1993, based on data compiled by the World Resources Institute, 1992), the global loads in terms of resource demands and environmental degradation would be tripled *even if world population miraculously halted at the 1989 level* (Table 1). Can Earth handle this burden? What do we, as earth scientists, have to contribute toward changing this projection, which is for a time not all that far into the future?

Should we advocate that certain *accessible* resources be deliberately set aside as economic preserves for the future, even as we set aside public lands for that purpose? If so, what and how much must we give up for our own consumption in the interest of future needs? How can we do so with equity; can a formula be devised and agreed upon by the world community? The Laws of the Sea Regime, the Montreal Convention, and the Rio Treaty give hope that many of our political leaders can and will face the reality and take creative steps, but they need support and help from the scientific community. How can we work within a network of other professional and academic communities, worldwide, to accomplish our common goal? Geologists have an opportunity here, perhaps not to be repeated if we don't take up the challenge soon.

Let the committee hear from you.

REFERENCES CITED

World commission on Environment and Development (G. H. Brundtland, chairman), 1987, Our common future: Oxford, United Kingdom, Oxford University Press, 400 p.

World Resources Institute, 1992, World resources, 1992–1993: New York, Oxford University Press, 385 p.

Zen, E-an, 1993, The citizen-geologist: GSA Today, v. 3, p. 2–3. ■

TABLE 1. COMPARISON OF CONSUMPTION OF INDEX RESOURCES AND GENERATION OF INDEX POLLUTANTS BY ONE DEVELOPED AND FOUR DEVELOPING COUNTRIES, AND A POSSIBLE PROJECTION

	United States pop. 249×10^6		(A) 0.25 U.S. pop.,	China 1139×10^6 (B)			India, Brazil, Indonesia pop. 1187×106 (C)		
	Total	Per capita	per capita	Total	Per capita	A × B	Total	Per capita	C × A
Commercial energy consumption (joules)	$73,370 \times 10^{15}$	295×10^9	73.75×10^9	$26,156 \times 10^{15}$	23×10^9	$84,000 \times 10^{15}$	$12,426 \times 10^{15}$	10×10^9	$87,541 \times 10^{15}$
Aluminum (tons)	4352×10^3	17.5×10^{-3}	4.375×10^{-3}	650×10^3	0.57×10^{-3}	4983×10^3	n.d.	n.d.	5193×10^3
Copper (tons)	2143×10^3	8.61×10^{-3}	2.153×10^{-3}	512×10^3	0.45×10^{-3}	2452×10^3	n.d.	n.d.	2556×10^3
Crude steel (tons)	102.351×10^6	0.411	0.1028	69.504×10^6	0.061	117×10^6	n.d.	n.d.	122×10^6
Industrial CO_2 (tons)	4869×10^6	19.7	4.925	2389×10^6	2.2	5610×10^6	997×10^6	0.84	5846×10^6
Anthropogenic methane (tons)	37×10^6	0.15	0.0375	40×10^6	0.04	43×10^6	51×10^6	0.04	46×10^6
CFCs (tons)	130×10^3	523×10^{-6}	131×10^{-6}	120×10^3	11×10^{-6}	149×10^3	110×10^3	9×10^{-6}	155×10^3

Note: Population, consumption, and pollution production figures are for 1989. Source of data: World Resources Institute (1992), from Tables 16-1, 21-2, 21-5, 24-1, and 24-2; n.d. indicates no data from that publication.

GSAF UPDATE

Robert L. Fuchs

IEE to Benefit from Kennecott Five-year Grant

Kennecott Corporation, a major natural resource company, has awarded a grant of $40,000 per year for five years to GSA's Second Century Fund for Earth • Education • Environment. This leadership grant will be applied to the activities of the Institute for Environmental Education.

Kennecott originated in Alaska more than 80 years ago. At about that time, another mining company was formed that was subsequently acquired by Kennecott and is today the heart of Kennecott's North American operations. In 1903 a young metallurgist named Daniel C. Jackling, a graduate of the Missouri School of Mines, proposed to a group consisting of Charles M. MacNeill, Charles L. Tutt, Sr., Spencer Penrose, and Spencer's brother R. A. F. Penrose, Jr., a business venture to develop a copper porphyry deposit located 18 miles southwest of Salt Lake City. The location was the Bingham mining district, from which copper ore was first shipped in December 1896 and which was ultimately to become the single most productive copper mine in history. Jackling had been a consulting engineer for MacNeill and Spencer Penrose in Colorado's Cripple Creek district, so the partners were well aware of his judgment and ability. R. A. F. Penrose, subsequent GSA president and major benefactor, provided the technical project review for the investors, and upon his favorable recommendation, the group formed Utah Copper Company, forerunner of today's Kennecott Corporation.

A few sidelights of this start-up venture are worth noting here. R. A. F. Penrose was asked by the group to be the company's first president. He declined, saying he "did not want to be tied down too much," so MacNeill was elected president, Spencer Penrose secretary/treasurer, and Jackling general manager. Tutt was slated to be vice president, but he withdrew from this then-speculative venture within about a year, selling his stock to Spencer. However, Spencer Penrose and the Tutt family remained very close over the years in business and philanthropic dealings. Today's president of El Pomar Foundation in Colorado Springs, which was formed by Spencer Penrose and contains his estate, is R. Thayer Tutt, Jr., great-grandson of Charles L. Tutt, Sr. El Pomar is another leading contributor to GSA's Second Century Fund.

From beginnings at the Bingham Canyon mine, Kennecott has grown to become a leader among American mining companies. Through Kennecott Minerals Company, Kennecott owns and operates several major mineral-producing properties—Barneys Canyon gold mine in Utah, Flambeau copper mine in Wisconsin, Greens Creek silver mine on Alaska's Admiralty Island, Rawhide gold and silver mine in Nevada, and Ridgeway gold mine in South Carolina. Kennecott Energy Company is one of the ten largest coal producers in the United States, with four large mines in the Powder River Basin, and Colowyo mine in northern Colorado. The Green Mountain uranium mine in Wyoming is currently being developed. Kennecott Exploration Company has offices in five cities in the United States, Canada, and Mexico. This subsidiary has brought six new mines on line in the past five years.

Kennecott maintains an intense dedication to environmental work in conjunction with all its operations. This dedication is demonstrated in the construction of major new facilities such as the Utah Copper smelter, which captures 99.9% of sulfur emissions, reduces water usage by a factor of four, and requires only 25% of the natural gas and electrical power formerly used per ton of copper produced. Other company-wide environmental operations include projects that reduce dust and emissions, eliminate threats to ground-water quality, and reclaim and revegetate disturbed areas at mined properties.

This focus on environmental improvement lies behind Kennecott's decision to support IEE. In notifying GSA of the grant, Tom Patton, the company's Senior Vice President of Exploration, said, "The programs underway and envisioned for IEE dovetail with Kennecott's continuing concentration on environmental enhancement. GSA's ability to provide sound science and to act as a learning and information resource for both scientists and the public are important to clear, well-thought-out environmental decisions and actions."

Paul Bailly, former GSA president and industry vice-chair of the Second Century Fund Committee, stated, "Kennecott's decision to make this grant gives GSA a good start on long-term financing for IEE, and allows the Society to begin to plan ahead with respect to program expenditures for staffing and nationwide activities." ■

Pooled Income Fund Challenge Announced

Two current participants in the GSA Foundation Pooled Income Fund will make additional contributions to the fund on a challenge basis as new investments are made by other GSA members. Larry Sloss and Bill Heroy have advised the Foundation that they will add $1 to their fund holdings for each $2 of new funds. Both the new contributions and the challenge money will be considered as Second Century Fund gifts.

The Pooled Income Fund is a deferred gift mutual fund for GSA members and friends, whereby benefactors and spouses receive income for life. Upon the survivor's death, his or her portion of the fund becomes part of the Foundation's endowment, and the income is then used in support of GSA programs and activities. The appeal of the fund to retired members such as Larry Sloss and Bill Heroy is the ability to dedicate financial assets to the Society while retaining the income during retirement.

The GSA Foundation Pooled Income Fund generated a cash return of 6.0% in 1994, which was down 0.3% from the earnings of the prior year. The net asset value of the fund declined 8.1% as interest rates rose throughout the year, a result widely experienced by fixed income investors. The good side of these rising interest rates is higher fund earnings, and by the last quarter of 1994 the annualized cash return was in excess of 7%.

At the end of 1994, the fund's net asset value was $223,902, 4.3% higher than the 1993 value. The fund's holdings included Warburg Pincus Fixed Income and Global Fixed Income Funds, Steinroe Income Fund, and corporate bonds.

An investment in the Pooled Income Fund brings with it tax attributes in the form of current year tax deduction and capital gains tax avoidance on appreciated securities. The result can be an effective return to the donor on the net after-tax gift as much as 40% higher than the current earnings of the fund. If you would like to learn more about this estate and retirement planning method, please send us the accompanying coupon, or call the Foundation office—(303) 447-2020, ext. 154. ■

Donors to the Foundation—February 1995

Claude C. Albritton, Jr. Fund
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Name ______________________________

Address ______________________________

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Phone ______________________________

CALL FOR GSA COMMITTEE SERVICE—1996

The GSA Committee on Committees wants your help. The committee is looking for potential candidates to serve on committees of the Society or as GSA representatives to other organizations. You can help by volunteering yourself or suggesting the names of others you think should be considered for any of the openings and submitting your nomination on the form below. Younger members are especially encouraged to become involved in Society activities.

Listed here are the number of vacancies and a brief summary of what each committee does and what qualifications are desirable. If you volunteer or make recommendations, please give serious consideration to the special qualifications for serving on a particular committee. *Please be sure that your candidates are Members or Fellows of the Society and that they meet fully the requested qualifications.*

Volunteering or making a recommendation

All nominations received at headquarters by **July 15, 1995,** on the official one-page form will be forwarded to the Committee on Committees. *Council requires that the form be complete.* Information requested on the form will assist the committee members with their recommendations for the 1996 committee vacancies. Please use one form per candidate (additional forms may be copied). The committee will present at least two nominations for each open position to the Council at its November 7, 1995, meeting in New Orleans, Louisiana. Appointees will then be contacted and asked to serve, thus completing the process of bringing new expertise into Society affairs.

Committee on Committees

The 1995 committee consists of the following people: Chair **Priscilla C. Grew,** 302 Administration Building, University of Nebraska—Lincoln, Lincoln, NE 68588-0433, (402) 472-3123; **Christopher R. Barnes,** Centre of Earth and Ocean Research, University of Victoria, P.O. Box 1700, Victoria, British Columbia, Canada V8W 2Y2, (604) 721-8847; **Mark T. Brandon,** Department of Geology and Geophysics, Yale University, P.O. Box 208190, New Haven, CT 06520-8190, (203) 432-3135; **Robert A. Matthews,** Department of Geology, University of California—Davis, Davis, CA 95616, (916) 752-0179; **Molly Fritz Miller,** Department of Geology, Vanderbilt University, Box 6001, Station B, Nashville, TN 37235, (615) 322-3528; **Joaquin Ruiz,** Department of Geosciences, University of Arizona, Tucson, AZ 85721, (602) 621-2365.

Continuing Education *(2 vacancies)*
Will direct, advise, and monitor the Society's continuing education program, review and approve proposals, recommend and implement guideline changes, and monitor the scientific quality of courses offered.

Committee members should be familiar with continuing education programs or have adult education teaching experience.

Day Medal *(2 vacancies)*
Selects candidates for the Arthur L. Day Medal. Committee members should have knowledge of those who have made "distinct contributions to geologic knowledge through the application of physics and chemistry to the solution of geologic problems."

Education *(3 vacancies—2 members-at-large, 1 elementary teacher)*
Stimulates interest in the importance and acquisition of basic knowledge in the earth sciences at all levels of education.

Committee members work with other interested scientific organizations and science teachers' groups to develop precollege earth-science education objectives and initiatives. The committee also promotes the importance of earth-science education to the general public.

Geology and Public Policy *(3 vacancies)*
Translates knowledge of the earth sciences into forms most useful for public discussion and decision making.

Committee members should have experience in public-policy issues involving the science of geology. They should also be able to develop, disseminate, and translate information from the geological sciences into useful forms for the general public and for the Society membership; they should be familiar with appropriate techniques for the dissemination of information.

Honorary Fellows *(2 vacancies)*
Selects candidates for Honorary Fellows, usually non–North Americans.

Committee members should have knowledge of geologists throughout the world who have distinguished themselves through their contributions to the science.

Membership *(2 vacancies)*
Evaluates membership benefits and develops recommendations that address the changing needs of the membership and attract new members. *Committee members must be GSA Fellows* and must be able to attend one meeting a year. Previous experience in benefit, recruitment, and retention programs is desired.

Minorities and Women in the Geosciences *(4 vacancies)*
Stimulates recruitment and promotes positive career development of minorities and women in the geoscience professions.

Committee members should be familiar with minority and female education and employment issues and have expertise and leadership in such areas as human resources and education. Membership shall include representation of minorities and women and representatives from government, industry, and academia.

Nominations *(5 vacancies; one to be a member from Canada or Mexico)*
Recommends to the Council nomi-

Committees *continued on p. 103*

NOMINATION FOR GSA COMMITTEES FOR 1996

(One form per candidate, please. Additional forms may be copied.)

(Please print)

Name of candidate ____________________

Address ____________________

____

Phone (   ) ____________________

COMMITTEE(S) BEING ☐ VOLUNTEERED OR ☐ NOMINATED FOR (please check):

Committee(s):

Comment on special qualifications:

☐ GSA Fellow   Section affiliation:
☐ GSA Member   Division affiliation(s):

Brief summary of education:

Brief summary of work experience (include scientific discipline, principal employer—mining industry, academic, USGS, etc.):

If you are VOLUNTEERING to serve GSA, please give the names of 2 referees/references (please print):

Name: ____________________

Phone: (   ) ____________________

Name: ____________________

Phone: (   ) ____________________

If you are NOMINATING SOMEONE other than yourself to serve GSA, please give your name, address, and phone number (please print):

Name: ____________________

Address: ____________________

____

Phone: (   ) ____________________

DEADLINE: Please return this form to headquarters by July 15, 1995. Form must be complete to be considered. Mail to GSA Executive Director, P.O. Box 9140, Boulder, CO 80301.

Committees *continued from p. 102*

nees for the positions of GSA officers and councilors.

Committee members should be familiar with a broad range of well-known and highly respected geological scientists.

Penrose Conferences *(2 vacancies)*
Reviews and approves Penrose Conference proposals; recommends and implements guidelines for the success of the conferences.

Committee members must either be past conveners or have attended two or more Penrose Conferences.

Penrose Medal *(1 vacancy)*
Selects candidates for the Penrose Medal.

Committee members should be familiar with outstanding achievements in the geological community that are worthy of consideration for the honor. Emphasis is placed on "eminent research in pure geology which marks a major advance in the science of geology."

Publications *(1 vacancy)*
Makes recommendations to the Council concerning Society publications.

Committee members should be familiar with a wide range of scientific publications and especially GSA publications. Should also have some knowledge of publication processes and costs and should have concern for the quality of content and presentation of GSA publications.

Young Scientist Award (Donath Medal) *(2 vacancies)*
Selects candidates for the Donath Medal.

Committee to have members covering a broad range of disciplines—geophysics, economic geology, stratigraphy, etc.

Committee members should have knowledge of young scientists with "outstanding achievement(s) in contributing to geologic knowledge through original research which marks a major advance in the earth sciences."

Joint Technical Program Committee GSA Representatives-at-Large *(3 vacancies)*
Supervises the review of abstracts for papers to be presented at the GSA annual meeting.

Representatives-at-large should be specialists in computers, Precambrian geology, or paleoceanography-paleoclimatology, and must be able to attend a meeting in August. These subdisciplines are not represented by any of the associated societies or GSA divisions.

GSA Representative to the North American Commission on Stratigraphic Nomenclature *(1 vacancy)*
Must be familiar with and have expertise in stratigraphic nomenclature.

Council acknowledges with thanks the many member-volunteers who, over the years, have stimulated growth and change through their involvement in the affairs of the Society.

Each year GSA asks for volunteers to serve on committees, and many highly qualified candidates express their willingness to serve. Not everyone can be appointed to the limited number of vacancies; however, members are reminded that there are also opportunities to serve in the activities and initiatives of the sections and divisions. Annually, Council asks sections and divisions to convey the names of potential candidates for committee service to the Committee on Committees. The Southeastern and South-Central Sections have diligently responded to this call.

LETTER FROM WASHINGTON

Forest Health Policy: What Role for Earth Scientists?

Jill S. Schneiderman, GSA Congressional Science Fellow

Early in the first session of the 104th Congress, Senator Larry Craig (R—ID) introduced the Federal Lands Act Forest Health Amendments of 1995. The goal of the bill is to promote forest health by harvesting stands of dead and dying trees in the national forests. This is an admirable objective and necessary. Throughout the country, and particularly in the intermountain west, forests are ill. Stands of dead and dying trees, the result of persistent drought, disease, insect infestation, and past mismanagement, pose serious risks of fire. We rely on our national forests for a wide variety of activities, including wildlife conservation, recreation, and timber harvesting. Earth scientists can offer expertise that is necessary to maintaining those forests in the healthiest condition possible.

Senator Craig's bill is a reaction to the forest fires that in the summer of 1994 burned thousands of acres of forest throughout the west and claimed the lives of women and men of the U.S. Forest Service (USFS). However, the issue of forest health is a complicated one that involves important objectives such as maintaining species habitat, preventing soil erosion, ensuring that insect infestations and diseases are within a historic range of variability, safeguarding stream quality, and protecting the overall long-term sustainability of forest ecosystems. Though Senator Craig's bill provides a framework for addressing some of these issues, concerns have been raised that the legislation would provide overly broad discretion to the federal agencies and inadequately provide opportunities for deliberation and analysis by the public. Hearings were held on the bill in February in the Energy and Natural Resource Committee and will be marked up in the coming weeks.

The forest health problem in this country developed over the course of many years and thus should be dealt with in a deliberate manner. Solutions must emerge from sound scientific bases of understanding about forest ecosystems and not solely from economic motivations. At a forum for presidents and executive directors of earth science societies at the National Academy of Sciences in November 1994, U.S. Geological Survey Director Gordon Eaton asserted that our environmental responsibilities "require a much better understanding of the complex *interrelationships* among components of the biosphere, the atmosphere, the hydrosphere, human activities, and the land around us." This sage advice applies to the forest health problem.

Ecosystem management, a broad approach to managing the nation's lands and natural resources over time, should, I believe, be the philosophy with which we approach a solution to the forest health problem. Since my arrival on Capitol Hill I have heard a number of Senators scoff at the word "ecosystem" at more than one hearing dealing with management of federal lands. At numerous hearings, they have asked sarcastically whether the witness considers humans to be part of ecosystems. It seems to me that our public servants would benefit from greater knowledge about earth system science and ecology. Policy makers need to appreciate that ecosystems comprise physical and organic structures, geological, biological, and chemical processes, and organisms, including humans, that interact to sustain life in discrete, although not isolated, communities. Knowledge about the duration of geologic time and the history of life, could foster an awareness among decision makers that the long-term health and sustainability of ecosystems is profoundly affected by human activities. It is unfortunate that, currently, many environmental and natural resource policy decisions are made without the benefit of this understanding of the natural world.

A recent National Research Council report on a National Academy study of forestry research found that "the existing level of knowledge about forests is inadequate to develop sound forest-management policies. Current knowledge and patterns of research will not result in sufficiently accurate predictions of the consequences of potentially harmful influences on forests, including forest-management practices that lack a sound basis in biological and geological knowledge." This is because, historically , the USFS research program focused strongly on topics related to commodity production and effects of management practices undertaken for commodity production. This was in keeping with the general approach to resource management.

Exceptions to the commodity production approach began in the 1970s, with interdisciplinary ecosystem research programs developed through USFS–university partnerships at a number of experimental forests around the country. These ecosystem research programs have grown in scope and importance. Results of this ecosystem research and the development of new management approaches by researcher-manager teams at these sites have contributed to development of ecosystem management.

Leading ecosystem research sites have been developed through cooperation of the USFS with other agencies, notably the National Science Foundation. A primary example is the Long-Term Ecological Research (LTER) program, funded by NSF with substantial involvement of the USFS, which with an initial set of six sites selected in 1980 conducts research on long-term ecological phenomena in the United States. The present total of 18 sites represents a broad array of ecosystems, including forests, and research emphases encompass earth science. Research topics in the forest ecosystems include: forest-stream interactions; successional processes associated with wildfire and floodplains; riparian zones as regulators of terrestrial-aquatic linkages; dynamics of detritus; patterns and rates of decomposition; and disturbance regimes in forest landscapes. At the same time Congress calls for greater amounts of "salvage" timber to be harvested, it must safeguard valuable USFS research programs like LTER. It is unlikely, however, that senators and representatives who do not understand the definition of an ecosystem will be easily convinced of the value of such research.

It is fortunate that educators can teach their students the value of interdisciplinary thinking and research. Courses such as that taught at Oregon State University on forest geomorphology and landscapes can equip students to become citizens who can educate members of their Congressional delegations. The objective of the Oregon course is to develop a geomorphic foundation for landscape ecologic thinking. Forest geomorphology deals with the interactions between geological and biological processes, the patterns that influence them, and the patterns they produce, both in forested hillslope patches and in stream networks. According to its instructors, a geomorphic perspective for the understanding of landscape and ecosystem dynamics, including land use and climate change, will result in understanding of the spatial and temporal variability of patterns and processes, and how they change with increasing scale from hillslopes to regions.

Earth scientists, with our knowledge of Earth as a system of interacting reservoirs, can appreciate the value of ecosystem approaches to our natural world. For example, the USGS is at the forefront among several federal agencies with its critical ecosystem projects in San Francisco Bay and the Florida Everglades. As stated in the NRC report, such approaches acknowledge "the need for fundamental change in how public lands are managed, the social and biogeochemical consequences of not changing, and the necessity for broad public understanding that their expectations cannot exceed the capacity of the ecosystem to meet them." Earth scientists can add this much-needed perspective to the forest health debate. ■

Jill S. Schneiderman, 1994–1995 GSA Congressional Science Fellow, is serving on the staff of Senator Thomas Daschle (S. Dak.). Schneiderman may be contacted at (202) 224-2321. The one-year fellowship is supported by GSA and by the U.S. Geological Survey, Department of the Interior, under Assistance Award No. 1434-94-G-2509. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. government.

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The Gros Morne Declaration

Assessing Rapid Environmental Change

The following statement originated at the International Workshop on Geological Indicators of Rapid Environmental Change, held July 11–17, 1994, in Corner Brook and Gros Morne National Park, Newfoundland, Canada. It is reprinted from Episodes, no. 1 and 2, 1994.

Preamble

We, earth scientists from many nations, peoples and cultures, speaking through the Commission on Geological Sciences for Environmental Planning of the International Union of Geological Sciences, urge that governments and other responsible authorities recognize the fundamental importance of understanding natural (see Note) and human-induced environmental changes, in which geological processes and geoindicators play a pivotal role. This recognition is a requirement to achieving any kind of sustainable development.

Note: While recognizing that concepts of 'nature' and 'natural' are linked with cultural values, this statement uses the terms to indicate environments uninfluenced by human activities, i.e., nature as wilderness.

We emphasize that:

Change is an inevitable aspect of our dynamic world. So that both natural and human-induced environmental change can be recognized, accommodated and managed, it is necessary to monitor a wide range of Earth-surface processes, both biotic and abiotic. Geological records of past environmental changes provide a major key to understanding on-going processes and to anticipating the future.

It is essential to ensure that long-term datasets are systematically collected and preserved, modifying procedures to take into account new issues and techniques. Applied and basic research, as well as routine study, are required to advance knowledge and understanding of the causes and directions of environmental change.

The public and the scientific community must recognize coordinated, long-term environmental monitoring as a mission of fundamental importance. The results provide the data necessary to assess the effects of environmental policies, legislation and management practices. Policy-makers, planners and the public must be informed of the benefits of environmental monitoring and the costs of not doing so.

Rationale

Natural and human-induced environmental change

Nature is complex and unstable. Change is the rule, not the exception, and surprises are common. Natural systems rarely remain for long in equilibrium. They adjust continually to new conditions, for example in climate, hydrological flow and sea level. Some changes are sudden, catastrophic and newsworthy, but there is a background of continual, small-scale change, the cumulative impact of which may be of even greater significance. All environmental change cannot, therefore, be blamed on human actions. Nevertheless, distinguishing between natural and human-induced change can be extremely difficult, as in the current debate on climate change.

In the case of some environmental changes, human influences may be inconsequential, as in volcanic eruptions and deep-focus earthquakes. In others, it may not be possible to separate natural from anthropogenic causes, as for example in the switching of river channels, coastal erosion, landsliding and the encroachment of deserts. It is also important to recognize that many changes, such as the contamination of groundwater, permafrost melting, desertification, and the degradation of soils, may be irreversible over time scales of importance to society.

Some changing environments reflect global trends, but it is important not to generalize all local and regional

Change *continued on p. 105*

LETTER TO THE EDITOR

In the November 1994 *GSA Today,* in book reviews on facing pages, are the following:

"Though still not absolutely proven it is now conventional wisdom that a catastrophe did occur" (p. 280; Euan G. Nisbet reviewing *Understanding Catastrophe: Its Impact on Life on Earth*).

"In a deductive science such as geology, one is driven to prove causal relations from correlations" (p. 281, George D. Stanley, Jr., reviewing *The Great Paleozoic Crisis*).

Both statements can be read as saying science can prove things; both can be pointed to as supporting the idea that there is such a thing as scientific proof.

Statements such as, "There is no scientific proof that …" are thrown up constantly in public discourse as strong objection to a wide range of things, from the possibility of global warming as a result of combustion of fossil fuels to the idea that unconstrained growth in the human population will result in pushing Earth beyond its carrying capacity, to the theory of organic evolution (it need not be taken seriously because it is just a theory—unproven). It is important to get across that theories are what science has to offer, and getting that message across is going to be done (1) not by talking about the scientific method but by saying at the start when addressing a lay audience that science cannot prove things; (2) by not using in our own talking and writing any mention of proof and proving as applied to what science does.

GSA has recognized the importance of improving communication between the scientific community and society at large. It is not easy to get across to a lay audience that science cannot prove things—just saying it is not enough; going over examples of what it would mean to be able to prove something about the natural world can help—but few things would be more helpful in imparting some understanding of the nature of the scientific effort.

Dennis M. Hibbert
North Seattle Community College
Seattle, WA 98103

Forum *continued from p. 99*

ers' most important tools. Consider what is at stake. Many of you saw the photograph of a breast cancer patient after her radical mastectomy on the cover of the *New York Times Magazine* on August 15, 1993. The present best therapy for breast cancer is disfiguring surgery followed by an unpleasant course of chemotherapy. A new pharmaceutical, taxol, may be useful in both the treatment and prevention of breast cancer. Researchers recently discovered the BRCA-1 breast cancer gene that may contribute to breast cancer's being passed down from mother to daughter. In the future, it may be possible not only to diagnose this potential problem but, through gene therapy, to "reengineer" defective, cancer-causing genes, eliminating a genetic source of breast cancer. Both of these wonderful potential cures require years more of medical research that will generate low-level radioactive waste in need of a safe place for disposal.

Leslie Bernard-Thomas is 37 years old. For the past 23 years, she has lived with rheumatoid arthritis, a progressively degenerative, debilitating disease. She has had surgery almost every year and has two artificial elbow replacements and five joint fusions. She has exhausted every form of conventional therapy and is now in a phase-two clinical trial with an oral Type II collagen. Laboratory and clinical research with collagen uses radioisotopes.

Jim Conway has multiple sclerosis. On good days he uses crutches. Other days he cannot leave his wheel chair. Scientists are studying the treatment of multiple sclerosis with beta and gamma interferon. This research uses radioisotopes.

My hometown newspaper, the *San Diego Union-Tribune,* recently ran a feature story on Manny Kalogeris, who as the result of diabetes and a surgeon's scalpel, lost his right leg. When asked how he felt, he replied, "Life is a crap shoot. You never know how the numbers are going to come up. All you can do is roll the dice." Advances in medical research and the early detection of diabetes some day may allow for lucky "rolls of the dice" to come up more often.

I have had multiple myeloma for 15 years. I have had radiation treatment. I still receive chemotherapy. I have taken alpha interferon three days a week for four years. To develop recombinant alpha interferon, researchers used radioactive phosphorus, iodine, and tritium.

Why don't researchers use some other, nonradioactive methods? Of course, they do when they can, but the exquisite sensitivity and generality of radioisotope methods often make them the best techniques by many orders of magnitude. George Palade, Nobel laureate and Dean, Scientific Affairs, University of California at San Diego Medical School, says, "You cannot do modern medical research without using radioisotopes." Kary Mullis, Nobel laureate in chemistry, invented the polymerase chain reaction (PCR), a crucial tool in modern genetic research. Mullis says, "PCR has proven very beneficial, but without radioisotopes to assist in clinical trials, it is of little benefit." Nobel laureate Roger Guillimin is now the chief scientist of the Whittler Institute for Diabetes and Endocrinology in La Jolla. He says, "There is simply no way we can do quality research in diabetes without the use of radioisotopes."

California is at present without a disposal facility for low-level radioactive waste generated by the more than 2250 licensed users of radioactive material. Users include Genentech Pharmaceuticals, Gensia Inc., IDEC Pharmaceuticals, Stanford University, all of the University of California campuses, the Salk Institute, and many other organizations making ground-breaking progress in the fight against cancer, AIDS, and other diseases that claim the lives of thousands of Americans each year.

Virtually all medical research is dependent upon having continued access to low-level radioactive waste disposal sites. Lack of storage capacity by hospitals and universities will lead to disruption or cessation of medical services and related scientific studies. Vital AIDS and cancer research will be directly impacted. Literally thousands of individual laboratories and hundreds of federal research grants will be adversely affected.

But Barnwell, South Carolina, the nation's last available disposal site, closed its gates on July 1, 1994, to outsiders. California is not alone. It is just the forerunner. New York, New Jersey, Maryland, Massachusetts, Minnesota, and Michigan have no solution. That means Memorial Sloan-Kettering, Merck, Pfizer, the National Institutes of Health, Massachusetts General Hospital, Harvard, Massachusetts Institute of Technology, and the Mayo Clinic have no solution.

With no site, generators store waste where it was generated. Licensed generators are legally storing radioactive waste in parking lots, temporary facilities, loading docks, and basements. Soon they will begin reaching physical and regulatory limits. In any case, are more than 2000 storage locations preferable to one scientifically designed, controlled, and monitored facility away from habitation?

Geologists are especially aware of the awesome destructive power of the recent Northridge earthquake. One of the heavily damaged buildings

Forum *continued on p. 105*

Change *continued from p. 104*

changes to the global scale. All local increases in sea level, for example, are not indicative of global rise.

The record of the past

All environments at the Earth's surface result from or are affected by the interaction of climate, human and other biological activity, and geological processes. Even if it is not now possible to predict environmental changes with confidence, data on the recent geological past are fundamental to establishing trends and baselines, both of which are essential for developing new models and concepts. Government, academic institutions and industry must cooperate to provide the data needed to validate and calibrate models and to identify change.

It is essential to continue past efforts at environmental monitoring, to protect existing archives, to maintain and preserve long-term datasets, and to create new databases, such as on global permafrost. Long-term monitoring efforts (e.g. onstream sediment loads) are commonly abandoned as a result of short-term financial and administrative considerations. Irreplaceable information is also being lost because monitoring programs are not in place. Long-term records, for example on tides, stream discharge and water quality, CO_2 and ozone in the atmosphere, provide significant scientific and social benefits that were not anticipated when existing programs were established. These examples underscore the need to select appropriate indicators and begin monitoring immediately so that baselines can be established, and so that the links between natural and human impacts on the environment can be assessed.

Indicators of rapid environmental change

In order to assess the state of any environment, reliable indicators are needed, just as doctors use blood pressure and body temperature as simple, inexpensive guides to human health. Even if causes cannot be determined, we must be able to detect change and warn of dangerous conditions. Many monitoring tools and techniques required to achieve these goals are already available.

Geoindicators are measures of magnitudes, frequencies, rates and trends of geological processes and phenomena occurring over periods of 100 years or less, at or near the earth's surface, that are subject to variations of significance for understanding rapid environmental change. Geoindicators measure both catastrophic events and those more gradual but evident within a human lifespan. Some are complex and costly, but many are relatively simple and inexpensive to apply.

Examples of useful geoindicators include 1) visual observations of beach profiles and vegetation characteristics, which permit rapid assessment of the current stability of beaches and coastlines; 2) growth patterns of coral reefs, which provide detailed information on changes in ocean temperature and salinity, as well as discharge characteristics of major river systems; and 3) seismic events and ground deformation, which can be used to warn of impending volcanic eruptions. It is possible to utilize certain highly responsive natural settings as 'automated environmental recording stations', whose records can be read for both current and long-term changes. These include corals, cave deposits, water in the unsaturated zone, ground temperature conditions in permafrost areas, tree rings and lichens.

In searching for sustainability, we cannot afford to ignore important environmental indicators and the minimum datasets required to assess changes in erosion, sea levels, river flow, water quality or other earth processes that influence all eco-systems and our own well-being. ■

Forum *continued from p. 104*

at the California State University at Northridge contained low-level radioactive wastes. At Cedars Sinai Hospital, in Beverly Hills, a newly constructed low-level radioactive waste storage room was in a parking garage rendered unusable by the quake. Fortunately the storage room was not yet in use.

Suitable locations for low-level radioactive waste facilities are found using state-of-the-art geological studies reviewed by credentialed experts in open forums. In California, the process has been going on for more than ten years. These studies are often challenged in the media and in the courts. Neither of these venues are known for their value in scientifically based public decision making. The media publicize potential risks without regard to probabilities and find balanced studies to be un-newsworthy. The courts, unable to distinguish solid scientific work from scientific speculation, become engines of interminable delay.

Geologists can act on this matter on several fronts. Within the profession, they should act to clearly define that arena of basic knowledge upon which public officials can confidently base their risk-management decisions. The choice of Ward Valley as a site for the storage of low-level radioactive wastes and the design of the facility itself depend particularly on the movement of water. Opponents of Ward Valley would have us believe that geologists cannot tell which way or how fast water will move in the desert. In the public arena, geologists should act to protect their reputation. Allowing judges to decide about matters of geology will soon discredit the profession of geology, as it has discredited the expert testimony of psychologists and psychiatrists. The profession should act to inform the public and the courts that there is no serious disagreement among geologists as to the fundamentals of the science of hydrology and that the choice of Ward Valley for California's low-level radioactive waste site was based upon those fundamentals. Finally, as citizens, geologists should demand that their elected representatives act decisively to protect medical research and to get radioactive waste out of our neighborhoods and into the desert where it belongs. For more information, you may contact the CALRAD Forum at (510) 283-5210. ■

CALL FOR RECIPES

Field Cooking Techniques Open Symposium at '95 Annual Meeting

In recognition of New Orleans, a city famous for its cuisine, GSA announces its first cooking contest. Geoscientists have learned to adapt to producing meals under less than ideal conditions in a variety of field situations. We are aware of methods ranging from automotive techniques (also known as radiator cookery) to the Davy Crockett living-off-the-land approach. Deer rifles, jeeps, and campfires will not be allowed in the convention center, so for this event we have chosen to limit the contest to one common field situation: the problem of eating well when only nonperishable food such as anything that will survive in a normal climate without refrigeration for one week or more is available—for example, canned and dried foods, plus other foods like onions, carrots, potatoes, etc.

We are soliciting recipes in two forms: poster and oral. **Poster** format is a recipe only (to be published in a cookbook). You are encouraged to make as many poster presentations as you please and need not follow the strict rules of the contest (e.g., we will allow strange cooking techniques, roadkill recipes, etc.). **Oral** format (limited to one per entry) is a recipe to be considered for judging and tasting at a cook-off competition held at the convention center and will be subject to a review by a cook-off committee. A select group of about 10 entries will be chosen for a cookoff during the Annual Meeting. Prizes will be awarded for the top two entries. Entry cost is $7 and includes a copy of the cookbook.

Your recipe(s) should be submitted on a Cook-Off Form by <u>August 1, 1995</u>. If you have questions, contact Terry Pavlis, University of New Orleans, Dept. of Geology and Geophysics, 2000 Lakeshore Drive, New Orleans, LA 70148; (504) 286-6797; E-mail: tpavlis@geology.uno.edu, or Kathy Lynch, GSA headquarters, E-mail: klynch@geosociety.org.

<u>Contest Entry Form</u>—

Open Symposium on Field Cooking Techniques

Author Name (cook) ______________________________

Institution/Affiliation ______________________________

Address ______________________________

____

Daytime Telephone (_______) ______________________________

Fax (_______) ______________________________

E-mail address: ______________________________

Cost for Entry Submission/Author: $7 *(includes a copy of the cookbook).*

Payment by ☐ Check
or Charge: ☐ MasterCard ☐ Visa ☐ American Express
Card # ______________________ Expires __________

Recipe Titles Submitted (only one in oral presentation format):

1. ______________________________
   ☐ Oral ☐ Poster *(for cookbook)*
2. ______________________________
   ☐ Poster *(for cookbook)*
3. ______________________________
   ☐ Poster *(for cookbook)*
4. ______________________________
   ☐ Poster *(for cookbook)*
5. ______________________________
   ☐ Poster *(for cookbook)*

Attach your camera-ready recipes on one 8½ × 11 in. sheet, single spaced. Type should be 12 point. We reserve the right to reject any recipe dealing with illegal substances or potentially health threatening ingredients (e.g., roadkill older than several days will not be acceptable as "nonperishable ingredients"). **Please enclose payment at time of submission.**

MAIL TO: Kathy Lynch
GSA Cook-off
P.O. Box 9140
Boulder, CO 80301-9140

Fossil Horses: Systematics, Paleobiology, and Evolution of the Family Equidae. *Bruce J. MacFadden. Cambridge University Press, Cambridge, UK, 1992, 381 p., $74.95.*

This book is most definitely about fossil horses, but it is not just about fossil horses. MacFadden masterfully uses fossil horses as a vehicle to describe and elucidate many new and exciting advances in paleontology, paleobiology, paleoecology, evolution, geochronology, and related disciplines—advances ranging from the revolution engendered by the widespread application of cladistic methodology to the reconstruction of "family trees" to new techniques in isotope geochronology and magnetostratigraphy. Additionally, MacFadden touches on the history of vertebrate paleontology, the development of evolutionary thought, fossil collecting and the establishment of natural history museums, the lore of horses and humans, the philosophy and historiography of science, and many other topics.

Indeed, after reading this book one feels that an introductory course in modern paleontology has just been completed (and I dare say the book could easily be used as a supplementary text for such a course). By the time even the novice reader has finished this book she or he should have a good grasp of such subjects as systematics and the classification of fossil animals; geologic time; paleobiogeography; evolutionary trends, rates, and processes; functional morphology; population dynamics; paleoecology; paleoethology; and terrestrial community evolution over the past 58 million years. And on top of it all, the book is well written and profusely illustrated with black and white photographs, line drawings, diagrams, and charts.

But what about the horses? Horses are the principal subject of this book and are always the focus of the discussion. Humans have long had a special relationship with horses and this is certainly not the first book to be written about them (McFadden cites one estimate that more than 40,000 books have been written about various aspects of equids). So why another book on horses? The horse lineage has been cited as a textbook example of a well-documented evolutionary story ever since Othniel Charles Marsh of Yale's Peabody Museum reconstructed the first horse lineage, from "*Eohippus*" to *Equus*, in the 1870s.

Perhaps a dozen books have been written specifically addressing the evolution of horses, but the last major work on the subject is now over 40 years old (G. C. Simpson's 1951 book *Horses: The Story of the Horse Family in the Modern World and through Sixty Million Years of History*). In the past few decades a wealth of new fossil horses have been uncovered, and a new generation of workers, including MacFadden, have entered the field. The early scenarios were overly simplistic, and as might be expected, the modern story of horse evolution is much more complicated than previously believed, but also more satisfying. In this book MacFadden draws heavily on his own research regarding the evolution of equids in North America while also synthesizing recent work on fossil equids from around the globe. In sum, the time is right for a new book on the evolution of horses, and MacFadden fulfills the need with his *Fossil Horses.*

Robert M. Schoch
Boston University
Boston, MA 02215

Fire Under the Sea. *Joseph S. Cone, First Quill Edition, William Murrow and Company, New York, 1991, $12 (paperback).*

The remarkable discovery in 1977 of hydrothermal vents and exotic biological communities nearly 2500 m below sea level on the Galapagos Rift resulted in an unprecedented rush to explore our planet's most volcanically active region: the midocean ridge system. Joseph Cone's *Fire Under the Sea* is a meticulously crafted and compelling description of the scientific and technological achievements gained during these multidisciplinary programs of sea-floor exploration and provides a revealing look at the diverse community of scientists who conducted the search.

In early chapters, Cone chronicles the work of Harry Hess, J. Tuzo Wilson, Fred Vine, and other pioneers whose collective efforts in the 1950s and 1960s led to the hypothesis of sea-floor spreading within the evolving paradigm of plate tectonics. On the basis of this new model for the genesis of oceanic crust and other fragmentary evidence that hot springs might exist on ocean ridges (e.g., the discrepancy between measured and theoretical heat flow values), marine scientists dived on the Galapagos Rift. Their observations of low-temperature (<20 °C) shimmering water streaming upward through pillow basalt and associated concentrations of clams, mussels, limpets, and tubeworms led to the vigorous period of research and the many discoveries of high-temperature (300 to 400 °C) "black smoker" vents at ocean ridges (Cone emphasizes investigations in the northeastern Pacific) in the 1980s. Two of the later and perhaps most stimulating chapters in the book focus on the ongoing discoveries of new species of vent fauna and the intriguing implications that chemosynthetic organisms have for the origin of life on earth.

The seamless style and lucid descriptions throughout this book should make reading it a treat for scientists and nonscientists alike. In something of a tour de force, Cone translates the arcane terminology of science (e.g., cracking fronts, megaplumes, dueling propagators, black body radiation, nucleic acid, thermophilic bacteria) and technology (CTDs, multibeam echo sounders, sidescan sonar systems) into a language easy to digest. There are also thought-provoking digressions into peripheral issues such as "paradigm shifts" and the Law of the Sea Treaty. Other attractions are the eight-page mid-section of well-chosen color photographs, a helpful set of background notes, an extensive list of references, and a detailed index.

What gives this book an added and welcomed dimension is the infusion of the human element into each chapter. Through a series of personality snapshots, the author introduces some of the talented and often colorful scientists, engineers, and pilots who challenged this deep-ocean frontier. Vicariously, we tag along on their research vessels, dive in cramped submersibles, and gaze in amazement at the dynamic and fertile environment of the hydrothermal vents. We begin to get a sense of both their passion to explore and their need to understand and quantify the processes operating in this natural underwater laboratory. Finally, we share in their effort to comprehend the profound implications of what they have discovered. Indeed, reading Joseph Cone's book is the next best thing to being there.

Randolph A. Koski
U.S. Geological Survey
Menlo Park, CA 94025

Computers in Geology—25 Years of Progress. *Edited by John C. Davis and Ute Christina Herzfeld. Oxford University Press, New York, 1993, $45.*

This volume, the fifth in the series Studies in Mathematical Geology, is a collection of 24 chapters written by well-known and well-published geomathematicians. As stated in the preface, this book serves two functions: (1) it demonstrates the breadth of computer applications in the earth sciences (excluding geophysics), and (2) it illustrates how the subfield of mathematical geology has progressed during the past 25 years. The book has been ably edited by John Davis (an old guard) and Ute Herzfeld (a new-generation geomathematician), and although the chapters are written by a diversity of authors with a wide spectrum of background, it comes across with a pleasing, uniform appearance.

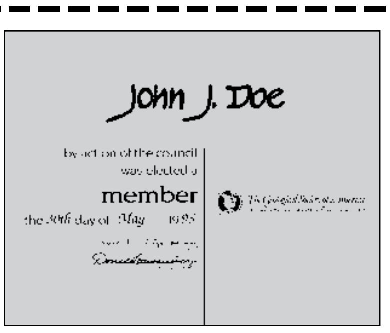
Most papers may be characterized as overview papers. The primary goal of this publication—to inform the reader of the current breadth of geomathematical applications—is admirably met, because the 24 chapters in the book include 10 subdisciplines. They are: economic geology (chapters 2, 3, and 4); sedimentology (5); petroleum geology (6, 7, and 8); mapping (9 and 17); stratigraphy (10, 11, and 12); paleontology (13 and 14); hydrogeology (15); petrology (16); geomorphology (18 and 23); crystallography (19); environmental geology (21); marine geochemistry (22); and general geology (20). Chapter 20 is entitled "Uncertainty in Geology," the topic that is of utmost concern in this day of modeling and simulation in dealing with practical problems, such as nuclear waste disposal, or purely academic problems, such as estimation of local range of taxa. The last chapter (24) is an entertaining anecdote of legendary R. G. V. Eigen, "Father of Mathematical Geology."

In addition to uncertainty analysis, some other state-of-the-art techniques employed by various authors are worth some comment. The techniques of kriging essential in spatial statistics are used in prospecting for gold (chapter 3). Use of expert systems is illustrated, in chapter 4, in regional mineral resource evaluation and, in chapter 21, to assess the potential risk to ground water from contamination by waste dumps. Computer modeling-simulation of carbonate platforms is explained in chapter 14. Fractals and chaos are introduced in chapter 18 in the context of sea-floor topography. Applications of geographic information systems (GIS) are mentioned in connection with mapping in chapters 2, 17, and 21. Last but not least, fuzzy-logic approaches are imple-

Book Reviews *continued on p. 107*

GSA Archaeological Geology Division Student Award

The Archaeological Geology Division announces a $500 travel grant for a student to attend the annual meeting of GSA in New Orleans, November 6–9, 1995. The grant will be awarded on the basis of evaluation of an abstract and 1500–2000-word summary paper prepared by a student for presentation in the Archaeological Division's technical session at the GSA meeting. The summary paper may include one figure and must have a single author. The awards committee must receive the abstract and summary paper by June 24, 1995. Send these items to Rolfe Mandel, Awards Committee Chair, 1730 SW High Ave., Topeka, KS 66604-3121.



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Book Reviews *continued from p. 106*

mented in oil exploration (chapters 6 and 8). Fuzzy logic is a concept derived from the branch of mathematical theory of fuzzy sets and capable of expression in linguistic terms, thus allowing the emulation of the human reasoning processes. This approach has just begun to bear fruit in process control, and one will no doubt see more applications in geosciences where the data or information are fuzzy—imprecise and insufficient.

Even though this book is mostly for the use of geomathematicians, earth scientists in general will greatly benefit from just scanning the titles and perhaps even reading some of the abstracts. I am sure they will be tempted to consult geomathematician(s) for more details.

J. H. Fang
University of Alabama
Tuscaloosa, AL 35487

Stress Regimes in the Lithosphere. *Terry Engelder. Princeton University Press, Princeton, New Jersey, 1993, $75.*

The state of stress in a solid is a concept that has played an important role in scientific and engineering analyses since at least 1660 when Hooke discovered his famous law of linear elasticity. It has long since become routine in numerous disciplines to relate applied stress to the corresponding deformation by means of a variety of laws, including that of Hooke. The state of stress throughout most of Earth was, in fact, described in the 1940s when Jeffreys, Gutenberg, and Bullen determined its seismic velocity and density structure.

To the contrary, however, it is somewhat ironic that within the most accessible part of our planet, the lithosphere, substantial gaps exist in our understanding of the state of stress. There are many reasons for this state of uncertainty. First, compared to the deeper, higher temperature parts of Earth, the lithosphere is strong and, therefore, capable of supporting deviatoric stresses for indefinite periods of time. Second, the forces applied to the lithosphere to cause deviatoric stress states are not well understood. Third, to the astonishment of many, there is even substantial debate as to what the state of lithospheric stress would be in the absence of applied tectonic forces. The fourth reason involves the data set, which in most locations is too scanty to define the manner in which lithospheric stress varies with depth and position. Only the uppermost lithosphere is accessible to measurement. Moreover, stress measurements, especially those at depths of several kilometers or more, tend to be technically difficult and expensive. For all these reasons, and more, our ignorance about many aspects of the state of lithospheric stress is profound.

Accordingly, the earth scientists engaged in studies related to stress in the lithosphere are working in a "frontier" discipline within which the problems to be solved are first order and fundamental. This challenging area of research has grown rapidly during the past several decades, has attracted a very multidisciplinary group of practitioners, and has spawned a literature that is growing by leaps and bounds; this literature is distributed broadly through numerous engineering, industrial, and earth science journals.

By synthesizing virtually all of these disparate studies of lithospheric stress into a comprehensive, scholarly monograph, Terry Engelder has performed a valuable service for the earth science community by making this widespread discipline vastly more accessible than was previously the case. Having personally contributed heavily to the crustal stress database and literature and having also worked closely with many other major contributors to this field, Engelder is exceptionally qualified to write this text. In fact, the chapters describing shallow stress measurements convey to the reader the sense of actually participating in these projects with Engelder.

The content of this monograph, however, is certainly not limited to Engelder's personal expertise and contributions. In fact, *Stress Regimes* is remarkably comprehensive and balanced in its treatment of the myriad of subdisciplines that contribute to our understanding of lithospheric stress. After introducing some fundamental aspects of the state of stress, Engelder describes deformation processes in the lithosphere, as divided into three layers, that might limit the state of deviatoric stress. The central chapters describing various stress-measuring techniques, including hydraulic fracturing, borehole and core deformation, strain relaxation, rigid-inclusion stress meters, and flatjacks, are fascinating reading not only because they are imbued with Engelder's personal experience but also because they include some of the industrial history leading up to the development of these methods. The two chapters on microcrack phenomena and residual stresses are, in my view, somewhat of a digression from the main theme of the book, but the following chapter on earthquakes as stress direction indicators provides a fine review of this important technique. Stress data compilations have featured highly in the development of this field, and so it is fitting that Engelder devoted a chapter to reviewing these efforts. The monograph concludes with an excellent summary of what geodynamicists consider to be the primary sources of the applied forces that cause the state of stress.

Needless to say, the state of lithospheric stress is of essential concern to a broad spectrum of earth scientists engaged in the study of many different geologic processes. Not only is *Stress Regimes* the only textbook providing ready access to this key field, but it is also one of exceptional quality and balance. The book is well illustrated and highly readable throughout, and Engelder has paid sufficient attention to detail that typographic errors are hard to find. Thus, I have no hesitation in recommending *Stress Regimes* to any earth scientist who has a need to know something about the forces responsible for shaping the surface of our planet.

Art McGarr
U.S. Geological Survey
Menlo Park, CA 94025

Applications of Paleomagnetism to Sedimentary Geology. *Edited by D. M. Aissaoui, D. F. McNeill, and N. F. Hurley. Tulsa, Oklahoma, Society for Sedimentary Geology (SEPM) Special Publication 49, 1993, $78.40.*

The stated purpose of this volume is to bring the disciplines of sedimentary geology and paleomagnetism closer together through a collection of papers on current research combining these disciplines. The need for such a volume is clear. As the editors state in the preface, new advances await sedimentary geology through the novel approaches to fundamental problems in this field offered by new advances in paleomagnetism (and rock magnetism) developed during the past several years. Such fundamental problems are precise age control, stratigraphic correlation, and the timing and nature of postdepositional diagenetic fabrics. New techniques in paleomagnetism are also indispensable in attempts to understand relatively new topics of study, such as the intriguing relation between hydrocarbon migration and magnetization and the effect on magnetic mineralogy and fabric due to changes in the environment of deposition.

In almost every aspect, this volume succeeds in fulfilling its promise. The success is, in part, due to a broad range of subject matter relevant to the focus of the symposium upon which the volume is based. Contributions to symposia volumes are too often controlled by who has the time and money to attend the meeting rather than whose research is truly appropriate to its theme. In this case, however, all of the contributions are relevant, and most are even representative of various carefully chosen subthemes. The success of this volume is also due to rigorous peer review evident in the quality of the papers and from the reputation of the scientists included in the list of reviewers.

Book Reviews *continued on p. 108*

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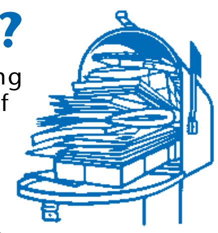

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Book Reviews *continued from p. 107*

Nonspecialists interested in what paleomagnetism has to offer sedimentary geology should first read the article by Steiner and others, a study on the magnetostratigraphy of the Moenkopi Formation as exposed along a several hundred kilometer transect in northeastern Arizona. This study has straightforward sedimentologic-stratigraphic applications, including the establishment of a major lithologic change from mudstone to dominantly sandstone as representing a nearly simultaneous depositional event along the entire transect rather than a slowly migrating, time-transgressive event as is often assumed by sequence stratigraphers. Furthermore, Steiner and others use the magnetostratigraphy to suggest a global lowstand during Late Triassic time and also to establish dissimilar ages for several vertebrate fossil occurrences. Another magnetostratigraphic study is presented by Sheraz and others on the Monterey Formation, a prominent petroleum source rock and reservoir responsible for most of the hydrocarbon production in California. This paper shows that carefully done magnetostratigraphy can provide a temporal framework in an otherwise sparsely dated sedimentary unit. Those of us in the California oil patch greatly appreciate the potential of accurate age control to contribute to an understanding of the origin and stratigraphic distribution of this economically and academically important formation.

The article by Herrero-Bervera and Helsley presents results that are representative of recent research extending the use of magnetostratigraphy to a much finer temporal scale (<1000 yr) by the precise correlation of geomagnetic excursions and secular variations. In a recent paper in the *Journal of Geophysical Research,* Herrero-Bervera and Helsley built upon the important results shown in this volume by correlating rapid geomagnetic events in their record from Pringle Falls, Oregon, with those of lacustrine records from other localities in western North America.

Rock magnetism is quickly becoming a valuable means of detecting anthropogenic and climate-induced changes in depositional environments. This is exemplified in an intriguing paper presented by Hawthorne and McKenzie in which they use a combination of rock magnetic, petrographic, and geochemical techniques in the detection of anthropogenic changes in the environment of deposition of a lacustrine system.

This volume also contains several papers that demonstrate the dependence of paleomagnetic studies on a firm understanding of both the physical and chemical aspects of sedimentology. For example, the contribution from Gillett and Geissman is an excellent example of the need to consider the timing of fabric and mineral genesis in relation to paleomagnetic remanence acquisition, especially in the study of carbonate rocks.

I would consider this volume for use in a graduate seminar as long as it is supplemented with one of the many fine traditional references listed at the end of the preface. It would also be a good reference volume for all broad-minded sedimentologists with even a modest quantitative background and for all paleomagnetists who might want access to well-written papers covering a broad range of recent research on the paleomagnetism of sedimentary rocks.

Rob Negrini
California State University
Bakersfield, CA 93311

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ARCHAEOLOGICAL GEOLOGY OF THE ARCHAIC PERIOD IN NORTH AMERICA
edited by E. Arthur Bettis III, 1995
Climatic, biotic, and geomorphic changes that had dramatic effects on prehistoric human populations occurred during the early and middle Holocene in North America. This volume focuses on the stratigraphic record of that period, and the controls that sedimentary and pedologic processes have exerted on our perceptions of the associated archaeological record of the Archaic Period. A variety of approaches to investigating and modeling the archaeological geology of the early and middle Holocene in North America are presented. These seven papers summarize what is known of the archaeological geology of the Archaic Period from the St. Lawrence Lowland, through the Mid-continent and Plains, to the Rocky Mountains, and on the continental shelf.
SPE297, 158 p., paperback, indexed. ISBN 0-8137-2297-7, $45.00

LOW-GRADE METAMORPHISM OF MAFIC ROCKS
edited by Peter Schiffman and Howard W. Day, 1995
Mafic rocks recrystallized to the zeolite, prehnite-pumpellyite, and contiguous facies are found within a large part of Earth's crust, but particularly at divergent and convergent plate margins. Study of these low-grade metamorphic rocks can provide significant insights into understanding the thermal and chemical evolution of diverse tectonic settings, including mid-oceanic spreading centers, accretionary prisms, and island arcs and their adjacent sedimentary basins. Ten papers address the low-grade metamorphism of mafic rocks from a wide range of these settings and employ various research methodologies in problem solving.
SPE296, 174 p., indexed, ISBN 0-8137-2296-9, $50.00

GEOLOGIC AND TECTONIC DEVELOPMENT OF THE CARIBBEAN PLATE BOUNDARY IN SOUTHERN CENTRAL AMERICA
edited by Paul Mann, 1995
Presents 17 papers on various aspects of the complex geologic and tectonic development of southern Central America, defined here as the combined land areas of Panama and Costa Rica, and their adjacent offshore areas in the Caribbean Sea and Pacific Ocean. This work represents a milestone in the integration of onland and marine geologic and geophysical data from this tectonically complex focal point among the Caribbean, Nazca, Cocos, and South America plates. The authors document the composition and paleomagnetic history of the Jurassic-Cretaceous crust beneath southern Central America; the composition and structure of the overlying Cretaceous/Tertiary volcanic arc; Neogene plate boundary faults and associated structures inferred from onshore and offshore mapping studies; and patterns of present-day seismicity and plate motions as inferred from seismological and GPS-based studies.
SPE295, 381 p., paperback, 8 plates on 4 sheets in pockets, indexed, ISBN 0-8137-2295-0, $100.00

PERMIAN-TRIASSIC PANGEAN BASINS AND FOLDBELTS ALONG THE PANTHALASSAN MARGIN OF GONDWANALAND
edited by J. J. Veevers and C. McA. Powell, 1994
After reconstructing Permian-Triassic Gondwanaland, authors writing on South America, South Africa, Antarctica, and Australia profusely illustrate the relevant geology of each sector in maps and time-space diagrams underpinned by robust biostratigraphic and radiometric dating. The work is then drawn together in a stratigraphic-tectonic synthesis, which features the specifically Gondwanan glaciogene and coal facies, the Early and Middle Triassic coal gap, and the interplay of Pangean and Panthalassan tectonics.
MWR184, 372 p., hardbound, ISBN 0-8137-1184-3, $100.00

THE GEOLOGY OF ALASKA
edited by G. Plafker and H. C. Berg, 1994
GNA-G1, 1,066 p., hardbound, w/13 plates in slipcase, and 1 microfiche card, indexed, ISBN 0-8137-5219-1, $135.00

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Geologic Evolution of the Red Sea. *Robert G. Coleman. Oxford University Press, New York, 1993, 186 p, $59.95.*

Coleman prefaces his book with a disclaimer regarding the ambitious scope of work contained therein, and rightly so! This small volume attempts to integrate a vast spectrum of geological and geophysical literature so as to furnish a "starting point for scientists interested in the geology of the Red Sea."

In attempting to describe the geomorphology, stratigraphy, volcanism, geophysics, structure, and tectonics of the Red Sea, Coleman vacillates between ponderous detail (e.g., in the chapter on volcanic history) and highly interpretive summaries (e.g., the chapter on stratigraphy). One can argue that Coleman does not adequately honor a rich source of data from the Egyptian side of the Red Sea. The book suffers from a lack of well-designed illustrations and inherent fine print.

Coleman's primary contribution stems from his efforts to integrate all forms of data. His relentless and complex treatment of volcanic history along the Red Sea margins in conjunction with his interpretation of crustal geometries leads one to conclude that previous interpretations of the geologic history of the Red Sea were highly simplistic. The concept of "contemporaneous magma underplating and invasion of the thinning crust" during extension of the Red Sea certainly illustrates a fruitful approach to further work.

Coleman describes his book as a starting point. It should be required reading for graduate students as well as a springboard for serious research on continental rifting and ocean-floor spreading. Future work outlined by Coleman in the epilogue promises to continue enriching our understanding of one of Earth's great "natural laboratories." I recommend that you read this book.

Arthur O. Beall
Baylor University
Waco, TX 76798

The Geology of the Guiana Shield. *A. K. Gibbs and C. N. Barron. Oxford Monographs on Geology and Geophysics No. 22, Oxford University Press, New York, 1993, 258 p., one fold-out color map, $89.95*

This book is the most comprehensive summary of the geology of a region that presents formidable logistic difficulties to the geologist on the ground, and for the most part is shrouded in a rain forest and a regolith up to 150 m thick. No wonder the Guiana Shield remains little known, in spite of extensive remote sensing data acquired by air photography, airborne radar and Landsat imagery, and airborne and satellite-based geophysical surveys.

The introduction contains a useful description of techniques of ground geological survey in a tropical environment. Five subject-matter parts follow: I, Archean and Lower Proterozoic supracrustals (four chapters); II, Trans-Amazonian tectono-thermal episode (two chapters); III, Middle Proterozoic cover (five chapters); IV, Upper Proterozoic and Phanerozoic (four chapters); and V, economic geology (one chapter). Appendices include: (1) database and access to sources; (2) regional maps and remote sensing data sources; and (3) a tentative historical model, followed by a 30-page bibliography, an index, and a color geological sketch map.

The Guiana Shield, that part of the Amazonian craton north of the Amazon River, is notable for its extensive Early Proterozoic magmatism and high-grade metamorphism of the Transamazonian (= Eburnean) orogeny. Archean greenstones, granulites, and minor belts of supracrustal rocks are concentrated in the northeast part of the shield. The widespread Middle Proterozoic volcanic and sedimentary cover with rapakivi-type granite intrusions forms a northwest-trending belt. Neoproterozoic shearing and development of wide mylonite belts ended the evolution of basement rocks of the Guyana Shield .

The economic potential of the Guyana Shield is large. To date, important supergene deposits of bauxite, kaolin, and manganese and gold and diamond placers and paleoplacers have been worked. The basement is a minor producer of iron ore, cassiterite, and gold.

The book navigates the reader through the maze of regional terminology of Brazilian, Colombian, Venezuelan, Surinamese, French Guyanan, and Guyanan origin. Chapter 15 of Part IV contains an interesting discussion of the evolution of climate and hydrographic systems, helping the reader to understand the complexities of supergene and placer deposits formation. Arid-climate savanna vegetation covered the shield during Pleistocene glacial periods. The idolized rain forest became established much later than environmental worshippers would care to admit.

The synthesis of a large volume of data as presented in the book will retain its value for a long period. The maps are informative, although necessarily sketchy. The tables, typed on a poorly maintained typewriter, look ugly and are the most serious flaw of this otherwise respectable and useful book.

Raphael Unrug
Wright State University
Dayton, OH 45435

The Tancheng-Lujiang Wrench Fault System. *Edited by Xu Jiawei. John Wiley & Sons, New York, 1993, 279 p., $175.*

The Tancheng-Lujiang (Tan-Lu) wrench fault system is a prominent crustal structure along the continental margin of eastern Asia with more than 700 km of sinistral displacement along a 3600-km-long system of faults. The fault system is one of the more exhaustively studied faults in the world. This book provides a comprehensive evaluation of the fault system, including a historical review of studies performed along the fault since the late 1800s. The 19 articles by various authors range from detailed studies of individual faults or segments of the system to regional analyses on the timing and magnitude of displacement to structural and deformation characteristics of exhumed parts of the fault system.

The Tan-Lu fault system is an excellent example of a fault with repeated episodes of deformation in a variety of tectonic environments. The strength of this book is the detailed treatment of the evolution of the fault system from its principal phase of sinistral slip during Late Jurassic to Early Cretaceous time, to extensional rifting during the Late Cretaceous to Eocene, to its present phase of minor transpressional dextral slip in the Neogene. In addition, the articles provide strong docu-

Book Reviews *continued on p. 109*

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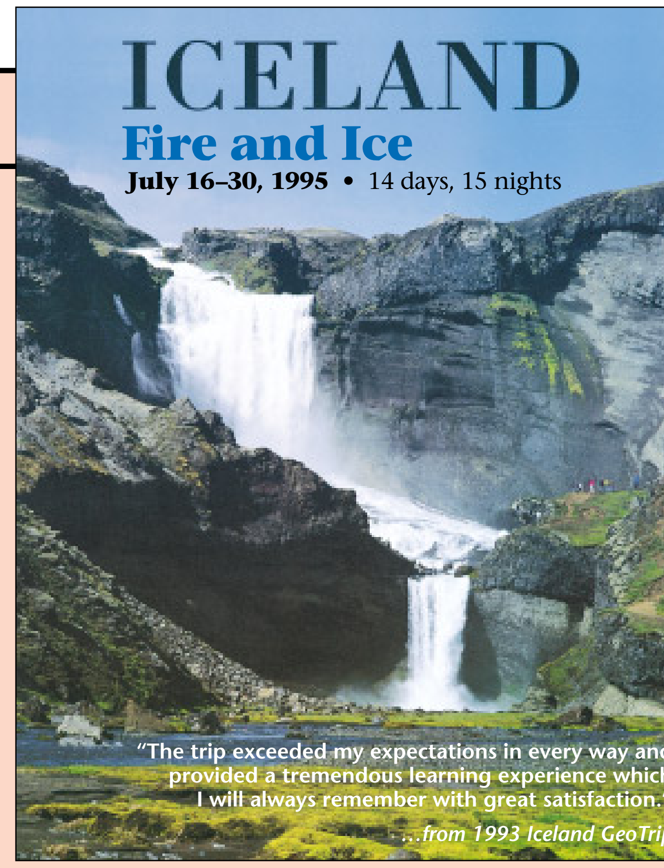

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Scientific Leaders:
Haraldur Sigurdsson, *Graduate School of Oceanography, University of Rhode Island*
Haukur Johannesson, *Natural History Institute, Reykjavik, Iceland*

A native of Iceland and professor of oceanography, *Haraldur Sigurdsson* is a leading volcanologist with an international reputation for his research on many aspects of volcanism in Iceland, Italy, Mexico, Colombia, the United States, and Indonesia, among others. *Haukur Johannesson* has devoted most of his career to the geologic mapping of the uncharted volcanic regions of Iceland. He is an expert in the tectonic structure and origin of the Iceland basalt plateau and is also very knowledgeable about the natural history of Iceland in general.

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This trip will reveal many unaltered and fresh geologic features that can be seen nowhere else on land. Expect to acquire a newly expanded understanding of volcanoes, hotspots, and rifts. There will be great views of steep-walled and flat-topped hyaloclastite ridges derived from subglacial eruption, young hyaloclastite islands produced by submarine eruptions, great explosion craters, tephra cones, calderas, blocky obsidian flows, waterfalls descending into the rift valley, and, of course, extraordinary glacial panoramas.

Lodging, Meals, Transportation. During most of the trip, the group will stay in country hotels (Edda hotels), rural secondary and high schools operated as simple but comfortable summer hotels. Food will be provided at all lodging locations, plus picnics during the day. Travel will be by four-wheel-drive mountain trail bus and by car ferry to the volcanic Westmann Islands.

Air Transportation. The Baltimore gateway has the best connecting flights to most of North America. Round trip travel from Baltimore to Reykjavik will be on IcelandicAir. The current group round-trip fare is $748. Trip participants are required to travel on the group flight so that everyone can benefit from the advantages of a group reservation. You may use air mile coupons for your domestic flights, however. Travel arrangements are being handled by Volcano Tours—TR Consultants, which can help you with plans for your entire itinerary (1-800-923-7422, fax 401-247-0270). They will also offer a brief post-trip option to Greenland.

Fee includes all meals in Iceland; double-occupancy lodging; comfortable bus and ferry transportation; transfers and entrance fees; baggage handling; geologic road log; and field guidebook. **Not included** are airfare to and from Reykjavik, and hotel nights and meals, if any, in Baltimore.♦

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Book Reviews *continued from p. 108*

mentation of the extent and geometrical features of the fault, the strike-slip character of the fault, and the change from brittle to ductile deformation at different tectonic levels in the fault system.

The book presumes a general understanding of the tectonic evolution of eastern Asia. A discussion of the overall tectonic setting of that area is not provided. Thus, the reader may not appreciate fully the tectonic implications of the Tan Lu fault system in reconstructing the paleogeographic and paleotectonic framework of eastern Asia. In addition, the book is heavily oriented toward assessment of structural deformation during the fault's Mesozoic sinistral phase of movement. Very little attention is focused on the contemporary style of faulting and earthquake hazards along the fault system.

This book provides a collection of well-written, well-illustrated articles on the evolution of the Tan-Lu fault system. The authors of its articles have carried out a systematic field and laboratory analysis of the fault system integrating data from a variety of earth science disciplines and from a variety of geographic locations and tectonic levels along the fault system. These articles provide an excellent documented example of complex strike-slip faulting that evolved over a variety of tectonic periods. They will prove useful for comparison with and understanding of strike-slip faulting on other major transcurrent faults worldwide.

William R. Lettis
William R. Lettis & Associates, Inc.
Oakland, CA 94607

Geologic, Hydrothermal, and Biologic Studies at Escanaba Trough, Gorda Ridge, Offshore Northern California. *Edited by Janet L. Morton, Robert A. Zierenberg, and Carol A. Reiss. U.S. Geological Survey Bulletin 2022, 1994, 359 p., $27.*

The Gorda Ridge is the only mid-oceanic ridge spreading center situated within the U.S. Exclusive Economic Zone. That is why the U.S. Geological Survey has recently concentrated its efforts on investigations ultimately directed toward evaluating potential resources associated with hydrothermal activity on this northeast Pacific ridge segment. The southern segment of the Gorda, the Escanaba Trough, is a sedimented ridge, and hydrothermal processes that mitigate massive sulfide deposition in this environment entail both fluid-basalt and fluid-sediment interactions. Elucidating the nature of these complex interactions entails a multidisciplinary approach. This volume, subdivided into three major sections (Geological Processes, Hydrothermal and Geochemical Studies, and Biologic Studies), contains 18 research contributions that collectively provide an exceedingly comprehensive view of the Escanaba Trough. Land-based geologists will be delighted to find that studies in virtually every geological subdiscipline, and then some, are represented here: structural and geophysical modeling, sedimentology and sediment diagenesis, volcanology, igneous petrology, hydrothermal fluid chemistry, stable isotope systematics of fluid-rock interactions, organic geochemistry of hydrothermal petroleum formation, hydrothermal vent macrofauna and benthic microfauna, and of course, massive sulfide deposits. The editors have done their job in ensuring an overall high standard of scholarship for this volume. The chapters are uniformly well illustrated with high-quality maps, photographs, and line drawings, including more than 20 full-page color illustrations and photographic plates. For the price of $27, you get great value. Who says that the USGS isn't providing a valuable service to the U.S. public and scientific community?

Peter Schiffman
University of California
Davis, CA 95616

Geological Structure of the North-Eastern Mediterranean (Cruise of the Research Vessel 'Akademik Nikolaj Stakhov'). *Edited by Valery A. Krasheninnikov and John K. Hall. Historical Productions—Hall Ltd., Jerusalem, 1994, $50.*

This new volume compiles data collected during the 1987 Cruise 5 of the R/V *Akademik Nikolaj Strakhov*, administered by the Geological Institute of the Russian Academy of Sciences. The extensive geophysical and supporting geological data of the eastern Mediterranean contained within this volume are, in the words of the publishers, presented in the "tradition of the DSDP (ODP) Reports and the GSA D-NAG Series." This is a handsome book and, in many respects, does indeed appear strikingly similar in appearance to those of the DNAG (Decade of North American Geology) series. Few scientific revelations are to be found within this volume that cannot be gleaned from previous cruises to the region and from the existing literature. However, it does represent a useful, well-illustrated compendium of new data pertinent to the complex crustal structure of the eastern Mediterranean.

The book is divided into 18 chapters, the first chapters being devoted to seismic, magnetic, and gravity data, the middle chapters covering sediments and fossils of the Levantine Sea and of southern Cyprus, and the ending chapters representing tectonic interpretation of the region and a regional bibliography; a pocket contains four plates showing bathymetric charts and seismic profiles. The chapters covering the geophysics of the region are clearly the best part of this work and would be the main reason for obtaining it. In addition to oversized color maps summarizing bathymetric, magnetic, and gravity data for the eastern Mediterranean, 51 new seismic sections are reproduced. These data are focused in the area between Cyprus and the Levant and provide a detailed view of the thickness and structure of sediments and of probable crustal types. Of particular interest is the detailed information provided bearing on the structure and crustal nature of the Eratosthenes Seamount. These data, together with results of dredging on the seamount, are summarized in a thoughtful chapter (6) "Geological Structure of Eratosthenes Seamount." Although the authors favor the interpretation of the seamount as a foundered extension of the Afro-Arabian platform, they provide a useful discussion of previously proposed models. I found the reproductions of seismic profiles in this book, particularly

Book Reviews *continued on p. 110*

Book Reviews *continued from p. 109*

those within the pocket, to be of high quality and actually useful—a commendable achievement when they are compared to many seismic profiles published elsewhere.

Of considerably less interest in this volume than the geophysical data are the four chapters (11–14) devoted entirely to the stratigraphy and paleontology of the Perapedhi Formation and younger sediments of southern Cyprus. These chapters detract from the coherency of the volume because they do not relate to the bulk of the book in any straightforward manner; it appears that these chapters were appended simply because the work had been done. Although presenting much detailed stratigraphic and fossil data for the various formations lying above the Troodos ophiolite, these chapters present little that has not been previously published. Chapter 18, "Eastern Mediterranean Regional Bibliography: Geology, Geophysics, Oceanology, and Related Subjects," will probably be of interest only to newcomers to the region. The 3596 references in this 87-page chapter are an attempt to provide the reader with a complete resource for published marine data for the eastern Mediterranean and an overview of supporting geological and geophysical data from adjacent continental regions. As is usually the case with such compilations, it is, by the author's admission, incomplete and represents one person's view of what literature is important. With available on-line searching of digital library data bases, I wonder about the usefulness of such printed bibliographies to researchers targeted by volumes such as this.

Despite its somewhat uneven character, *Geological Structure of the North-Eastern Mediterranean* is a good resource for basic, geophysical data from this complex region. The illustrations are excellent (I especially appreciated the liberal use of historical prints and maps) and useful to anyone interested in the structure and tectonics of this part of the Mediterranean. Given its relatively low price, the shortcomings of this book are more than outweighed by its strengths.

Robert J. Varga
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GSA ANNUAL MEETINGS

■ 1995

New Orleans, Louisiana
November 6–9
Ernest N. Morial Convention Center,
Hyatt Regency New Orleans

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Technical Program Chair: *Laura Serpa, University of New Orleans*
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■ 1996

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Call for Field Trip Proposals: *Please contact the Field Trip Chairs listed below.*
Charles L. Pillmore, Ren A. Thompson
U.S. Geological Survey, MS 913, P.O. Box 25046
Denver Federal Center, Denver, CO 80225
phones: Charles L. Pillmore, (303) 236-1240; Ren A. Thompson (303) 236-0929

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The GSA Committee on Continuing Education invites those interested in proposing a GSA-sponsored or cosponsored course or workshop to contact GSA headquarters for proposal guidelines. Continuing Education courses may be conducted in conjunction with all GSA annual or section meetings. We are particularly interested in receiving proposals for the 1996 Denver Annual Meeting or the 1997 Salt Lake City Annual Meeting.

Proposals must be received by December 1, 1995. Selection of courses for 1996 will be made by February 1, 1996. For those planning ahead, we will also consider courses for 1997 at that time.

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

■ FUTURE

Denver	October 28–31	1996
Salt Lake City	October 20–23	1997
Toronto	October 26–29	1998
Denver	October 25–28	1999

For general information on any meeting call the GSA Meetings Department, 1-800-472-1988 or (303) 447-2020, ext. 141; E-mail: mball@geosociety.org

GSA SECTION MEETINGS

■ 1995

ROCKY MOUNTAIN SECTION
Montana State University, Bozeman, Montana, May 18–19, 1995. Information: Stephan G. Custer, Department of Earth Sciences, Montana State University, Bozeman, MT 59717-0348, (406) 994-6906, fax 406-994-6923, E-mail: uessc@msu.oscs.montana.edu.

CORDILLERAN SECTION
University of Alaska, Fairbanks, Alaska, May 24–26, 1995. Information: David B. Stone, Geophysical Institute, University of Alaska, Fairbanks, AK 99775-0800, (907) 474-7622, fax 907-474-7290, E-mail: ffdbs@aurora.alaska.edu.

■ 1996

SOUTH-CENTRAL SECTION, University of Texas at Austin, Austin, Texas, March 11–13.
SOUTHEASTERN SECTION, Ramada Plaza Hotel, Jackson, Mississippi, March 14–15.
NORTHEASTERN SECTION, Hyatt Regency, Buffalo, New York, March 21–23.
ROCKY MOUNTAIN SECTION, Rapid City Civic Center, Rapid City, South Dakota, April 17–19.
CORDILLERAN SECTION, Red Lion Hotel, Portland, Oregon, April 22–24.
NORTH-CENTRAL SECTION, Iowa State University, Ames, Iowa, May 2–3.

IEE-Sponsored Symposium at Rocky Mountain Section Meeting To Examine Environmental Impact of Mines and Smelters

GSA's Institute for Environmental Education will sponsor a symposium, "Characterization and Remediation of Environmental Impacts from Metal Mines and Smelter Operations in the Rocky Mountains," at the GSA Rocky Mountain Section meeting in Bozeman, Montana, May 18–19, 1995. The symposium will bring together hydrologists, hydrogeologists, geochemists, and microbiologists who are deciphering the physical and chemical processes that mobilize and disperse solute and particulate metals in a broad range of environments. Organizers of the session are William W. Woessner and Johnnie N. Moore, Department of Geology, University of Montana.

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Positions Open

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The Department of Geological Sciences at the University of Texas at El Paso is seeking a person to manage its computer operations. The existing facilities include a substantial network of UNIX workstations and peripherals, and a variety of personal computers. The software packages employed include PROMAX, IDL, and Interleaf. This position involves the maintenance, expansion and improvement of this system and the facilitation of its use by students and faculty.

The supervisor must also direct students who are assigned to help operate the system. In addition to the knowledge needed to keep our system running, we are looking for a person with a good knowledge of computer applications in the geosciences. There also would be opportunities to participate in studies employing computer-oriented equipment.

A B.S. degree in science or engineering and considerable UNIX experience are required. A M.S. degree and training in the geosciences is desirable. The salary would be competitive.

The position is available beginning September 1, 1995. Position will remain open until filled but screening will begin about July 1, 1995. To apply, send letter of application, resume, and provide three letters of reference to: Dr. G. R. Keller, Chair, Department of Geological Sciences, The University of Texas at El Paso, El Paso, Texas 79968-0555.

The University of Texas at El Paso does not discriminate on the basis of race, color, national origin, sex, religion, age or disability in employment or the provision of services.

HYDROGEOSCIENCE AND GEOPHYSICS
VIRGINIA TECH

The Department of Geological Sciences at Virginia Polytechnic Institute and State University (Virginia Tech) will be seeking rolling applications to hire five faculty, in the next four years, to fill openings due to planned retirements and to restructure itself for the 21st century. At this time, applications are invited for two tenure track faculty positions at the Assistant Professor level only in: 1) Hydrogeoscience with strong quantitative background in fluid transport in subsurface porous media; and 2) Geophysics with strong background in exploration geophysics and 3-D subsurface imaging. The department intends to hire one in 1995-96 and one in 1996-97 academic years. A Ph.D. is expected at the time of appointment. Review of applications will begin May 1, 1995, and continue until positions are filled.

The present faculty, 20 full-time tenured and 2 part-time, have diverse strengths and represent economic geology, earthquake seismology, exploration and geophysics, geochemistry, mineralogy, paleontology, petrology, sedimentology, structural geology, and tectonics. For detailed information the applicants are encouraged to look at the departmental home page at http://www.geol.vt.edu.The department offers B.S., M.S., and Ph.D. degrees in geological and geophysical sciences. Faculty are expected to supervise and teach introductory level undergraduate geoscience courses and undergraduate/graduate level courses in their areas of expertise. They are also expected to direct M.S. and Ph.D. candidates while developing and maintaining externally funded research programs. New faculty will play a central role in collaborating with complementary department programs and developing applied programs to prepare students for future job markets. Candidates must be able to demonstrate expertise in quantitative applications in the geosciences.

Interested applicants should send a letter of interest, curriculum vitae, transcripts, names of three references, a statement of anticipated research and teaching interests, along with a short essay explaining where the applicant would like to see him/herself within the geosciences in the 21st century. Applicants should send their application package to Cahit Çoruh, Chairman, Department of Geological Sciences, Virginia Tech, 4044 Derring Hall, Blacksburg, VA 24061-0420; Phone 703-231-6894; TDD 703-231-3749; Fax: 703-231-3386; Email: coruh@vt.edu.

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COAL GEOLOGIST III (2 POSITION)

The West Virginian Geological and Economic Survey (State Agency) seeks to fill two (2) Coal Geologist positions for a five (5) year GIS-based coal bed mapping project. The positions are to start approximately July 1, 1995. The requirements are: a Ph.D. degree in geology; or a MS and three years experience as a professional geologist; or a BS in geology and five years of experience as a professional geologist. Experience with computers and computer manipulation of data is desirable. Other requirements: must work closely with other geologists and program personnel; must have effective verbal and written communications skills, be able to define and solve problems, work independently, and supervise other personnel; and must accept responsibility toward meeting deadlines.

All interested geologists should submit a letter of applications; college transcripts; and have three (3) letters of reference sent to the West Virginia Geological Survey, P.O. Box 879, Morgantown, WV 26507-0897, attn: Gloria Rowan, by May 19, 1995 the closing date. The pay grade for this position is 14 = $24,240-39,432. If any further information is required, please call 304/594-2331 ex. 320.

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This facility was dedicated in 1991, with a principal focus to provide 14C data for the NSF-Ocean Sciences Community. The NOSAMS facility currently has a staff of 12 people with an annual budget of about $1.5 M. It occupies a dedicated 860 square meter facility which houses the dual input accelerator mass spectrometer, two stable isotope mass spectrometers and a sample preparation unit with fully automated seawater stripping lines and graphitization reactors.

A successful candidate will join our tenured scientific staff with a mandate to maintain the present high level of expertise in radiocarbon technology, to provide for the long-term viability of the facility, and to exercise scientific leadership in building active research areas involving institution colleagues as well as collaborations with external parties.

Send resume to S. R. Hart, Chair, NOSAMS Search Committee, P.O. Box 54PAB, Woods Hole Oceanographic Institution, Woods Hole, MA 02543. WHOI is a smoke free workplace.

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The Department of Geosciences invites applications for a tenture-track faculty position, to be filled at the junior level, in the field of hydrogeology and/or hydrogeochemistry. Special consideration will be given to individuals involved in the quantitative assessment of hydrological processes using fundamental geological and geochemical principles. Possible concentrations might include theory and observation of the hydraulic properties of heterogeneous media and/or the study of subsurface fluid flow with geochemical methods. The successful applicant will join an active group of faculty and researchers committed to excellence in both teaching and research, with specialties in most areas of the geosciences and earth system science. State-of-the-art equipment at Penn State includes several mass spectrometers, inorganic and organic chemical laboratories, hydrogeological and geophysical field equipment, and extensive computing facilities. Applicants should demonstrate a history of, or potential for, funded research and high-quality teaching. The position is available Jan. 1, 1996; a Ph.D. is required at the time of appointment. Interested individuals should submit a current vita, a statement of research and teaching interests, and the names and addresses of at least three references by June 30, 1995, to: Head, Dept. of Geosciences, The Pennsylvania State University, 503 Deike Building, Box C, University Park, PA 16802. An Affirmative Action/Equal Opportunity Employer. Women and minorities encouraged to apply.

Opportunities for Students

Visiting Fellows and Students/Institute for Rock Magnetism. Applications are invited for visiting fellowships (regular and student) lasting for up to 3 weeks during the period from September 1, 1995, through February 28, 1996.

Topics for research are open, although fellows are encouraged to take advantage of the chosen focus for cooperative reasearch in a given year. During 1995-6, the focus for research will be the connections between the fundamentals of rock magnetism and paleomagnetic observations.

Short proposals (two pages, single-spaced text plus necessary figures and tables) are due by June 9, 1995, for consideration by the Institute's Review and Advisory Committee (Bob Butler, Chair).

Successful applicants will be notified in early August, 1995.

A limited number of travel grants of $500 are available to researchers who can demonstrate no existing financial resources. No funds are available for per diem expenses.

The Institute Staff (Bruce Moskowitz, Associate Director, and Christopher Hunt, Facilities Manager) will be happy to provide application forms and information necessary for proposal preparation.

Deadline for submission is June 9, 1995, at the following address: Chris Hunt, Facilities Manager, Institute for Rock Magnetism, Univeristy of Minnesota, 293 Shephard Laboratories, 100 Union St. SE, Minneapolis, MN 55455-0128, 612-624-5274; fax: 612-625-7502; E-mail: chunt@maroon.tc.umn.edu.

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Only new or changed information is now being published in *GSA Today* . A complete listing can be found in the **Geoscience Calendar** section on the Internet: **http://www.aescon.com/geosociety/index.html.**

1995 GSA Penrose Conferences

August

August 22–27, **Fault-related Folding,** Banff, Alberta, Canada. Information: David Anastasio, Department of Earth and Environmental Sciences, Lehigh University, Bethlehem, PA 18015-3188, (610) 758-5117, fax 610-758-3677, E-mail: dja2@lehigh.edu.

August 31–September 4, **Fault Rocks,** Leavenworth, Washington. Information: Jerry F. Magloughlin, Department of Geological Sciences, 1006 C.C. Little Building, University of Michigan, Ann Arbor, MI 48109-1063, (313) 747-0664, fax 313-763-4690, E-mail: jerry.magloughlin@um.cc.umich.edu.

September

September 28–October 3, **Tectonic Development of the Canada Basin and Surrounding Regions,** Banff, Alberta, Canada. Information: Lawrence A. Lawver, Institute for Geophysics, University of Texas at Austin, 8701 N. MoPac Expressway, Austin, TX 78759-8397, (512) 471-0433, larry@utig.ig.utexas.edu.

October

October 6–11, **Mesozoic Evolution of the Cordilleran Continental Margin in Central and Southern California,** Tehachapi, California. Information: Andrew Barth, Department of Geology, Indiana/Purdue University, Indianapolis, IN 46202-5132, (317) 274-1243, E-mail: ibsz100@indyvax.iupui.edu.

October 14–20, **Argentine Precordillera,** San Juan, Argentina. Information: Ian W. D. Dalziel, Institute for Geophysics, University of Texas at Austin, 8701 N. Mopac Blvd., Austin, TX 78759-8397, (512) 471-0341, fax 512-471-8844, E-mail: ian@utig.ig.utexas.edu.

1995 Meetings

May

May 19–21, **Midwest Friends of the Pleistocene Annual Field Conference,** in and around the Mississippi and Cache valleys, southern Illinois and eastern Missouri. Information: Steven Esling, Dept. of Geology, Southern Illinois University, Carbondale, IL 62901, (618) 453-7363, fax 618-453-7393, E-mail: esling@qm.c-geo.siu.edu.

September

September 3–9, **Fifth International Conference on Radioactive Waste Management and Environmental Remediation,** Berlin, Germany. Information: Leslie Friedman, (212) 705-7788, fax 212-705-7856.

September 17–20, **Carpatho-Balcan Geological Association XV Congress,** Athens, Greece. Information: D. Papanikolaou, National Centre for Marine Research, Agios Kosmas, Ellinikon, 166 04 Athens, Greece, phone 30-1-9820214, fax 30-1-9833095.

October

October 1–5, **American Institute of Professional Geologists Annual Meeting,** Denver, Colorado. Information: Conference Associates, 1776 Lincoln Street, Suite 620, Denver, CO 80203, (303) 863-9506, fax 303-863-9507.

October 4, **Joseph F. Poland Symposium on Land Subsidence,** Sacramento, California. Information: Jim Borchers, U.S. Geological Survey, (916) 278-3005, fax 916-278-3013, E-mail: jborcher@usgs.gov.

October 6–8, **26th Binghamton Geomorphology Symposium,** Biogeomorphology—Terrestrial and Freshwater Aquatic Systems, Charlottesville, Virginia. Information: Cliff R. Hupp, U.S. Geological Survey, 430 National Center, Reston, VA (703) 648-5207, fax 703-648-5484, E-mail: crhupp@wrdmail.er.usgs.gov.

October 12–13, **Seismological Society of America, Eastern Section Annual Meeting,** Palisades, New York. Information: Noël Barstow, Lamont-Doherty Earth Observatory, Route 9W, Palisades, NY 10964, (914) 365-8477 or 8486. *(Abstract deadline: September 8, 1995.)*

November

November 6–10, **Curved Orogenic Belts: Their Nature and Significance,** Buenos Aires, Argentina. Information: fax 54-1-788-3439, E-mail: pepe@lpgfcg.uba.ar, Jose Selles-Martinez, Coordinador COB'95, Dpto. de Ciencias Geologicas, Pabellon 2 Ciudad Universitaria, 1428 Buenos Aires, Argentina.

1996 Meetings

February

February 27–29, **Applied Geologic Remote Sensing, Eleventh Thematic Conference and Workshops,** Las Vegas, Nevada. Information: ERIM/Geologic Conference, P.O. Box 134001, Ann Arbor, MI 48113-4001, (313) 994-1200, ext. 3234, fax 313-994-5123, E-mail: wallman@erim.org.

May

May 14–18, **Paleogene of South America,** Santa Rosa, La Pampa, Argentina. Information: Silvio Casadio, Dpto. Ciencias Naturales, Universidad Nacional de La Pampa, Uruguay 151, 6300 Santa Rosa, La Pampa, Argentina, phone 54-954-33093, fax 54-954-33408.

June

June 19–21, **North American Rock Mechanics Symposium,** Montreal, Quebec, Canada. Information: Michel Aubertin, Conference Chair, École Polytechnique, Department of Mineral Engineering, C.P. 6079, Succ. Centre-ville, Montréal, Québec, Canada, (514) 340-4046, fax 514-340-4477. *(Abstract deadline: August 1, 1995.)*

September

September 16–19, **Deep Geological Disposal of Radioactive Waste Conference,** Winnipeg, Manitoba, Canada. Information: K. Nuttall, AECL Research, Pinawa, Manitoba, R0E 1L0, (204) 753-2311, fax 204-753-2455, E-mail: woronas@url.wl.aecl.ca.

October

October 28–31, **Geological Society of America Annual Meeting,** Denver, Colorado. Information: GSA Meetings Dept., P.O. Box 9140, Boulder, CO 80301, (303) 447-2020, fax 303-447-6028.

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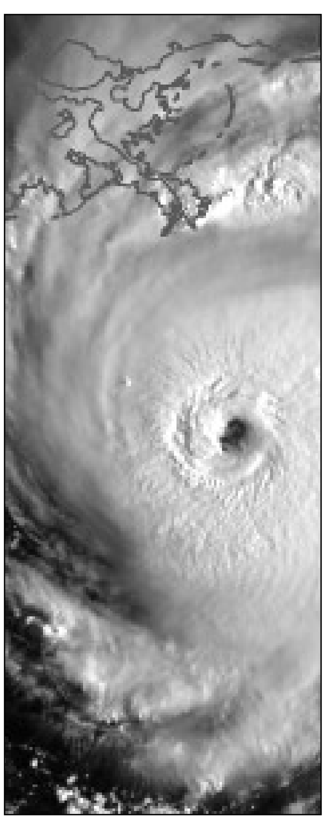

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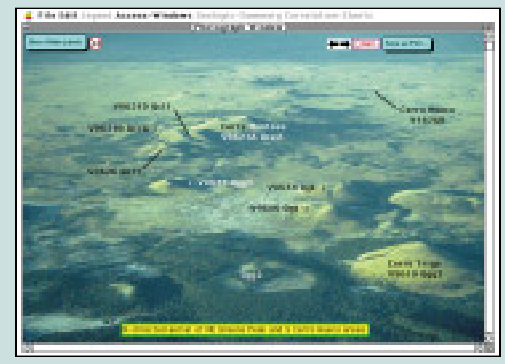
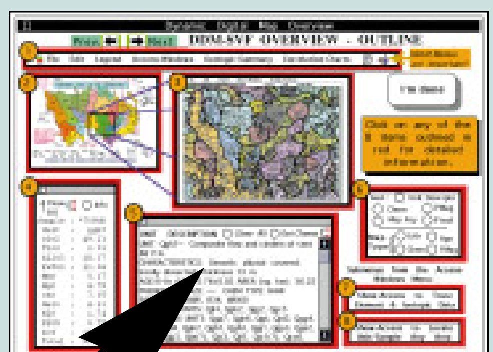


The CD-ROM map describes the geology of the Springerville volcanic field, Arizona, and includes 24 digital maps, 75 digital color photos, 23 correlation charts, and more than 1200 chemical and geophysical analyses, as well as text, figures, and tables. It also contains about 10 additional geological HyperCard stacks on such subjects as tsunamis, earthquakes, fossils, and the Northridge earthquake, all by Tau Rho Alpha.



Overview gives step-by-step instructions to the user about how the eight different major window types are activated. Maps can be printed out in color on desktop printers, or saved as separate files, and all data can be saved from the program to tab-delimited ASCII format. See the science article in the April 1995 issue of *GSA Today*.

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GSA Journals on CD is available for both DOS and Macintosh as follows:

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