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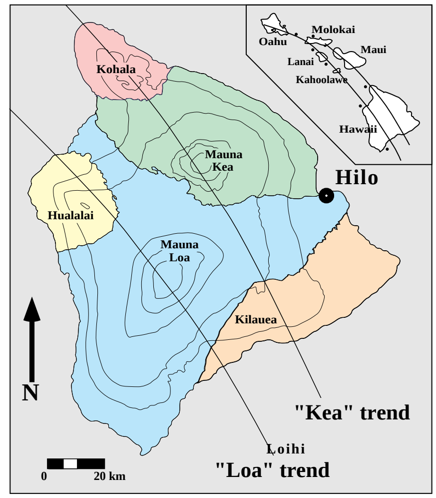
INSIDE

Hawaii Scientific Drilling Project: Summary of Preliminary Results

*Hawaii Scientific Drilling Project Team**



ABSTRACT

Petrological, geochemical, geomagnetic, and volcanological characterization of the recovered core from a 1056-m-deep well into the flank of the Mauna Kea volcano in Hilo, Hawaii, and downhole logging and fluid sampling have provided a unique view of the evolution and internal structure of a major oceanic volcano unavailable from surface exposures. Core recovery was ~90%, yielding a time series of fresh, subaerial lavas extending back to ~400 ka. Results of this 1993 project provide a basis for a more ambitious project to core drill a well 4.5 km deep in a nearby location with the goal of recovering an extended, high-density stratigraphic sequence of lavas.

INTRODUCTION

Intraplate or "hot-spot" volcanic island chains, exemplified by Hawaii, play an important role in plate-tectonic theory as reference points for absolute plate motions. The origin of hot spots, however, is not explained by the plate tectonic paradigm. The most widely held view is that hot-spot volcanoes represent magma generated by decompression melting of localized, buoyant upwellings in the mantle. These upwellings, or "plumes," are believed to originate at boundary layers in the mantle, and the cause of the buoyancy may be both compositional and thermal. Mantle plumes represent a secondary form of mantle convection and constitute an important mechanism for cycling mass from the deep

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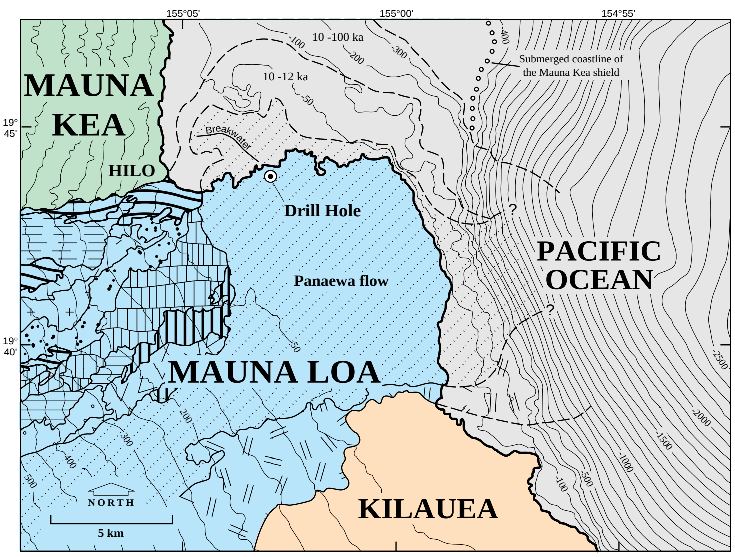

Figure 1. Top: The Hawaiian Islands (inset) and island of Hawaii showing volcanoes in the "Loa" and "Kea" trends and the location of the HSDP pilot hole at Hilo. Bottom: Geologic map of the Hilo vicinity showing location of the pilot hole. After Lipman and Moore (1996).

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mantle to Earth’s surface. Studies of the chemical and isotopic compositions of intraplate lavas, especially from ocean-island volcanoes, have contributed significantly to our knowledge of magma genesis and compositional heterogeneity in the mantle. Of particular importance is the identification of distinct compositional mantle end members, the origin and distribution of which provide insights into differentiation of the mantle-crust system, recycling of oceanic crust and continent-

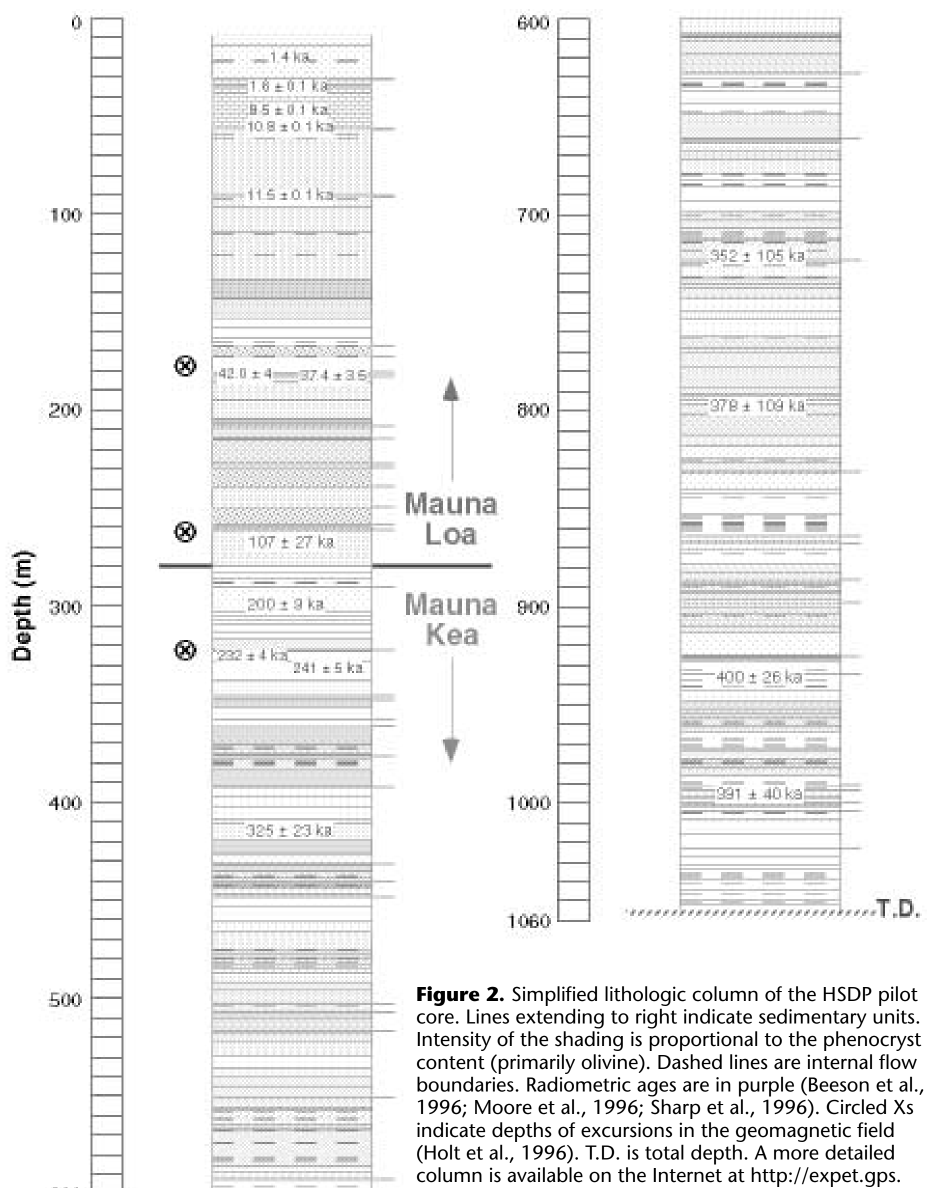


Figure 2. Simplified lithologic column of the HSDP pilot core. Lines extending to right indicate sedimentary units. Intensity of the shading is proportional to the phenocryst content (primarily olivine). Dashed lines are internal flow boundaries. Radiometric ages are in purple (Beeson et al., 1996; Moore et al., 1996; Sharp et al., 1996). Circled Xs indicate depths of excursions in the geomagnetic field (Holt et al., 1996). T.D. is total depth. A more detailed column is available on the Internet at http://expet.gps.caltech.edu/Hawaii_project.html.

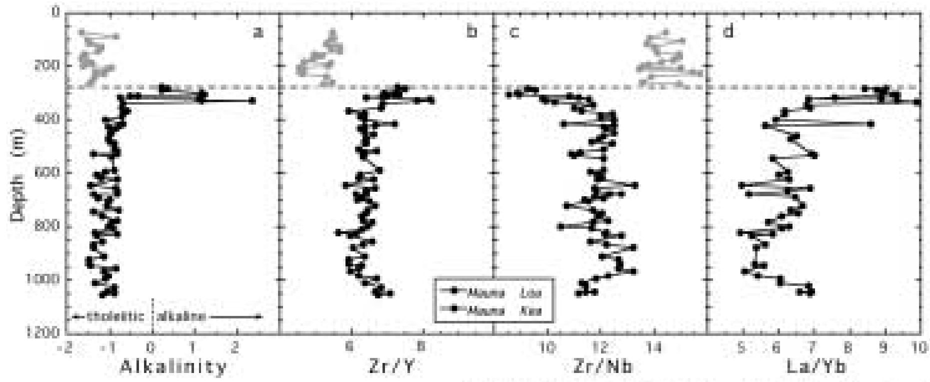
derived sediment into the mantle, and lithospheric history.

An intraplate oceanic volcano can be viewed as a probe, sampling magmas produced by melting of the plume as the oceanic plate carries the volcano over the plume and recording this output in stratigraphic succession in its lavas. Sampling and analysis of an extended part of such a succession of lava flows would provide critical information on mantle plume structure and origin. However, a limitation in the study of hot-spot volcanoes is that the major volume of each volcano is inaccessible because it is below sea level. Even for those parts of oceanic volcanoes above sea level, erosion typically exposes only a few hundred meters of buried lavas (out of a total thickness of 6–20 km). For example, although the Hawaiian-Emperor chain has been active for at least 70 m.y., all we can generally examine for any individual volcano is that small fraction (5%–10%) of its history for which evidence is now exposed subaerially. Thus, although the late stages of Hawaiian volcanoes can be studied and viewed as a time sequence, the evolution of a single volcano during its ~1 m.y. passage across the plume is almost entirely inaccessible. If sequences of lava flows from ocean-island volcanoes spanning sufficiently long time periods could be collected, they could be uniquely valuable as probes of plume structure and related magmatic processes. Continuous core drilling through a lava sequence on the flank of an oceanic volcano is probably the only way to obtain such a stratigraphic sequence.

Hawaii Scientific Drilling Project

In recognition of the opportunities afforded by drilling through the flank of an oceanic volcano, the Hawaii Scientific Drilling Project (HSDP) was conceived in the mid-1980s to core continuously to a depth of several kilometers in the flank of the Mauna Kea volcano (DePaolo et al., 1991). Hawaii is the natural target because it is the archetype of ocean-island volcanism.

Core drilling of the “pilot hole” in Hilo, Hawaii, was done by Tonto Drilling Services, Inc. (Salt Lake City, Utah) from October to December 1993. The following 18 months were devoted to petrological, geochemical, geomagnetic, and volcanological characterization of the recovered core and the downhole logging and fluid-sampling program. In addition to these primary scientific goals, the “pilot hole” served as a test bed for a more ambitious, several-kilometer-deep-core hole by demonstrating the technical feasibility of the drilling program and the ability of the multidisciplinary, international group of project scientists to work together effectively. The pilot hole was funded by the National Science Foundation Continental Dynamics Program.



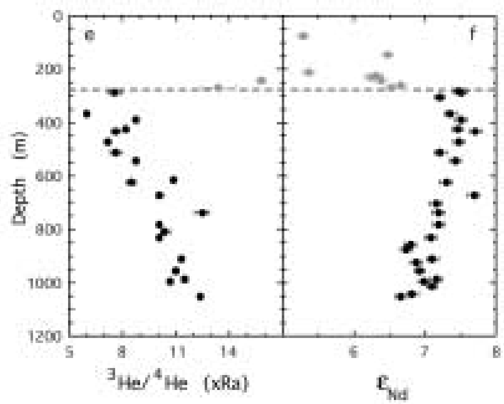


Figure 3. Chemical parameters vs. depth in HSDP core. Note boundary between Mauna Loa and Mauna Kea lavas. A: Alkalinity index distinguishing tholeiitic from alkalic lavas (Rhodes, 1996). B and C are from Rhodes (1996). Note that lower Zr/Nb and higher Zr/Y reflect lower degrees of mantle melting. In D (from Yang et al., 1996), a higher ratio indicates lower degrees of melting and more garnet in residue. In E and F (from Hauri et al., 1996; Kurz et al., 1996; Lassiter et al., 1996), the lack of change at the top of the Mauna Kea section suggests that the tholeiitic to alkaline transition involves changes in mantle melting conditions, not source composition.

The HSDP pilot hole drill site was near Hilo Bay on the ~1400-year-old Panaewa flow series from Mauna Loa volcano (Fig. 1). The site was chosen to (1) be far from volcanic rift zones to minimize chances of encountering intrusion, alteration, and high-temperature fluids; (2) be close to the coastline, to maximize the probability of encountering submarine flow units and relatively old lavas; and (3) drill through some Mauna Loa lavas before encountering Mauna Kea lavas, to test our ability to distinguish between lavas of different volcanoes. Other factors were related to permitting and avoiding disturbance of the community.

Drilling lasted 46 days, reaching a total depth of 1056 m at an average penetration rate of >20 m per day. The penetration rate during periods of drilling (excluding logging time, waiting for cement, etc.) was ~30 m per day. Core recovery for the hole averaged about 90%; major losses occurred in unconsolidated sediments not effectively captured by the core barrel and in rubble zones that jammed the core barrel.

DESCRIPTION OF THE STRATIGRAPHIC SECTION

Core logging led to the designation of the 227 units in the generalized lithologic section in Figure 2. Of these, 208 are lava flows; the rest are ash beds, marine and beach sediments, and soils. No intrusive units have been identified. The location of the contact between Mauna Loa and Mauna Kea lavas at a depth of 280 m is unambiguous. Evidence comes from: (1) abrupt changes in trace element and He, O, Sr, Pb, and Nd isotopic ratios (Fig. 3); (2) projection of the exposed slope of Mauna Kea to depth; (3) lava flows shallower than 280 m being interlayered with nearshore sediments and systematically thicker than those below, as expected for Mauna Loa lavas erupted as gently sloping lava deltas extending into Hilo Bay rather than for Mauna Kea lavas erupted on steep slopes well above sea level; (4) a significant soil horizon at the geochemically defined boundary; (5) intercalation of alkalic and tholeiitic lavas in the 50 m below the geochemically defined boundary, consistent with the end of shield building at Mauna Kea (Fig. 3); and (6) major element compositions of tholeiites above and below the contact being consistent with known differences between Mauna Loa and Mauna Kea lavas.

All sampled Mauna Kea lavas have been interpreted as subaerial, not submarine. The discovery of subaerial lavas more than 1 km below current sea level is not surprising, because Hawaii is subsiding at a rate of 2.0–2.5 mm/yr (Moore, 1987). At this rate, the minimum age of the lavas at the base of the core would be ~400 ka. Still unresolved is the nature and structure of the submarine part of the section (e.g., fragmental pillow vs. coherent lava flows vs. hyaloclastites deposited offshore as a prograding delta). This is potentially a technical as well as a scientific problem

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to be addressed by deeper drilling, as conditions may change in the submarine section.

An initial surprise was the importance of sediments in the Mauna Loa section. A thick (>25 m) succession of carbonate sediments rich in coral fragments was encountered immediately below the Panaewa flow. These are interpreted as Hilo Bay lagoonal deposits recording sea-level rise since 10 ka. Dating by ^{14}C and U/Th techniques provides constraints on subsidence of the drill site (by comparison with known sea-level curves) and on dates of the two most recent flows. Other sediments include volcaniclastic units, beach and dune sands, hyaloclastites, and a "bog" deposit. The "bog" deposit (believed to be related to the Pahala ash) is rich in organic carbon and has a ^{14}C age of ~40 ka. Assuming a roughly constant subsidence rate, ages of the sediments deposited at or near sea level can also be estimated from their depth in the core (Fig. 4). A sand layer interpreted as a wind-blown sediment occurs in the Mauna Kea section at a depth of 867 m. Throughout the core, weathered ash deposits are readily recognized as soils.

An important unknown before drilling was the extent of alteration at depth. A factor in choosing the Hilo site was the likely minimal interaction of the lavas with hydrothermal solutions due to distance from rift zones and evidence from water well studies. The possibility had been raised of local intrusions and hot-water flows associated with the nearby Halai Hills and the northeast rift of Mauna Loa. As a whole, the recovered samples are remarkably fresh lavas, although there is some alteration associated with weathering or eruption (e.g., thin iddingsite rims on olivines, oxidized groundmass, low K/P ratios in some lavas) and minor zeolite precipitation is observed in vesicles in the deepest part of the core. The key point is that geochemical and petrological studies have not been compromised by alteration and metasomatism.

Another uncertainty prior to drilling was how to date the core, because important insights into temporal variations in a volcano and connection to mantle processes depend on some fixed time points. The presence of dateable and ancient shoreline sediments in the Mauna Loa section (Fig. 4), giving information on the growth rate of the volcano at the drill site, was fortuitous. As expected, results from Ar-Ar and K-Ar dating of the lavas are mixed (Figs. 2 and 5). Alkalic lavas at the top of the Mauna Kea section have enough K for relatively precise dating. Low-K tholeiites deeper in the Mauna Kea section give less precise ages, but these ages are consistent with gradual slowing of volcano growth toward the end of shield

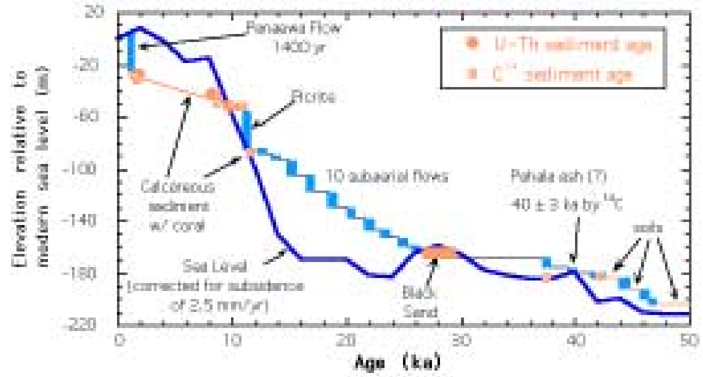

Figure 4. Measured and inferred depth-age relations for the first 200 m of the HSDP pilot hole core. The curve labeled Sea Level represents paleo–sea level in the core and was calculated by using a sea-level curve derived from benthic foraminifera $\delta^{18}O$ values and a subsidence rate of 2.5 mm/yr (Moore et al., 1996). Thick vertical bars indicate actual thicknesses of lava flows. Symbols indicate radiometric age determinations (Beeson et al., 1996; Moore et al., 1996). The only age tie point between 12 and 40 ka is a black sand unit assigned an age of 28 ka on the basis of inferred formation at sea level.

building and with the base of the core being >400 ka. Although the pilot hole did not reach the first major magnetic field reversal (Brunhes-Matuyama boundary at ~790 ka), several polarity excursions were "captured" in the shallower parts of the core. Correspondence of their ages to those of excursions found elsewhere in the world provides a consistency check on ages based on sediment subsidence and radiometric dating of the lavas and sediments.

SCIENTIFIC HIGHLIGHTS FROM THE HSDP PILOT PROJECT

The ultimate goal of the HSDP is a core of several kilometers in the Mauna Kea volcano that can provide information on volcanic evolution that is inaccessible from surface exposures. However, even with a depth of only ~1000 m, the pilot hole significantly extended our knowledge of the evolution of the Mauna Loa and Mauna Kea volcanoes and gave us an indication of the rich insights that can be expected from a deeper hole. The scientific value of the core reflects several factors: (1) The fresh and essentially continuous nature of the core yielded information unavailable from surface reconstructions and disproved some prior expectations. (2) Both the Mauna Loa and Mauna Kea sections in the core spanned gaps between the oldest known subaerially exposed lavas (except a few very old Mauna Loa subaerial lavas along fault scarps) and submarine lavas dredged from the volcano's submarine rifts and thus filled unsampled parts of these volcanoes' histories. (3) Perhaps most significantly, the integrated, multidisciplinary approach taken here yielded a more detailed view than had previously been achievable.

Temporal Evolution of the Petrology and Geochemistry of Mauna Kea and Mauna Loa Lavas

Subaerially exposed Mauna Kea lavas are divided into older (70–250 ka), tholeiitic to alkalic basaltic Hamakua Volcanics and younger (4–65 ka), evolved alkalic (hawaiites and mugearites) Laupahoehoe Volcanics (Wolfe et al., 1995). The only other previously sampled Mauna Kea lavas are submarine tholeiites with estimated ages of ~400 ka (Wolfe et al., 1995) dredged from the east rift of Mauna Kea (Frey et al., 1991; Garcia et al., 1989; Yang et al., 1994). Geochemical data place the HSDP Mauna Kea samples on a continuum between the younger Hamakua series and older submarine lavas. Dating puts them in the ~200 ka gap between these groups, making the HSDP pilot hole the longest continuous compositional record for any Hawaiian volcano.

What do we learn from this unprecedented continuous record of Mauna Kea volcanism? The conventional view has been that magmas over most of the history of a Hawaiian volcano are monotonous tholeiitic lavas with alkaline lavas erupting at the start and close of the volcano's life. Except at the very top of the Mauna Kea section (i.e., <~240 ka), the pilot hole samples are indeed tholeiites, but with significant long-term variations in radiogenic isotope and trace element ratios (Fig. 3). The isotopic variations must reflect changes in source characteristics. Major and trace element variations in the HSDP Mauna Kea tholeiites and the tholeiitic-to-alkalic transition series have been interpreted as a trend with decreasing age toward decreasing extents of melting from garnet-bearing residues at increasing depths of melt segregation (Fig. 3). The trend to decreasing degrees of melting is consistent with progressively decreasing magma fluxes and growth rate of the volcano at the end of shield building (Fig. 5). High-frequency fluctuations superimposed on the long-term compositional trends of the tholeiites provide information on sizes of source heterogeneities. Reversals in some overall isotopic trends and in the trend of decreasing melt fraction with age near the bottom of the core are not understood. All of these variations show that magma

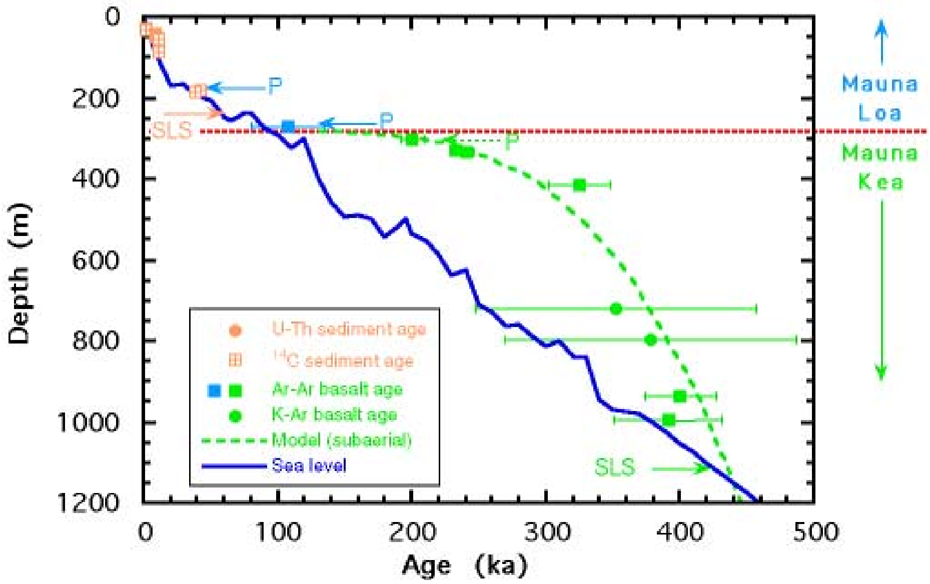

Figure 5. Summary of geochronology of the HSDP core based on radiometric dating (Beeson et al., 1996; Moore et al., 1996; Sharp et al., 1996), paleomagnetism (P) (Holt et al., 1996), and sea-level subsidence (SLS). Right-pointing arrows show minimum ages from the sea-level curve assuming a subsidence rate of 2.4 mm/yr. Left-pointing arrows indicate short magnetic polarity reversals with ages assigned from similar events elsewhere. Also shown are a calculated paleo–sea-level curve (assuming a subsidence rate of 2.5 mm/yr; Lipman and Moore, 1996) and a model depth-age curve for Mauna Kea (dashed-line curve; from DePaolo and Stolper, 1996). The endpoint of the model Mauna Kea curve is set arbitrarily to an age of 130 ka. The Hilo site reached maximum elevation near the end of the tholeiitic part of the shield-building stage (~330 ka). Elevation increased rapidly between 420 and 330 ka as lava accumulation (about 6–7 mm/yr) outpaced subsidence. After 330 ka, lava accumulation was slower than subsidence, and elevation gradually decreased to sea level. Since about 100 ka, Mauna Loa lava accumulation has kept pace with subsidence, and the site has remained close to sea level.

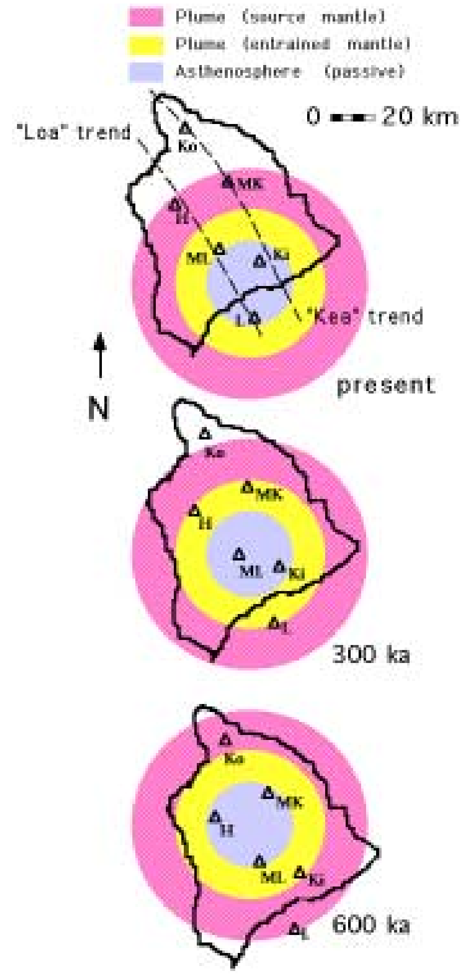

Figure 6. Schematic diagram illustrating northwestward movement (8.6 cm/yr; Clague and Dalrymple, 1987) of Hawaii over a concentrically zoned mantle plume (Hauri et al., 1994, 1996; Lassiter et al., 1996). The plume is envisioned to be heterogeneous due to entrainment of ambient mantle during lower mantle upwelling. Translation of the Pacific plate over the plume leads to progressive sampling of zones. Top: the zero age (i.e., current) configuration—nearly dormant Mauna Kea (MK) is northwest of the plume center, overlying "normal" asthenospheric upper mantle; ML is Mauna Loa, L is Loihi, Ko is Kohala, and Ki is Kilauea. Center: 300 ka (near the middle of the MK section in the HSDP pilot hole)—MK was over the zone of the plume dominated by entrained (lower?) mantle material; Bottom: 600 ka—MK is projected to have been over the central zone of the plume.

sources and genesis were changing as far back as 200 ka in the shield-building phase of Mauna Kea.

Although not as long as the Mauna Kea section, the Mauna Loa section (1.4 to ~100 ka) also fills the temporal gap between exposed subaerial flows and fault scarp and submarine tholeiitic flows thought to be older than 100 ka. As with the Mauna Kea section, chemical and isotopic compositions (Fig. 3) are variable, confirming recent reports of a wider chemical range in Mauna Loa tholeiites than generally appreciated (Garcia et al., 1995; Hauri and Kurz, 1996; Kurz and Kammer, 1991; Kurz et al., 1995; Rhodes and Hart, 1995). For example, variations in incompatible trace element ratios from the base of the section at ~280 m to a core depth of ~200–250 m (corresponding to an age of ~50–80 ka) indicate increasing degrees of melting. An intriguing observation is that like submarine lavas from rift zones in Hawaii (Clague et al., 1995; Garcia et al., 1989, 1995) and in contrast to typical subaerial Hawaiian lavas, picritic lavas (i.e., rich in olivine) are the rule in the core. This could be a local phenomenon due to the hole being low on the volcano flank or a more general phenomenon reflecting high-temperature picritic parental magmas (Clague et al., 1991) and their processing in high-level magma chambers (Garcia et al., 1995; Rhodes, 1995). A final observation is that although the growth rate of Mauna Loa is variable on a 10^4 scale, on a longer time scale magmatic growth appears to be in approximate balance with island subsidence. The observation that Mauna Loa is no longer growing vigorously or even maintaining its size above sea level is consistent with other indications that it is in or nearing its postshield stage.

Mantle Reservoirs and Inferred Plume Structure

Another objective of the HSDP is to obtain an isotopic time series from Mauna Kea lavas. The goal is to set constraints on the nature and temporal variations of the mantle sources of plume lavas in order to deduce the chemical and perhaps physical structure of the intraplate plume source. Previous work on Hawaiian volcanoes has identified several isotopically distinct mantle sources (Chen, 1987; Chen et al., 1991; Stille et al., 1986; Tatsumoto, 1978; West et al., 1987) and has shown that proportions of mantle components change in the postshield and posterosional phases of some volcanoes. These variations are thought to indicate changes in the interaction between the plume and its surroundings. Persistent chemical and isotopic differences between "Loa" trend volcanoes (Loihi, Mauna Loa, Hualalai, etc.) and "Kea" trend volcanoes (Kilauea, Mauna Kea, Kohala, etc.) have also been used to infer plume structure and evolution (Ihinger, 1995; Tatsumoto, 1978).

Isotopic variations in the HSDP tholeiites (Fig. 3) demonstrate long-term changes in source characteristics that precede the prominent change to more alkaline lavas and the decrease in magma flux at the very end of shield building. Pilot project results have been interpreted in terms of a concentrically zoned plume (Fig. 6), in which long-term variability reflects northwestward motion of the vol-

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cano on the Pacific plate over the plume. The concentric plume is envisioned as having a core of material from a deep boundary layer, a ring of entrained lower mantle material, and an outer zone of upper mantle material. With time, the volcano moves over these concentric zones, sampling them in turn. This interpretation can account for long-term differences between "Kea" and "Loa" trend volcanoes, because these volcanoes can be in different positions relative to the concentric zones (see Fig. 6). The shape of the postulated concentric plume is poorly constrained, but this interpretation predicts that as drilling proceeds deeper into the Mauna Kea section, the nature of the sources should change toward the characteristics of the deep plume source in the center of the plume, and that deeper still, the ring of entrained material should again dominate. Although non-unique (alternatives include the "plumelet" hypothesis of Ihinger [1995], a role for the underlying oceanic crust [Eiler et al., 1996], and vertical heterogeneity or shorter length scale heterogeneities [DePaolo, 1996]), this view provides a framework for connecting plume structure and observables in Hawaiian lavas. The old view that the tholeiitic, shield-building phase of a Hawaiian volcano is monotonous and unchanging and that significant variability is confined to the beginning and end of the volcanic life cyle is clearly incorrect.

Growth Rates of Volcanoes

Little is known about the duration of shield building of Hawaiian volcanoes, yet such knowledge is critical for understanding why and how the volcanoes form and are fed. Key observations are that the summits of Hawaiian volcanoes are typically spaced 50 ± 10 km from each other and that Pacific plate velocity is ~10 cm/yr. Some investigators have suggested that the shield-building stages of individual volcanoes are nonoverlapping and that the main phase of growth is ~500 ka (e.g., Moore and Clague, 1992). Others have suggested that the volcanoes overlap significantly and that their active lifetimes could be >1000 ka (e.g., Lipman, 1995; Moore, 1987). The latter is a good reference number, because at a plate velocity of 10 cm/yr, it takes 1000 ka for a volcano summit to traverse a plume of 50 km radius. The pilot hole provides information on the vertical growth rate of Mauna Kea over several hundred thousand years, putting valuable constraints on the time scale of activity.

The expected age vs. depth relation of an idealized Hawaiian volcano has been modeled given simple assumptions about the geometry and subsidence rate of the volcano and about the relation between magma supply and the position of the volcano over the plume. As shown by the dashed curve in Figure 5, this model, which suggests a lifetime for shield building of ~700–800 ka for Mauna Kea, yields an excellent match to actual depth vs. age data for the Mauna Kea pilot hole section. The model also matches constraints on Mauna Kea's volume, thickness, pre-alkalic summit elevation, and lava accumulation rates. The key point here is that the temporal variability of these parameters is potentially obtainable from an extended time series from a single volcano.

In Figure 5, subaerial lavas plot above the sea-level curve, submarine lava flows plot below it, and sediments and lavas emplaced at sea level plot on it. As expected, on the basis of the discussion above, Mauna Loa points roughly follow the sea-level curve. Mauna Kea lavas are all subaerial, consistent with the core site elevation reaching a maximum of ~400 m above sea level at ~330 ka. According to this analysis, Mauna Kea's subaerial-submarine transition would have been encountered if the pilot core had gone a few tens of meters deeper.

A growth rate of 2–3 mm/yr and a magma flux of 0.02–0.03 km^3/yr can be derived for the part of Mauna Loa history sampled by the pilot core. These values, results from the Ninole Hills and Kealakekua fault, and results from the Mauna Kea part of the HSDP core suggest that Mauna Kea was at the same stage of evolution from about 400 to 300 ka as Mauna Loa has been from 100 ka to the present. The inferred 300 ka age difference between Mauna Kea and Mauna Loa is consistent with a 10 cm/yr plate velocity and the fact that Mauna Loa is 30 km farther down the plume trace than is Mauna Kea (Fig. 6).

Geomagnetic Results

The HSDP core provides the longest continuous volcanic record of geomagnetic field behavior yet available. These data provide an important complement to records obtained from deep-sea sediments in which field directions are averaged over a few thousand years and may suffer from variable amounts of compaction-induced inclination shallowing. Although the HSDP core is azimuthally unoriented, the high-quality "snapshots" of geomagnetic field intensity and inclination at Hawaii over the past 400 ka have yielded new insights into the global extent of polarity excursions, the relation of excursions to secular variation, the strength of the nondipole field in the central Pacific, and long-term secular variation. The paleointensity signal is still preliminary, but there are patterns that suggest correlations to relative paleointensity records from deep-sea sediments. The inclination record provides evidence for three polarity excursions in the central Pacific. Age constraints

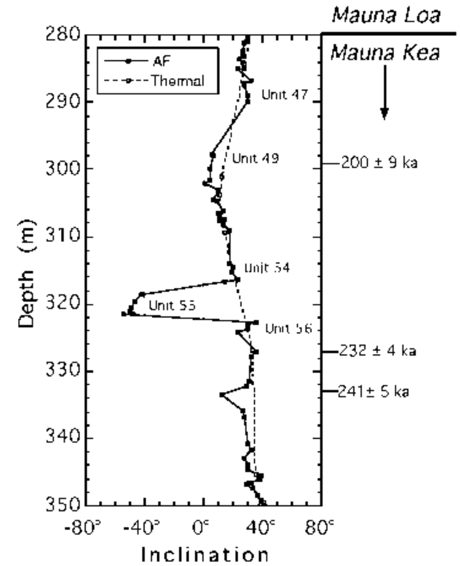

Figure 7. Geomagnetic inclination record for the top (i.e., 280-350 m depth interval) of the Mauna Kea section of the HSDP pilot core (Holt et al., 1996). Unit 55 shows an excursion to reversed inclination; on the basis of Ar-Ar dates (to right, from Sharp et al., 1996) this excursion is correlated with the Jamaica–Pringle Falls events at 200–220 ka.

from radiometric dating (Fig. 7) enable correlation with excursions elsewhere, supporting the hypothesis that excursions are global events, not localized perturbations of the geomagnetic field. In addition, two of these polarity jumps appear to interrupt briefly long-term changes in inclination (e.g., Fig. 7); i.e., whatever the cause, the field pops back into its long-term state with a considerable "memory." This suggests that excursions are not merely extreme cases of secular variation, but may result from an independent geodynamo process. Another question that can be addressed with these data is whether the currently weak nondipole field in the central Pacific region extends back through the Brunhes Normal Chron. Comparison of the amplitude of secular variation averaged over the past 400 ka at Hawaii (and hence the strength of the nondipole field) with global paleomagnetic data compilations for the same latitude suggests that the currently weak nondipole field in the central Pacific is not characteristic of most of the time period sampled by the HSDP core. Perhaps the most intriguing result from the HSDP core is the discovery of secular variation periodicities greater than 10 ka. This is considerably longer than typical estimates and has potential implications for geodynamo theory.

Downhole Geophysics

Downhole temperature logs show complex profiles (Fig. 8), with several excursions superimposed on a generally negative temperature gradient with depth.

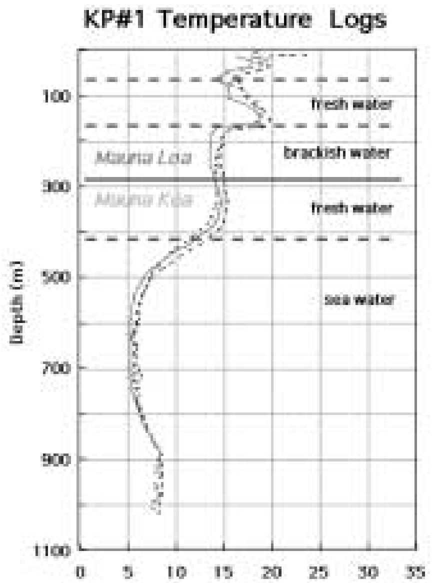

Figure 8. Three downhole temperature logs from an HSDP pilot hole taken between December 1993 (just after completion of drilling) and May 1995 (Thomas et al., 1996). Note the overall decrease in temperature with increasing depth, which contributed to the unaltered nature of the core. Ground-water zones (two freshwater, two saline) were identified by chemical and isotopic analysis of water samples and downhole logging (Paillet and Thomas, 1996; Thomas et al., 1996). The freshwater zone underlying the Mauna Loa–Mauna Kea boundary appears to be derived from high on the slopes of Mauna Kea. The deeper sea-water zone appears to be derived from direct, horizontal input from the ocean and is little changed by interaction with the volcanic pile.

The minimum temperature is about 5° C at a depth of 600 m. The similarity of the temperatures in the core hole to the ocean thermocline confirms the absence of hydrothermal activity and demonstrates the efficiency of ocean water circulation through rock units beneath the drill site. Temperature excursions at shallower depths (e.g., 70 m and 350 m; Fig. 8) suggest that water from several sources is passing through a series of vertically isolated subsurface aquifers underlying this site.

Borehole televiewer analysis of the strike and dip of downhole fractures indicates that the distribution of fracture orientations has changed with time. Because most of the fractures are inferred to be associated with tensional cracking during cooling of the lava flows, the observed change in orientations is interpreted as reflecting the evolution of surface slope angles during the growth of the Mauna Kea and Mauna Loa shields.

Ground-water Hydrology

Hydrological and water chemistry studies on the well after completion of drilling show a complex hydrological system beneath this site. Pumping drawdown and tidal flux measurements in the well prior to perforation show that compaction has not substantially changed aquifer permeability of deep (>700 m) units. These deep units contain relatively young saline water (~3.6–5.6 ka) only minimally changed in chemical composition from sea water by interaction with the basalts. The young age of this cool water demonstrates rapid circulation of sea water through the volcano at depths of ~1 km even in the absence of hydrothermal temperatures. Fluid at ~325 m is fresh water that the induction logs indicate is a thick zone with saline water above and below (Fig. 8). Its location below the soil layer at the Mauna Loa–Mauna Kea contact suggests that this is fresh recharge from Mauna Kea flowing beneath a barrier formed by this soil. Isotopic analysis of this water shows that it was derived from an average elevation of ~1800 m and has a maximum age of ~2.8 ka. This fresh water may be channeled beneath the overlying sea water–saturated Mauna Loa basalts and ultimately discharged by deep offshore submarine springs. There is also evidence for fresh water in a second, shallower zone in the Mauna Loa section (Fig. 8). The picture that emerges at the HSDP site of alternating intervals of fresh and salt water saturation in the nearshore environment and of freshwater transport beneath saline water contrasts with widely applied models of Hawaii's hydrology, which have changed little since they were introduced by Stearns and Macdonald (1946).

PROSPECTS FOR DEEPER SCIENTIFIC DRILLING IN HAWAII

The results of the ~1 km HSDP pilot project demonstrate that important issues in mantle geochemistry and geodynamics, volcanology, and paleomagnetism can be addressed in a unique and powerful way by drilling in Hawaii. Many of these issues cannot be adequately addressed in the absence of drilling. The experience from the 1993 HSDP pilot hole provides a solid basis for planning and implementing a more ambitious deeper drilling project in Hawaii. As an outgrowth of the pilot program, the National Science Foundation Continental Dynamics Program has recently recommended funding a program to extend the HSDP to greater depth. The current plan is to: (1) drill continuously ~4.5 km into the flank of the Mauna Kea volcano in the vicinity of Hilo; (2) perform a suite of downhole logs and experiments to characterize the hole; and (3) describe and analyze the recovered samples with a wide array of techniques. Extrapolation of pilot project results suggests that the age at the base of the proposed core will be 650 ± 100 ka. As with the pilot project, the major focus will be to recover and characterize a continuous sequence of samples that when properly logged and curated will serve as a valuable resource for future generations.

The drilling and scientific plans as currently envisioned consist of several phases. The site selection phase has already begun by evaluating several sites in the vicinity of Hilo. The tentative drilling program consists of three phases of continuous wire-line coring with target depths for Phase I of ~1700 m, Phase II of ~3400 m, and Phase III of ~4500 m. Each phase is expected to span two years, with about 6 months devoted to drilling and coring and the rest spent on downhole research and analyses of samples. The downhole logging program will be conducted at intervals through each drilling phase. After setting and cementing of the casing in the hole at the end of each phase, vertical seismic profile surveys will be conducted. This will be followed by perforation of the casing and sampling and analysis of fluids, as well as hydrologic analyses of the units. The syn- and postdrilling analytical program for each stage will be modeled after that in the pilot hole project, and will consist of modern geochemical, petrological, geochronological, and geomagnetic characterization of the recovered core. Core characterization will provide the basis for addressing issues in mantle structure and processes, volcano structure and evolution, and detailed tracking of the magnetic field, and it will guide future investigators in their use of this unique record of the history of a major oceanic volcano.

REFERENCES CITED

Beeson, M. H., Clague, D. A., and Lockwood, J. P., 1996, Origin and depositional environment of clastic deposits in the Hilo drill hole, Hawaii: Journal of Geophysical Research, v. 101, p. 11,617–11,629.

Chen, C.-Y., 1987, Lead isotope constraints on the origin of Hawaiian basalts: Nature, v. 327, p. 49–52.

Chen, C.-Y., Frey, F. A., Garcia, M. O., and Dalrymple, B., 1991, The tholeiite to alkalic basalt transition at Haleakala volcano, Maui, Hawaii: Petrogenetic interpretations based on major and trace element and isotope geochemistry: Contributions to Mineralogy and Petrology, v. 106, p. 183–200.

Clague, D. A., and Dalrymple, G. B., 1987, The Hawaiian-Emperor volcanic chain, part I, geologic evolution: U.S. Geological Survey Professional Paper 1350, p. 5–54.

Clague, D. A., Weber, W. S., and Dixon, J. E., 1991, Picritic glasses from Hawaii: Nature, v. 353, p. 553–556.

Clague, D. A., Moore, J. G., Dixon, J. E., and Freisen, W. B., 1995, Petrology of submarine lavas from Kilauea's Puna ridge, Hawaii: Journal of Petrology, v. 36, p. 299–349.

DePaolo, D. J., 1996, High frequency isotopic variations in the Mauna Kea tholeiitic basalt sequence: Melt zone dispersivity and chromatography: Journal of Geophysical Research, v. 101, p. 11,855–11,864.

DePaolo, D. J., and Stolper, E. M., 1996, Models of Hawaiian volcano growth and plume structure: Implications of results from the Hawaii Scientific Drilling Project: Journal of Geophysical Research, v. 101, p. 11,643-11,654.

DePaolo, D. J., Stolper, E. M., and Thomas, D. M., 1991, Physics and chemistry of mantle plumes: Eos (American Geophysical Union Transactions), v. 72, p. 236–237.

Hawaii *continued on p. 8*

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Eiler, J. M., Valley, J. W., and Stolper, E. M., 1996, Oxygen isotope ratios in olivine from the Hawaii Scientific Drilling Project: Journal of Geophysical Research, v. 101, p. 11,807–11,813.

Frey, F. A., Garcia, M. O., Wise, W. S., Kennedy, A., Gurriet, P., and Albarède, F., 1991, The evolution of Mauna Kea volcano, Hawaii: Petrogenesis of tholeiitic and alkalic basalts: Journal of Geophysical Research, v. 96, p. 14,347–14,375.

Garcia, M. O., Muenow, D., and Aggrey, K. E., 1989, Major element, volatile, and stable isotopic geochemistry of Hawaiian submarine tholeiitic glasses: Journal of Geophysical Research, v. 94, p. 10,525–10,538.

Garcia, M. O., Hulsebosch, T., and Rhodes, J. M., 1995, Olivine-rich submarine basalts from the southwest rift zone of Mauna Loa volcano: Implications for magmatic processes and geochemical evolution, *in* Rhodes, J. M., and Lockwood, J. P., eds., Mauna Loa revealed: Structure, composition, history, and hazards: American Geophysical Union Monograph 92, p. 219–239.

Hauri, E. H., and Kurz, M. D., 1996, Tracing magma migration beneath Hawaii: An osmium isotopic time series from Mauna Loa: Earth and Planetary Science Letters (in press).

Hauri, E. H., Whitehead, J. A., and Hart, S. R., 1994, Fluid dynamic and geochemical aspects of entrainment in mantle plumes: Journal of Geophysical Research, v. 99, p. 24,275–24,300.

Hauri, E. H., Lassiter, J. C., and DePaolo, D. J., 1996, Osmium isotope systematics of drilled lavas from Mauna Loa, Hawaii: Journal of Geophysical Research, v. 101, p. 11,793–11,806.

Holt, J. W., Kirschvink, J. L., and Garnier, F., 1996, Geomagnetic field inclinations for the past 400 kyr from the 1-km core of the Hawaii Scientific Drilling Project: Journal of Geophysical Research, v. 101, p. 11,655–11,663.

Ihinger, P. D., 1995, Mantle flow beneath the Pacific plate: Evidence from seamount segments in the Hawaiian-Emperor chain: American Journal of Science, v. 295, p. 1035–1057.

Kurz, M. D., and Kammer, D. P., 1991, Isotopic evolution of Mauna Loa volcano: Earth and Planetary Science Letters, v. 103, p. 257–269.

Kurz, M. D., Kenna, T. C., Kammer, D. P., Rhodes, J. M., and Garcia, M. O., 1995, Isotopic evolution of Mauna Loa volcano: A view from the submarine southwest rift, *in* Rhodes, J. M., and Lockwood, J. P., eds., Mauna Loa revealed: Structure, composition, history, and hazards: American Geophysical Union Monograph 92, p. 289–306.

Kurz, M. D., Kenna, T. C., Lassiter, J. C., and DePaolo, D. J., 1996, Helium isotopic evolution of Mauna Kea volcano: First results from the 1-km drill core: Journal of Geophysical Research, v. 101, p. 11,781–11,791.

Lassiter, J. C., DePaolo, D. J., and Tatsumoto, M., 1996, Isotopic evolution of Mauna Kea volcano: Results from the initial phase of the Hawaii Scientific Drilling Project: Journal of Geophysical Research, v. 101, p. 11,769–11,780.

Lipman, P. W., 1995, Declining growth of Mauna Loa during the last 100,000 years: Rates of lava accumulation vs. gravitational subsidence, *in* Rhodes, J. M., and Lockwood, J. P., eds., Mauna Loa revealed: Structure, composition, history, and hazards: American Geophysical Union Monograph 92, p. 45–80.

Lipman, P. W., and Moore, J. G., 1996, Mauna Loa lava accumulation rates at the Hilo drill site: Formation of lava deltas during a period of declining overall volcanic growth: Journal of Geophysical Research, v. 101, p. 11,631–11,641.

Moore, J. G., 1987, Subsidence of the Hawaiian Ridge: U.S. Geological Survey Professional Paper 1350, p. 85–100.

Moore, J. G., and Clague, D. A., 1992, Volcano growth and evolution of the island of Hawaii: Geological Society of America Bulletin, v. 104, p. 1471–1484.

Moore, J. G., Ingram, B. L., Ludwig, K. R., and Clague, D. A., 1996, Coral ages and island subsidence, Hilo drill hole: Journal of Geophysical Research, v. 101, p. 11,599–11,605.

Paillet, F., and Thomas, D., 1996, Hydrogeology of the Hawaii Scientific Drilling Project borehole KP-1: 1. Hydraulic conditions adjacent to the well bore: Journal of Geophysical Research, v. 101, p. 11,675–11,682.

Rhodes, J. M., 1995, The 1852 and 1868 Mauna Loa picrite eruptions: Clues to parental magma compositions and the magmatic plumbing system, *in* Rhodes, J. M., and Lockwood, J. P., eds., Mauna Loa revealed: Structure, composition, history, and hazards: American Geophysical Union Monograph 92, p. 241–262.

Rhodes, J. M., 1996, Geochemical stratigraphy of lava flows sampled by the Hawaii Scientific Drilling Project: Journal of Geophysical Research, v. 101, p. 11,729–11,746.

Rhodes, J. M., and Hart, S. R., 1995, Episodic trace element and isotopic variations in historical Mauna Loa lavas: Implications for magma and plume dynamics, *in* Rhodes, J. M., and Lockwood, J. P., eds., Mauna Loa revealed: Structure, composition, history, and hazards: American Geophysical Union Monograph 92, p. 263–288.

Sharp, W. D., Turrin, B. D., Renne, P. R., and Lanphere, M. A., 1996, The $^{40}Ar/^{39}Ar$ and K/Ar dating of lavas from the Hilo 1-km core hole, Hawaii Scientific Drilling Project: Journal of Geophysical Research, v. 101, p. 11,607–11,616.

Stearns, H. T., and Macdonald, G. A., 1946, Geology and ground–water resources of the Island of Hawaii: Territory of Hawaii Division of Hydrography, Bulletin 7, 344 p.

Stille, P., Unruh, D. M., and Tatsumoto, M., 1986, Pb, Sr, Nd, and Hf isotopic constraints on the origin of Hawaiian basalts and evidence for a unique mantle source: Geochimica et Cosmochimica Acta, v. 50, p. 2303–2319.

Tatsumoto, M., 1978, Isotopic composition of lead in oceanic basalt and its implications to mantle evolution: Earth and Planetary Science Letters, v. 38, p. 63–87.

Thomas, D., Paillet, F., and Conrad, M., 1996, Hydrogeology of the Hawaii Scientific Drilling Project borehole KP-1: 2. Groundwater geochemistry and regional flow patterns: Journal of Geophysical Research, v. 101, p. 11,683–11,694.

West, H. B., Gerlach, D. C., Leeman, W. P., and Garcia, M. O., 1987, Isotopic constraints on the origin of Hawaiian lavas from the Maui volcanic complex, Hawaii: Nature, v. 330, p. 216–220.

Wolfe, E. W., Wise, W. S., and Dalrymple, G. B., 1995, Geology and petrology of Mauna Kea volcano, Hawaii: A study of postshield volcanism: U.S. Geological Survey Professional Paper 1557.

Yang, H.-J., Frey, F. A., Garcia, M. O., and Clague, D. A., 1994, Submarine lavas from Mauna Kea volcano, Hawaii: Implications for Hawaiian shield-stage processes: Journal of Geophysical Research, v. 99, p. 15,577–15,594.

Yang, H.-J., Frey, F. A., Rhodes, J. M., and Garcia, M. O., 1996, Evolution of Mauna Kea volcano: Inferences from lava compositions recovered in the Hawaii Scientific Drilling Project: Journal of Geophysical Research, v. 101, p. 11,747–11,767.

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WASHINGTON REPORT

Bruce F. Molnia

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

Science and Technology and the Future of Cities

The fact is that science and technology have a crucial role and responsibility in providing solutions and in ensuring the long-term sustainability of cities.

— Nobel laureate F. Sherwood Rowland, Foreign Secretary to the U.S. National Academy of Sciences

Neither the pace of scientific research nor its transfer into practical application has kept up with the rapidity of urban growth, especially in developing countries.

— P. N. Tandon, former president of the Indian National Science Academy

Information released by the National Academy of Sciences (NAS) describes that on May 31, in Istanbul, Turkey, 72 of the world's academies of sciences issued a statement urging world leaders to raise to a higher priority the role of science and technology in solving urban problems. A related statement issued by 14 engineering academies also underscores the role that the world's engineering community should play in helping to resolve the seemingly inherent conflicts that surround the simultaneous pursuit of economic advancement and environmentally sustainable development. On June 6, both statements were officially transmitted to delegates of the United Nations Conference on Human Settlements, for their consideration. "The potential for science and technology to ameliorate or

Cities *continued on p. 9*

Cities *continued from p. 8*

solve the problems of the world's multiplying cities has not been realized," the science academies said. "A much broader discussion is needed on how the range of existing technological and scientific research findings can be translated into actions at the national, regional, and local levels." "Science and technology can produce widespread benefit for future generations only if there is a coordinated effort among scientific researchers, urban planners, and political leaders," the statement says.

The statement comes in response to concern among the world's science academies that science and technology issues were being ignored at the U.N. conference. The results of the conference likely will serve as a basis for future U.N. policy on urban development and a guide for world leaders in their efforts to deal with the problems of "megacities." Rowland stated that the concept of having education and training in place to ensure that scientific capacity continues to grow was missing from the U.N. document.

By the middle of the next century, most of the world's population will be living in cities. Urban growth—68 million a year—presents massive challenges for urban infrastructure and services. At the same time, urban growth has fueled the economic growth of countries and has contributed to lower birth rates. Cities throughout the world suffer from a host of problems, though, including traffic congestion, pollution, insufficient water supplies, wasteful use of energy, waste-disposal problems, inadequate housing, the spread of communicable diseases, and the deterioration of social support systems.

The statement identifies five technologies in which new discoveries in science and technology have the potential to help solve some of the problems facing "megacities," defined as urban areas with populations of 8 million or more. These are: (1) global positioning systems (GPS) and global information systems (GIS)—advances in GPS now permit entirely new methods of land management and tracking. These technologies, as part of the rapidly expanding GIS, can manipulate geographic, demographic, and other data, to serve as the basis for computer-assisted and, ultimately, computer-controlled transportation systems; (2) biotechnology and ecological engineering—advances in biotechnology and ecological engineering promise wiser use of local environments. For example, city parks carefully designed with certain types of plants may help reduce human exposures to air pollution from motor vehicles; (3) disease surveillance and control—rapid population growth in urban areas has contributed to the resurgence of some infectious diseases. Disease surveillance, through global computer systems and other technologies, could help considerably to contain outbreaks that otherwise may turn into epidemics. In addition, more emphasis on drug and vaccine development is essential for preventing and fighting infectious disease; (4) computational capability—vast improvements in computers over the past two decades give scientists a better understanding of Earth's atmosphere and climates. Computer capability exists, too, to model the microclimates of individual buildings, but the technology has rarely been applied, despite its obvious usefulness for reducing energy consumption and improving indoor air quality; (5) waste disposal and recycling—technologies developed to dispose of and recycle waste have yet to be put to extensive use globally. A cohesive plan for sustainable waste management in cities should include techniques to reduce waste generation; re-use and recycling; proper use of incineration and landfills; and innovative biological waste management processes.

Urban planning must become "a new priority discipline in which expertise is developed locally and shared more broadly," the science academies said. Political leaders, city managers, and planning experts must work with scientists and one another, and special attention must be paid to education and training. Universal basic literacy and education, with a foundation in "up-to-date scientific knowledge" is essential, the statement says.

The statement also underscores the importance of multinational cooperation. Governments and international agencies should support the scientific community in its efforts to develop collaborative research programs. "While some of these activities can be performed within current budgetary allocations, additional resources will often be necessary," the academies noted.

The statement was coordinated by the U.S. National Academy of Sciences and developed under the auspices of an Inter-Academy Panel on International Issues. The panel was created in 1995 to act as a forum through which national academies of science worldwide work together to advise governments and international organizations and to inform public opinion on scientific aspects of international issues. Science academies that signed the statement are: African Academy of Sciences; Albanian Academy of Sciences; Argentina National Academy of Exact, Physical, and Natural Sciences; National Academy of Sciences of Armenia; Federation of Asian Scientific Academies and Societies; Australian Academy of Science; Austrian Academy of Sciences; Academy of Sciences of Belarus; Royal Academy of Sciences, Letters, and Fine Arts of Belgium; National Academy of Sciences of Bolivia; Academy of Sciences and Arts in Bosnia and Herzegovina; Brazilian Academy of Sciences; Bulgarian Academy of Sciences; Royal Society of Canada; Caribbean Academy of Sciences; Chinese Academy of Sciences; Colombian Academy of Exact, Physical, and Natural Sciences; Croatian Academy of Sciences and Arts; Cuban Academy of Sciences; Academy of Sciences of the Czech Republic; Royal Danish Academy of Sciences and Letters; Academy of Scientific Research and Technology of Egypt; Estonian Academy of Sciences; Delegation of Finnish Academies of Science and Letters; French Academy of Sciences; Georgian Academy of Science; Conference of the German Academies of Sciences and Humanities; Ghana Academy of Arts and Sciences; Academy of Athens; Guatemalan Academy of Medical, Physical, and Natural Sciences; Hungarian Academy of Sciences; Indian National Science Academy; Islamic Republic of Iran Academy of Sciences; Royal Irish Academy; Israel Academy of Sciences and Humanities; Royal Scientific Society of Jordan; National Academy of Sciences of the Republic of Kazakhstan; Kenya National Academy of Sciences; National Academy of Sciences of the Republic of Korea; Latin American Academy of Sciences; Latvian Academy of Sciences; Lithuanian Academy of Sciences; Malaysian Academy of Sciences; Mexican Academy of Scientific Research; Academy of Sciences of Moldova; Mongolian Academy of Sciences; Royal Nepal Academy of Science and Technology; Royal Netherlands Academy of Arts and Sciences; Royal Society of New Zealand; Nigerian Academy of Science; Norwegian Academy of Science and Letters; Pakistan Academy of Sciences; National Academy of Science and Technology of the Philippines; Polish Academy of Sciences; Romanian Academy; Russian Academy of Sciences; Singapore National Academy of Science; Slovak Academy of Sciences; Slovenian Academy of Sciences and Arts; Academy of Sciences of South Africa; Royal Academy of Exact, Physical, and Natural Sciences of Spain; National Academy of Sciences of Sri Lanka; Royal Swedish Academy of Sciences; Conference of the Swiss Scientific Academies; Royal Institute of Thailand; Third World Academy of Sciences; Turkish Academy of Sciences; National Academy of Sciences of Ukraine; Royal Society of London; National Academy of Sciences of the United States of America; Academy of Sciences of the Republic of Uzbekistan; and National Academy of Physical, Mathematical, and Natural Sciences of Venezuela. For additional information, contact: Susan Turner-Lowe or Dove Coggeshall at the NAS at (202) 334-2138. ■

Robert L. Fuchs

Roy Shlemon Appointed to Board of Trustees

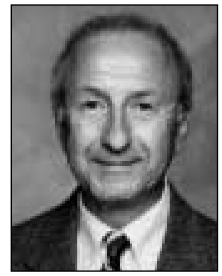
At the May meeting of the Foundation's Board of Trustees, Roy J. Shlemon was appointed a trustee, to fill the remaining term of Peter T. Flawn, who has resigned. This partial term will end in October 1999, following which Shlemon will be eligible to serve a new five-year term. New trustees are selected and appointed by the board from a list of candidates approved by the GSA Council. Trustee terms of office are five years, and individuals can serve a maximum of two consecutive five-year terms, not including completion of the unexpired part of a predecessor trustee's term.

Roy Shlemon is a consulting geologist and principal of Roy J. Shlemon & Associates, Inc. of Newport Beach, California. But that is only part of the story, for his biography also documents an extensive period spent in the academic world. As a practitioner, Shlemon has specialized in the application of Quaternary geology, geomorphology, and soil stratigraphy to engineering practice. While much of his work has been in California and the western United States, he has also undertaken projects in the Middle East and Latin America, for clients including U.S. and state government agencies, national laboratories, utility companies, and private engineering, mining, and geological consulting firms. As an academic, Roy Shlemon has held teaching and/or research positions at the University of California (Davis), Louisiana State University, Stanford, UCLA, and California State University (Los Angeles).

When he provided an endowment to the Foundation in 1994 to support applied Quaternary geology and geomorphology, Shlemon stressed the need to focus on the interchange of technology and ideas between the practicing scientist-engineer and the academic community, with special emphasis on geoscience students. This is the philosophy underlying the Shlemon Fund: the necessity for the research scientist to transfer ideas and accomplishments to those working in applied geology, and the necessity for practitioners in the consulting community and industry to inform academia, including geoscience students, about applied geology and its constantly changing requirements, opportunities, and challenges.

The initial product of this endowment is the Shlemon Mentor workshop, under the auspices of the Institute for Environmental Education. Students meet with engineering, hydro-, and environmental geologists to learn of the work of these private practitioners in dealing with "real world" geotechnical, environmental, and related administrative problems. During 1996 three such workshops were held at GSA Section meetings, and it is anticipated that there will be a larger number presented in 1997.

Call for Shlemon Mentor Nominations: see p. 13.



Roy Shlemon

Former Trustee Pete Flawn was a strong proponent and financial supporter of IEE during his years on the Foundation board. Thus, the availability of another strong IEE adherent to succeed him is particularly fortunate. Flawn commented on this when learning of the appointment. "IEE is a vital GSA initiative in today's world. We have all observed instances where science has been absent from environmental decisions. Sound environmental policy decisions require consideration of geologic information. I have become involved in the Environmental Defense Fund and the Nature Conservancy. Geologists can contribute a great deal to the programs of these organizations and others like them. It is appropriate and to IEE's and GSA's great benefit that Roy Shlemon has agreed to serve as a Trustee. I am confident that he will pursue activities and interests that are important to society and the Society."

News of the Second Century Fund Membership Campaign

You Could Be Going on a Geotrip

The Second Century Fund Committee has approved the award of a free GeoTrip to one of GSA's members contributing to the Second Century Fund during this membership campaign. The winner of the trip will be chosen at the Denver Annual Meeting in a drawing at 2 p.m. on October 30, 1996. Eligible participants are all those who have pledged at least $50 per year for five years, or made a one-time contribution of at least $250, to the membership campaign. If you would like the opportunity of winning one of the Society's popular GeoTrips, make sure to get your qualifying Second Century Fund pledge in soon!

Southeastern Section Names State Coordinators

Robert D. Hatcher, Jr., chair of the Southeastern Section Second Century Fund membership campaign, has organized a team of state coordinators to facilitate fund-raising campaigns in each of their respective states. We thank these individuals (listed here) for helping the Foundation with this important task. If you happen to get a phone call or letter from one of these folks, please take time to consider what GSA has done for you and your career—and then get out your checkbook!

Southeastern Section State Coordinators

Katherine Lee Avary, West Virginia
James C. Cobb, Kentucky
William W. Craig, Louisiana
Paul Geoffrey Feiss, North Carolina
Michael J. Neilson, Alabama
Ernest E. Russell, Mississippi
Walter Schmidt, Florida
Donald T. Secor, Jr., South Carolina
Stephen H. Stow, Tennessee
Samuel E. Swanson, Georgia
William A. Thomas, Kentucky
Robert C. Whisonant, Virginia

Pardee Coterie To Meet in Denver

The Pardee Coterie, a group of Foundation donors who have made planned gifts to support GSA and its programs, will meet for breakfast in Denver on October 30 during the 1996 Annual Meeting. Members of the Coterie and spouses meet at least annually, generally at the GSA meeting, for a meal followed by a talk and discussion on a topic of current interest to scientists and supporters of geology. The group is distinctly informal, educational, and entertaining—no bylaws, no officers, no committees.

The Joseph T. Pardee Memorial Fund originated through what is perhaps a classic example of planned giving—an estate bequest, a trust, and two charitable remainder unitrusts, transiting several lives. The resulting gift was the second largest ever received by GSA, exceeded only by the R.A.F. Penrose, Jr. bequest in 1931.

Pardee Coterie *continued on p. 11*

Media Workshop To Illustrate Effective Communication

The need for geoscientists to communicate effectively with decision-makers and the public has never been greater. Because the news media are the most important vehicle for reaching a broad, nontechnical audience, GSA is offering a hands-on workshop that can teach you how to get your message heard. If you have limited experience dealing with the media, if you've had negative experiences in past media interviews, or even if you're comfortable speaking to reporters but would like some additional pointers, this workshop will help prepare you for future encounters with the press, radio, and television.

The GSA Media Workshop will be held on Sunday, October 27, from 8:30 a.m. to noon. This event is offered as a public service at no cost to attendees of the GSA 1996 Annual Meeting in Denver. Workshop attendance is limited, however, so if you would like to participate, please contact: Sandra Rush, GSA Public Information Consultant, Geological Society of America, P.O. Box 9140, Boulder, CO 80301, (303) 494-1576, E-mail: rushsvcs@aol.com.

In Memoriam

James W. Baxter
Champaign, Illinois
April 14, 1996

W. Don Davison, Jr.
West Trenton, New Jersey

Ernest Dobrovolny
Golden, Colorado
May 18, 1996

Richard P. Sheldon
Washington, D.C.
June 8, 1996

William S. Twenhofel
Lakewood, Colorado
December 18, 1995

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Women in Science
Jane H. Wallace*

______

*Century Plus Roster (gifts of $150 or more).

Pardee Coterie *continued from p. 10*

GSA's Coordinator of Educational Programs, Ed Geary, will speak at this year's meeting about the Society's involvement in the rapidly moving field of K–16 science education, and new GSA educational outreach activities. President Eldridge Moores will highlight GSA developments and outlook.

Those who have made planned gifts to the Society or Foundation such as the Pooled Income Fund, charitable remainder trusts, gift annuities, or bequests have automatically been included in the Pardee Coterie roster of members. Others who have already included GSA in their wills but have not advised the Foundation or who are contemplating planned gifts are asked to notify the Foundation by calling or mailing the accompanying coupon. Membership in the Pardee Coterie can then be confirmed. ■

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ENVIRONMENT MATTERS

Institute for Environmental Education

The Rhetoric of Science

***Robert Frodeman,** Department of Philosophy, Fort Lewis College, Durango, CO 81301*

Scientists are expert at making arguments. It comes with the territory of science. They are less adept, however, at communicating the *significance* of their findings to those outside their field. In a tight funding climate, one of the crucial questions confronting science is: Can its arguments be both scientifically rigorous and rhetorically effective?

First a point of language. The term "rhetoric" is liable to misunderstanding. Its contemporary sense as "eloquence"—with an undertone of "manipulation"—obscures its original meaning: the presentation of an argument so that an audience grasps not merely its facts or conclusions, but also its significance for their lives as breadwinners and citizens. Much scientific research today is publicly funded. Thus, as the federal budget crisis persists, the rhetorical aspect of scientific knowledge is destined to grow in importance in the coming years.

Consider the question of global change, the complex of issues that include increases in greenhouse gases, the depletion of Earth's ozone shield, acid rain, the destruction of tropical and temperate rainforest, and the global loss of biodiversity. Information on these issues has been in the public domain (in one form or another, with differing degrees of accuracy and precision) for some years now. But the public remains confused, not simply by the presence of differing opinions concerning the seriousness of these dangers, but more fundamentally by the lack of a *context of understanding* for the information given. Thus we hear that increased levels of CO_2 in the atmosphere could lead to an increase of 1–4 °C in median world temperature by the year 2030. Whatever its accuracy, such a number gives little sense of what the effect of global warming might be upon a person living in Ohio or California.

Granted, there are signs that the literature on global change has had some effect upon public policy. Consider, for instance, the 1987 Montreal Protocol, which is leading to the world-wide phase-out of chlorofluorocarbons; or the 1992 conference in Rio, the largest gathering of world leaders in history, which took a global approach to questions of global change. But if the majority of the experts in these fields is to be believed, the overall public and political response has not been commensurate with the scale of the problem. Of course, it is possible that these dangers are overstated, or that new technologies will offer solutions to these challenges. My concern, however, is not with the particularities of the debate over global change, but rather with the effective use of scientific knowledge within our culture, and the gap that exists between the evidence of science and our personal and political behavior.

The scientific community's most characteristic response to this gap has been to call for further scientific research. In the past, the public—through its representatives in Congress—has usually assented to this request. But today there is a growing frustration with science, and a resistance toward its seemingly ceaseless demands for more time and money. Indeed, current government plans for balancing the budget call for reductions of 20%–35% in federal funding of scientific research by 2002.

> ***The current disconnect between science and public policy is underlain by the presumption that science ... can replace public debate about values.***

The assumption behind this demand for more funding, and thus more research, is that science must increase both the certainty and the precision of climate change predictions if the public is to take its counsel seriously. Conversely, if more research is not able to give an unequivocal answer in a timely fashion, we would then be justified in abandoning science for the naked strife of special-interest politics. Our standard for knowledge and action in either case remains Cartesian: unless and until we can be certain of our conclusions, the jury must remain out, and we are justified in postponing the painful task of adjusting our attitudes and lifestyle to any hypothetical new geo-ecological reality.

But is further research likely to increase appreciably the certainty of our findings in areas such as global change? Consider the comments of conservation biologist Paul Ehrlich. In a recent discussion about biodiversity, he asks, "Will refining knowledge of extinction rates make much difference?" The answer:

> Not scientifically. Rates are now so far above background that a major extinction episode is clearly underway. Biologists and others who appreciate the values of biodiversity need no more incentive to take action and to urge action… On the other hand, better understanding of biodiversity losses would be useful *politically*. Carefully documented rates of population and species extinction in a sample of groups could help counter lunatic claims such as that extinction rates are "less than one-thousandth as great as doomsayers claim."

Again, my point here is not to enter into the particulars of the debate over biodiversity, but rather to highlight the fact that while Ehrlich is sensitive to the political role of scientific knowledge, he passes over a crucial assumption—-that those who do not see a positive value to protecting biodiversity will be convinced otherwise through the further refining of extinction rate data. Ehrlich claims that the essential issue is one of values; but he then locates the solution to this problem in the discovery of more facts and in the improvement of our data base.

This confusion is not unique to Ehrlich, but in fact underlies our society's notion of rationality. In my view, the current disconnect between science and public policy is underlain by the presumption that science—if it will only reach certainty—can replace public debate about values. Descartes' criteria for rationality—that a claim must be certain and demonstrable on demand, and preferably expressed as a set of quantities—has been the gold standard for knowledge since the 17th century. This claim represented a bold departure from the traditional measure, which understood the nature of knowledge as varying with subject matter. This tradition finds its classic formulation in Aristotle's statement: "precision [or, we may add, certainty] is not to be sought for alike in all discussions ... it is the mark of an educated man to look for precision in each class of things just so far as the nature of the subject admits."

With the triumph of the scientific method in the 18th century, Aristotle's argument for the existence of different kinds of rationality fell out of favor. Of particular importance was the loss of a *political* rationality that addressed those areas of our lives fraught with uncertainty, but where action is demanded. Aristotle claimed that in addition to proving a claim through calculation, it is possible to rationally deliberate upon an issue. Aristotle's term for this type of understanding—*phronesis*, literally "prudence" or good judgment— identified our capacity for

Rhetoric *continued on p. 13*

Call for Nominations

Mentors in Applied Geology

The Geological Society of America's Institute for Environmental Education is now soliciting nominations for the Roy J. Shlemon Mentor Program in Applied Geology. Funded by an endowment from Roy J. Shlemon, the Applied Geology Mentor Program bridges the gap between the applied and academic geology communities. The mentors are experienced geologists currently practicing in various fields of applied geology. Each mentor presents a one-day workshop for graduate and senior undergraduate geology students focusing on professional opportunities and challenges in the applied geosciences. Workshops may include lectures and/or field and laboratory exercises, depending on the technical specialty of the mentor, as well as discussion of "practical problems" in applied geology such as running a business, marketing, hiring and firing, and legal and regulatory challenges.

Mentors receive an honorarium for conducting the workshop, in partial recognition of their outstanding contribution to the applied geosciences. Up to six Shlemon Mentor workshops will be held each year, in conjunction with the six GSA section meetings.

The 1996 Roy Shlemon Applied Geology Mentors are
James E. Slosson, Van Nuys, California—Rocky Mountain Section
William R. Cotton, Los Gatos, California—Cordilleran Section
Michael Hart, San Diego, California—Cordilleran Section
Dean Lewis, Ames, Iowa—North-Central Section

Criteria for Nomination

Mentors should be highly regarded practitioners in the applied geosciences. Preference will be given to nominees who emphasize one of the following specialties: Quaternary geology, geomorphology, environmental geology, engineering geology, geoarcheology, and hydrogeology. Nominees should have at least 15 years of experience outside of academia and government and should be working actively in an applied field. Nominees should also be active in the geological community, preferably with a record of presented or published papers.

Nominations should be in the form of a brief (one-half page) narrative summarizing the qualities and experiences of the nominee. This narrative may be supported by additional professional and biographical material. We request that nominators include their phone number and/or E-mail address.

Mentors will be selected by GSA section meeting committees from the pool of nominees.

Please send nominations to:
Roy Shlemon Applied Geology Mentor Program
Institute for Environmental Education
Geological Society of America
P.O. Box 9140
Boulder, CO 80301

Rhetoric *continued from p. 12*

reasoned thought concerning matters of human action. *Phronesis* or practical wisdom is essentially a conservative approach to questions of public concern, a conservatism rooted in the recognition of the fragility of community and the irreversibility of the historical process.

The consequences of the Cartesian revolution in our attitude toward rationality are difficult to exaggerate. If all knowledge is held to one measure, and if that measure insists upon certainty and demonstration upon demand, then entire areas of life—most notably, ethics, politics, and religion—become domains with no claim or pretension to rationality. The inevitable result is that conversation on these subjects degenerates into the solipsism of individual beliefs—and political turmoil. Furthermore, many of the sciences also suffer by comparison to this standard. This is the predicament in which the literature on global change—and the earth sciences generally—finds itself. Earth science disciplines are subject to the vicissitudes of time, where certainty, precision, or experimental demonstration are often not possible. Thus, despite the wealth of insight it has to offer to public debate, the usefulness of earth science information is impaired by our assumptions concerning what counts as useable knowledge.

The fundamental question confronting science today is how to make its knowledge effective, so that nonscientists can appreciate, if not the specifics of a scientific debate, then the overall meaning and values that are at stake. I am not suggesting that it is time for scientists to cede the field to humanists, who are supposedly better at talking about values, or to popularizers, who are supposedly expert at communicating with the public. Rather, I am advocating the enlargement of the scientist's job description, and thus a change in the role that science plays in society. Specifically, I am calling for another type of discourse in addition to that currently practiced by science—a way of talking, writing, and teaching that allows scientists to express and communicate the meaning and values of the work that they know so well.

The name for this type of discourse is "narrative logic." Briefly, what I am advocating is the recognition that stories are the means by which humans transform facts into meaning. "Story" may sound like another way of saying "fantasy" or "lie," but it is through the logical structure of a narrative that we make sense of experience—understanding our current situation in terms of our past and our possible futures. Narrative logic provides the context of understanding necessary for people to make sense of facts. Thus, rather than giving a number ("an increase of 1–4 °C"), the scientist describes a series of possible scenarios: more severe storms in the Atlantic, increased crop yields in Siberia, saltwater intrusion in Louisiana, or what have you. By describing these as possible scenarios, the scientist acknowledges his or her lack of certainty. But by placing the results of scientific work within a narrative framework, the scientist helps the community to grasp the potential implications of its acts. Thus, a connection is made between the use of private rather than public transportation, a possible increase in global temperature, and the effect of rising sea level on property values in New Orleans.

Without an enlarged sense of the parameters of rationality, we will remain paralyzed by questions that fall in the space between certainty and pure arbitrariness. Furthermore, the continued embrace of a Cartesian standard for what constitutes knowledge will only encourage the further growth of fundamentalist ideologies—religious and otherwise—which live off of an absolutist mentality and reject any type of thinking that recognizes uncertainty and ambiguity. (Thus, we are faced with the irony that our adherence to the Cartesian standard has aided and abetted the cause of the creationists.) By offering alternative accounts of our future, based in science, narrative logic allows science to contextualize data so that people can make use of it within their day-to-day lives. ■

Penrose Conference Scheduled

Paleocene-Eocene Boundary

April 24–30, 1997

The Paleocene-Eocene (P-E) boundary interval has become the focus of considerable attention in earth science circles in the past few years, owing to the recognition that it was a critical period in Earth history, when major changes occurred in the biotic and atmospheric–climatic realms. As a result of investigations on deep-sea cores, a large number of climatic and biotic events have been associated with the P-E boundary interval. A Geological Society of America Penrose Conference, Paleocene-Eocene Boundary Events in Time and Space, will be held April 24–30, 1997, in Albuquerque, New Mexico.

In an attempt to understand the significance of these events and to document their location and distribution in time and space, International Geological Correlation Program (IGCP) Project 308 was initiated and funded by the United Nations Educational, Scientific and Cultural Organization (UNESCO)–International Union of Geological Sciences (IUGS) in 1989 for a five-year period. At the same time, the Paleogene Subcommission of the International Commission on Stratigraphy (ICS) is actively engaged in the search for and delineation of stratigraphic sections that may serve as standard bearers for boundaries between epochs and series in the geologic-stratigraphic record. These Global Stratigraphic Sections and Points (GSSPs)—the so-called "Golden Spike"—are now the focus of several working groups, each concentrating on a different part of the stratigraphic column. In this context, IGCP Project 308 has also been active in seeking to provide the appropriate criteria by which the P-E boundary GSSP may be recognized and delineated and correlated.

As is the case with many such series and epoch boundaries, there is considerable controversy over the exact definition and location of the P-E boundary and its estimated age. One of the primary reasons for this difficulty is that many of the classical northern European sections are terrestrial to shallow marine and contain few biostratigraphically useful fossils. Many of these sections are stratigraphically discontinuous owing to rises and falls of sea level during the early Paleogene. In various countries there are outcrops of fossiliferous marine sediments and rocks that may provide a more suitable "type" section for establishing criteria for global correlations of the Paleocene-Eocene boundary.

IGCP Project 308 member scientists have been working actively to resolve how precisely to correlate distant sections and determine the best criteria to use in correlations of the boundary level. However, there remain significant questions as to how the boundary should be recognized. Also, at present there is no clear agreement among workers as to where the type section should be recognized. This Penrose conference will attempt to overcome these problems and will aim to establish agreement among workers as to how the boundary would be best correlated. The conference will provide an opportunity for workers from all over the world who are currently involved in research on the boundary interval to talk and discuss their respective results. In a unified forum, we hope to be able to resolve the outstanding issues that have precluded a definition of the boundary.

To date, IGCP Project 308 workers have focused their efforts on the following: (1) Local and regional stratigraphic studies using a sequence stratigraphic framework (for the purpose of providing criteria for regional global stratigraphic correlations where feasible); integrated magnetostratigraphic, biostratigraphic, stable isotope, and radioisotopic studies are basic components of this aspect of the IGCP Project 308 program; (2) event stratigraphy across the P-E boundary interval; (3) biostratigraphic and evolutionary studies across the P-E boundary interval; (4) determination of climatic-atmospheric evolution across the P-E boundary interval by means of stable isotopes and planktonic microfossils; (5) geochronologic investigations across the P-E boundary interval; IGCP Project 308 is now officially terminated (as of January 1995), but we are still working for the completion of a volume of contributed papers dealing with various aspects of the P-E boundary. In addition to this volume there has been (and still is) a plethora of publications concerning global biotic, climatic, and oceanographic changes across the Paleocene-Eocene boundary. It is clear from the extensive literature now being produced about this important boundary that the geologic community recognizes the significance of understanding how Earth's environment changed rapidly and how biota responded to such abrupt changes.

The new global change initiatives sponsored by the Earth and Ocean Science Divisions at the National Science Foundation recognize the early Paleogene, and the Paleocene-Eocene transition specifically, as a crucial period if we are to better understand the dynamics of the Earth environment and the impact that climatic and oceanographic changes will have on Earth's biota.

Within the next year a proposal will be set forth to locate a type section for the Paleocene-Eocene Series-Epoch boundary. In preparation, it is imperative that all workers currently involved in delineating geologic phenomena around the P-E boundary be brought together to discuss the quality and integrity of the various data sets and sections. Only with a full representation of the available information can an adequate assessment and proposal be put forth to the International Commission on Stratigraphy. This Penrose Conference will enable specialists who have been engaged in IGCP Project 308 studies on the P-E boundary to meet and review the huge database that now exists on this subject, to subject the data from various fields to careful scrutiny and analysis, and to integrate information from disparate areas.

Among the more outstanding problems we will focus on are:

1. Review and synthesis of the major climatic and biotic events that have been identified with the P-E boundary interval in both marine and terrestrial stratigraphies including recent attempts at improved climate modeling of the P-E boundary interval;

2. Assessment of the newly revised chronology of the Paleogene and in particular the Paleocene-Eocene boundary interval with a view to unifying the different geochronologies currently being applied to this interval; determination of the chronologic position and sequence of the various events that have been found to be associated with this interval;

3. Assessment of marine and terrestrial stratigraphic correlations with a view to providing a rigorously tested and high-resolution chronologic framework for the historical geology of this important time in Earth history;

4. Assessment of various bio-, chemo-, and magnetostratigraphic events currently used or favored in depicting the P-E boundary with a view to establishing the main criteria to be used in denoting the P-E boundary when the GSSP is proposed or selected; establish the criteria required to build an orbital stratigraphy;

5. Review of local and regional stratigraphic studies in the classic areas of northwestern Europe as well as the detailed studies that have been conducted in specific areas with a view to providing candidate sections for a suitable P-E GSSP for selection by the voting members of the Paleogene Subcommission and recommendation to the IUGS. This Penrose Conference will serve essentially as the termi-

nal meeting of IGCP Project 308, and all scientists who have played an active role in its activities or are directly interested in its objectives are urged to attend.

If you are interested in attending this Penrose Conference, contact Spencer Lucas, New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, NM 87104, (505) 841-2873; fax: 505-841-2866); E-mail: lucas@darwin.nmmnh-abq.mus.nm.us. Limited funding will be available for qualified graduate students. **The deadline for conference applications is December 1, 1996.**

Co-conveners of the conference are: ***William A. Berggren,*** Dept. of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, (508) 289-2593; fax: 508-457-2187, E-mail: wberggren@whoi.edu; ***Marie-Pierre Aubry,*** Institut des Sciences de l'Evolution, Université Montpellier II, Place Eugène Bataillon, 34095 Montpellier Cedex 05, France, phone 33-67-14-4716; fax: 33-67-14-3610); E-mail: Aubry@isem.univmontp2.fr; ***Spencer Lucas*** (address above); Lowell Stott, Dept. of Geology, University of Southern California, Los Angeles, CA 90089, (213) 740-4120, fax; 213-740-8801, E-mail: stott@usc.edu; ***James Zachos,*** Earth Sciences Dept., University of California, Santa Cruz, CA, 95064 (408) 459-4644, fax, 408-459-3074, E-mail: jzachos@earthsci.ucsc.edu. ■

Penrose Conference Scheduled

Tectonics of Continental Interiors

September 23–28, 1997

A Geological Society of America Penrose Conference, "Tectonics of Continental Interiors," will be held September 23–28, 1997, at Brian Head Resort, near Cedar City, Utah.

Continental-interior regions account for over 80% of the surface area of continents today. In many of these regions, continental crust has not been metamorphosed to high grades, nor has it been penetratively transposed within a continental-margin setting since the Precambrian. Thus, continental interiors include regions that have been shields or platforms for all or part of the Phanerozoic. The goal of this conference is to bring together a multidisciplinary group of geoscientists (structural geologists, geophysicists, geodynamicists, stratigraphers, and geochemists) to address the issue of how continental-interior regions worldwide formed and how they have behaved tectonically subsequent to their formation.

We will organize the conference around five major themes, ordered so that each new theme builds on the previous ones.

1. How continental-interior regions came to be in the first place. What were the processes in the Precambrian that "cratonized" extensive areas of continental lithosphere? How did long-lived fault zones in continental interiors begin?

2. Three-dimensional configuration of continental lithosphere in the present day. What is the variation in composition and strength of continental lithosphere with depth? Is the asthenosphere beneath continental interiors similar to or different from that found beneath other kinds of lithosphere? What controls major lateral variations in lithospheric structure?

3. Nature of strain in continental interiors. What are the manifestations and patterns of strain in interiors? What is the nature of fault reactivation? What is continental-interior orogeny, and why does it occur?

4. Epeirogeny and topography in continental interiors. What causes epeirogeny? Why does it occur where and when it does?

5. Neotectonics of continental interiors. What is the contemporary state of stress in continental interiors, and what is the origin of the stress? What features localize current seismicity?

During the past quarter century, much of the research effort in tectonics has focused on understanding the nature of geologic activity in the Phanerozoic and Precambrian orogens that formed along former continental margins. In contrast, there has been relatively little work concerning the nature of tectonism in continental interiors. Many of these regions have been dismissed as being "stable" and of little concern to tectonicists. In fact, continental interiors are not tectonically inactive, they simply behave differently from marginal orogens. We hope that by bringing together a diversity of geoscientists who have worked on a variety of aspects of continental-interior geology, participants will be able to develop a comprehensive image of what is now known about continental interiors and to see interrelationships among different geologic features. By the end of the meeting, participants should have a clear picture of future research directions concerning issues of continental-interior tectonics.

Vans will pick up meeting participants in Las Vegas. En route to Brian Head Resort, a guided tour will be provided across the transition between the Basin and Range rift and the Colorado Plateau. George Davis, University of Arizona, will guide a one-day field trip to see representative continental-interior structures as exposed on the plateau. The trip will include a stop in Bryce Canyon National Park. We have selected the Colorado Plateau region as the conference locale because it provides excellent exposures of continental-interior–type structures and rocks.

Participation in the conference will be limited to about 80 persons. Participants will be selected to include broad representation of different relevant disciplines and of different geographic regions. Graduate students are encouraged to apply; a partial subsidy will be available for some students. The registration fee, which will cover lodging, meals, ground transportation, field trip, and other conference costs except personal incidentals, is not yet established, but it is not expected to exceed $700.

Co-conveners of the conference are: ***Stephen Marshak,*** Department of Geology, University of Illinois, 1301 W. Green Street, Urbana, IL 61801, (217) 333-7705, fax 217-244-4996, E-mail: smarshak@uiuc.edu; ***Ben van der Pluijm,*** Department of Geological Sciences, University of Michigan, 2534 C.C. Little Building, Ann Arbor, MI 48109-1063, (313) 764-8545, fax 313-763-4690, E-mail: vdpluijm@umich.edu; and ***Michael Hamburger,*** Department of Geological Sciences, Indiana University, Bloomington, IN 47405, (812)855-2934, fax 812-855-7899, E-mail: hamburg@ ucs.indiana.edu

Application deadline is February 15, 1997. Invitations to participants will be mailed by April 1, 1997. We intend to have only a limited number of oral presentations, so a significant proportion of the meeting will be devoted to poster presentations and associated discussions.

Interested geoscientists should send a letter of application to Michael Hamburger at the above address. Applicants should include a brief statement indicating their area of interest, the relevance of their recent work to the themes of the meeting, and the subject and mode of their presentation if one is proposed. ■

Tectonic Evolution of the Gulf of California and Its Margins

Conveners:
Paul J. Umhoefer, *Department of Geology, Box 4099, Northern Arizona University, Flagstaff AZ 86011, paul.umhoefer@nau.edu*
Joann Stock, *Seismological Laboratory 252-21, California Institute of Technology, Pasadena, CA 91125, jstock@seismo.gps.caltech.edu*
Arturo Martín, *Departamento de Geología, Centro de Investigación Científica y de Educacíon Superior de Ensenada, CP 22830 Ensenada, Baja California, amartin@cicese.mx*

The Gulf of California is one of two examples on Earth of active transform-rift plate boundaries, a basic type of margin in the spectrum of plate tectonic boundaries. In the 1960s, the Gulf of California was one of the main locations where on-land geology and offshore oceanographic observations were considered to be in clear agreement with the theory of plate tectonics. As a geologically young and currently active plate boundary, the Gulf of California has been investigated since the 1960s by many types of geoscientists, and it is the focus of a growing community of researchers. These efforts have shown that upon closer inspection, the details of development of the plate boundary are not as simple and clear-cut as had been assumed.

In order to assess the current knowledge of the tectonics of the Gulf of California, investigate areas and topics of greatest potential future research, and stimulate collaboration on future research projects, a Geological Society of America Penrose Conference was held April 17 to 22, 1996, in Loreto, Baja California Sur, Mexico. The conference focused on the tectonic development of the Gulf of California region during the past ~20 m.y. and covered all aspects of this region, including plate motions, relation to the San Andreas fault, marine geology and geophysics, pre-gulf geologic framework, seismotectonics, magmatism, structural geology, tectonic geomorphology, stratigraphy, and paleontology. In addition, there were comprehensive contributions on the geology of other rifts that might offer instructive comparisons to the Gulf of California.

Here, we highlight those topics deemed by the participants of the conference to be of greatest importance and potential future research; the topics summarized here are naturally interdisciplinary, but were treated separately at the conference for simplicity. We list some of the major conclusions we can now make and the important questions that remain. Clearly, there are more questions than answers at this time.

A general conclusion is that a simple model for the gulf from the literature and from the meeting has some merit and yet needs much further testing. That model suggests that a simple convergent margin with a terrestial volcanic arc was present along the future gulf from ~25 to ~16–12 Ma. Extensional faulting occurred behind (east of) the arc during this period. The subduction zone was extinguished in jumps from north to south as a transform plate boundary formed on the west side of the future Baja peninsula. From ~15 to ~5 Ma, a proto-gulf stage of rifting was accompanied by one or two marine incursions. This rifting was generally part of regional strain partitioning, with the transform fault system to the west of Baja California and a broad zone of extensional faulting in the region of the present gulf and east on mainland Mexico. From ~5 Ma to the present, the system of transform faults and small rift basins formed as the plate boundary shifted into the gulf and joined to the San Andreas fault system in California. Many of the more specific points mentioned below stem from the need for a more thorough critique of this model for the evolution of the Gulf of California.

Relation to the San Andreas Fault System

We began with a summary of the known dextral offset across southern California on the transpeninsular faults, the San Andreas and San Jacinto faults, and the Mojave faults, showing that it is generally consistent with the ~300 km total offset suggested from geological tie points across the central Gulf of California. However, some of this slip must predate 5 Ma; there are no known large, strike-slip faults older than 5 Ma in the Gulf of California region, but such faults could be undiscovered (buried?) in Sonora or under the offshore region. The increasing evidence for pre–5 Ma extensional faulting and marine deposition, in various regions around the gulf, would be consistent with these data. The poorly organized strike-slip fault systems in eastern Oregon and the Walker Lane may be useful analogues to the early strike-slip faults in the gulf, before the young transform faults formed.

Plate Motions

The history of plate reorganizations west of the Baja peninsula is fairly well known. In contrast, there are few data from within the gulf itself that help to determine the beginning of oceanic rifting and transform faulting, or the details of kinematics of Baja California motion relative to mainland Mexico. There is evidence for recent ridge jumps within the gulf, but only a first attempt to link these to onshore geology. This subject and many others point to the great need for new seismic reflection data on the narrow shelves and new marine geophysical data from the deeps in the middle of the gulf.

Marine Geophysics

Marine geophysical studies were represented only by studies from the northern Baja and California borderland. These make good analogues to the gulf and help define the history of this critical area adjacent to the gulf. There is a real paucity of data from marine geophysical studies. Again, it was widely agreed that in order to make substantial progress in understanding the gulf, major investigations must be done that obtain integrated data from the marine part of the gulf. Progress is being made in this regard; in fact, several of our Mexican colleagues were unable to attend the Penrose Conference because they were running an onshore-offshore seismic experiment in the Gulf of California, in collaboration with Spanish scientists.

Pre-Gulf Geology

Three pre-gulf features were discussed as possible influences on the later gulf. The Cretaceous batholith, well exposed in the northern Baja peninsula and thought to be largely buried in the south, may have controlled the western margin of the rift by acting as a rigid block. Both a Cretaceous back-arc basin and/or the Miocene magmatic arc may largely occupy the position of the modern gulf. The Miocene arc has long been thought to have influenced the position of the gulf, but the role of the southern San Andreas fault system and the tectonics at the mouth of the gulf must be integrated into this interpretation.

Magmatism

There is a large deficit of basic geochemical and geochronologic data on the magmatic history of the gulf region. There does seem to be enough mapping and petrologic data to broadly define the Miocene arc that preceded rifting, and some major synrift volcanic provinces have been identified. Major points to be addressed include the following: Plate-motion studies suggest a contrast in timing of the beginning of rifting and perhaps the style of postarc volcanism between the northern and southern gulf, but this is not clear from petrologic data; the basic evolution of the lithosphere through time on both sides of the gulf must be addressed by isotopic studies; the position of magmatism relative to proposed rift segments and accommodation zones is not clear.

Structural Geology

The current knowledge of the history of deformation generally supports the three-stage model summarized above, but many key questions remain unanswered. Is there a migration of extension through time from Sonora westward into the modern gulf region as it now appears? If so, when did this occur? Did extension rapidly jump from the back-arc position to the gulf at about 12 Ma? Are the local structural patterns and kinematics that support the proto-gulf as an orthogonal rift supported by more widespread data? Current data from only a few areas seem to support the recently proposed model that the gulf is segmented, much like orthogonal rifts. Is this segmentation widespread, and did this pattern form in the proto-gulf, when orthogonal extension has been proposed? Some areas show a change in extension direction at about 5 Ma compatible with the proto-gulf rifting to modern transform model. Why don't other areas show this pattern? Where are the strike-slip faults one might expect in the early stages of the transform boundary? Or have they always been where the transforms are today?

Stratigraphy and Basin Analysis

Basin analysis is intimately linked to structural studies in an active plate margin. One of the major goals of future research is to test similarities and differences between orthogonal rifts and a more complex setting such as the gulf where possible early orthogonal rifting was followed by oblique rifting. Can the history of the oldest basins tell us more about how rifting started in the Gulf of California? Can the age and style of the oldest strata tell us if the interpretation of the proto-gulf as an orthogonal rift is correct? It is suggested in northern Baja that stratigraphic patterns differ between the centers of proposed rift segments and adjacent accommodation zones. Is this a general pattern throughout the gulf? There is some suggestion of areal unconformities that coincide with the initiation of formation of oceanic crust in the small transform-rift basins. Are these unconformities an early type of breakup unconformitiy? Or is it too early in the evolution of the plate margin to expect a change to thermal subsidence and a widespread unconformity? Are stratigraphic patterns and the shape, size, and style of basins compatible with the presence of a strike-slip margin for the entire last 5 m.y., when a transform boundary is thought to have been in the gulf? Can we differentiate between tectonic subsidence and eustatic sea level changes?

Paleontology

Many aspects of paleontology can augment other studies and provide fresh new data. Several paleontologists summarized micropaleontological and macrofossil data suggesting that the first marine incursion into the modern gulf was formed as a shallow seaway at about 12 –15 Ma, at about the same time that structural and magmatic data suggest initial rifting. But much more fossil control is needed from more widely spaced areas to substantiate this pattern. Furthermore, what is the timing of the initiation of a widespread proto-gulf based on fossil data? When was there a widespread deep-marine seaway? On the basis of fossils, are there any unconformities that are synchronous over most of the gulf? When and where were the seaways that linked the gulf and the Pacific Ocean, on the basis of the fossil record?

Other Rifts and Modeling

A key element to the conclusion of the conference was a series of stimulating presentations on other rifts around the world and recent modeling of oblique rifts that provided insights into the evolution of rifts and how they have been investigated by interdisciplinary methods. The geophysical methodology used to understand other rifts was particularly instructive, because that type of work is in its infancy in the Gulf of California.

The conference included a one-day field trip to the Loreto basin, an excellent and informative example of Pliocene basin tectonism and sedimentation during the evolution of the gulf. Paul Umhoefer, Becky Dorsey, and Larry Mayer showed the details of the complex stratigraphic and structural evolution of this region, taking the group to key outcrops of the Loreto fault zone, excellent examples of Gilbert-type fan-deltas, and wonderfully variable bioclastic sedimentary rocks. The field trip generated some lively discussion regarding structural models for the basin (half-graben, or transfer zone between two en-echelon oblique-slip faults?). It also provided a useful data set for comparison with laboratory models for oblique extensional settings, which had been presented earlier in the meeting.

Summary

We concluded that although there has been much progress in many local areas and on a few of the larger questions, many problems remain before we are to understand this critical plate boundary in the Gulf of California. Many important details from local areas have not been summarized here, but in most cases these remain local studies without a regional context. Much of the problem is that we lack the database for regional syntheses, and part of it is that the important models and questions of a regional scale that focus research are just now being asked. Thus, we have come a long way since the first Penrose Conference on the Gulf of California in 1974, particularly in the growing involvement of Mexican geologists in the research. But this conference left us with more ideas for future work rather than with grand conclusions.

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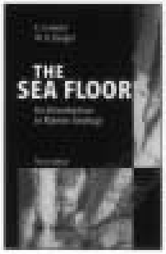

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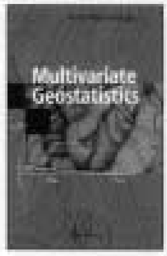

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Societal Benefit of Basic Research

Eldridge Moores, *President, GSA*

There seems no question that geology—and science in general—is in a crisis. Many of us came of age scientifically in the post-Sputnik era, when jobs and funding for research were abundant and geology was caught up in the excitement of the plate tectonic revolution. Many younger members of our society were attracted to the field by this excitement and the perceived opportunities, and now face a declining job and research funds pool. Many geologists from the U.S. Geological Survey, the U.S. Bureau of Mines, and industry face loss of jobs, by whatever euphemism, and the agony of job change in mid-career.

This crisis seems to be worse in geology than it is for many other branches of science, for several reasons: (1) There is very little knowledge of the geosciences among the public as a whole, although there seems to be a great hunger for knowledge on the part of many nonscientists. (2) There seems to be little knowledge or appreciation of geoscience in Washington in general and Congress in particular. (3) We as a nation are moving toward two separate societies, one science literate, of which we are a part, and the other science illiterate and increasingly in the thrall of religious fundamentalism, of whatever stripe. This latter part is growing in numbers and political influence and views much of what we do as anathema. (4) Many other sciences speak much more consistently with a single voice or at least a coordinated public stance; the geosciences, by contrast, are fragmented.

The problem, however, is even larger. The "social contract" between science and the public, which has been in force since the end of World War II, may be ending. As summarized by Radford Byerly Jr. and Roger A. Pilke Jr. (*Science*, Sept. 15, 1995, p. 1531–1532), this social contract was based on three assumptions: (1) scientific progress is essential to national welfare; (2) science provides a body of knowledge that can be applied to national needs; and (3) scientific progress on a broad front results from "free inquiry" of scientists working on matters of their own choosing. The metaphor that Byerly and Pilke use is that of a "reservoir" into which scientists put their work, and from which knowledge can be drawn for the greater public good. A corollary of this approach is that "pure research is better than applied." Any scientific research is good, and scientists are a better judge of what they should do than anyone else. Byerly and Pilke argue that a new social contract is in the making which will include answers to questions such as, How does science contribute to national welfare? and Can science be marshaled to assist in addessing specific societal problems? They argue that the new social contract will include the following points: (1) science is essential to national welfare; (2) science must develop a closer relationship with its constituency (i.e., the public at large) than was the case with the "reservoir" concept outlined above; and (3) science will be driven by internal and external problems, as well as curiosity. They also argue that professional societies should have a key role in the upcoming discussion. In addition, it is clear that individuals need to become more active in providing information to their representatives at a local or national level.

Early this year, members of the Council of Science Society Presidents were asked to come up with a one-page list of the societal benefits of research in their fields. The impetus for this request was the fact that ongoing budget negotiations in Washington had programmed a cut of approximately 30% for basic research funding over the next seven years. A selective, incomplete list was compiled, with the help of many GSA members, in just 10 days. The list, with references (numbers in parentheses) is reprinted here. This list might be interesting for readers either as a resource to be used in conversations with political representatives or as seminar topics in classes.

Societal Benefits from Basic Geological Research: A Partial List

Compiled by Eldridge M. Moores, President, Geological Society of America

Dynamic Planet: "Civilization exists by geological consent, subject to change without notice."—Will Durant

• We live on an active Earth. Slow motions (as fast as a fingernail grows) in the deep interior cause continents to move about, oceans to open and close. In the past, the western U.S. was next to Antarctica. The U.S. East Coast was next to Africa and before that northwest South America. (*1*)

• These motions determine the location of natural resources such as minerals and hydrocarbons and of natural hazards such as earthquakes and volcanoes. A zone of earthquakes and volcanoes extends along western North America from Mexico to Alaska. An old zone from the Mississippi River to Georgia and New England still has infrequent but large earthquakes. (*2*)

Saving Lives And Money—Understanding Earth Hazards

• U.S. earthquake studies have led to better forecasting, better understanding, and less loss of life and property in this country than in other parts of the world. More studies are needed. Geological research helps us develop building codes and zoning ordinances that help protect us against these hazards. (*3*)

• Many hidden faults were recently discovered beneath Los Angeles. A large earthquake beneath the city could devastate it, kill many people, and disrupt global financial communications. (*4*)

• The recent earthquake in Kobe, Japan, was a "dress rehearsal" for a quake in the San Francisco Bay area or San Diego, which would cause thousands of deaths, billions of dollars in property damage, and disruption of communications. (*5*)

• New research shows that Seattle, Portland, and St. Louis are at risk from very large but infrequent earthquakes. These cities are not prepared for such a devastating event. (*6*)

• Many western dams (e.g., in California, Utah, Oregon, Idaho, and Colorado) are near active earthquake faults and in greater danger of failure than earlier anticipated when built. (*7*)

• Some volcanic eruptions are violent. The U.S. is better prepared than some countries, but not as well as Japan. Major concerns are in the Pacific Northwest, Alaska, New Mexico, and California. (*8*)

• Studies of the 1980 Mount St. Helens eruption led geologists to forecast the 1992 Mount Pinatubo eruption in time to save tens of thousands of lives and several billion dollars worth of U.S. military equipment. (*9*)

• Satellite studies of erupting volcanoes save lives by allowing diversion of airliners; in the 1980s several planes nearly crashed after flying into erupting volcanic clouds (e.g., Mount St. Helens). (*10*)

• Mississippi Valley sediments up to 5000 years old indicate that past flooding was much greater than 1993 floods. This research allows more effective dam design and more realistic flood risk estimates. (*11*)

• Understanding landslides, mudflows, erosion, and land subsidence helps planning to minimize cropland erosion and property damage, maximize sustainable logging, and preserve stream quality and fish stocks. (*12*)

• Studies of coastline processes such as beach erosion help save billions of dollars in losses from hurricanes. (*13*)

• Understanding earthquakes and groundwater flow allows us to find safe locations for storing radioactive waste. (*14*)

• World's fastest moving landmass is the southeast part of Hawaii, moving 4 inches per year toward the ocean. An earlier

Research *continued on p. 20*

Research *continued from p. 19*

enormous landslide from northwest Hawaii produced a tsunami (tidal wave) 1000 feet high. (*15*)

Helping U.S. Economy and Health

- Water-flow studies in rocks improve understanding of ground-water supply. Growing population in arid regions, especially in the U.S. Southwest, will depend on this new knowledge to satisfy its demand for water. (*16*)
- New tools developed by geologists to study deep structure of continents and new geologic views of rock structure have improved the efficiency of oil and gas and mineral exploration. (*17*)
- Geologic studies of hot springs help us recognize new kinds of mineral deposits, leading to a new gold rush in the western U.S. (*18*)
- Geologists studying the ocean floor have discovered new offshore solid hydrocarbons that could exceed all known oil and gas reserves—a possible 21st century energy source. (*19*)
- New synthetic geologic materials can be used to safely encase radioactive wastes. (*20*)
- DNA analysis for biotechnology applications depends on enzymes from bacteria found by geologists in seafloor hot springs. (*21*)

Ensuring Human Survival

- Geologic research shows that Earth's climate can change greatly over short time periods. If society is prepared, it can respond successfully. (*22*)
- The El Niño effect—changes in direction of equatorial Pacific ocean currents from west-flowing to east-flowing—may result from volcanic eruptions. El Niño may cause major droughts and other weather changes in the U.S. By understanding its causes we may be able to forecast—and better prepare for—its consequences. (*23*)
- Cores from Greenland and Antarctic ice reveal rapid natural climate changes in just a few decades. A rapid warming trend today could submerge most coastal cities as polar ice melts and the oceans rise. (*24*)
- Major meteorite impacts severely affect climate and cause massive extinctions. Such an impact 65 million years ago probably caused the extinction of the dinosaurs and many other life forms. Another big meteorite could be headed toward us at any time. At present we have no means of response. (*25*)
- Volcanic eruptions affect climate. An 1815 Indonesia eruption caused famine in New England and northern Europe. The Mount St. Helens, Mount Pinatubo, and El Chichón eruptions had similar, if lesser, effects. The eruptive history and climatic effect of many volcanoes is still unknown. (*26*)

REFERENCES AND FURTHER INFORMATION

1. Moores, E. M., and Twiss, R. J., 1995, Tectonics: New York, W. H. Freeman & Co., 415 p.

DeMets, C., 1993, Earthquake slip vectors and estimates of present-day plate motions: Journal of Geophysical Research, v. 98, p. 6703–6714.

Dalziel, I. W. D., 1995, Earth before Pangea: Scientific American, v. 272, p. 58–63.

2. Oliver, J. E., 1991, The big squeeze—How plate tectonics redistributes mineral and organic resources: Sciences–New York, v. 31, no. 4, p. 23–28.

Rona, P. A., 1980, Global plate motion and mineral resources, *in* Strangway, D. W., ed, The continental crust and its mineral deposits: Geological Association of Canada Special Paper 20, p. 607–622.

Larson, Roger L., 1991, Geological consequences of superplumes: Geology, v. 19, p. 963–966.

Geophysics Study Committee, 1984, Explosive volcanism: Inception, evolution and hazards: Washington, D.C., National Research Council, National Academy Press, 176 p.

Geophysics Study Committee, 1986, Active tectonics: Washington, D.C., National Research Council, National Academy Press, 266 p.

Simkin, T., et al., 1981, Volcanoes of the world: A regional directory, gazetteer, and chronology of volcanism during the last 10,000 years: Stroudsburg, Pennsylvania, Hutchinson Ross, 240 p.

Ellis, Michael A., and Schweig, E. S., III, 1992, Tectonic setting of active deformation and the l811–1812 earthquakes in the New Madrid region [abs.]: Seismological Research Letters, v. 63, p. 50.

Seeber, Leonardo, et al., 1994, 1886 Charleston, SC, and 1993 central India; two of many large intraplate earthquakes with precursory seismicity, but no recognizable stationary source [abs.]: Seismological Research Letters, v. 65, p. 66.

Gelinas, Robert, et al., 1989, Paleoseismic investigations along the Atlantic Seaboard; implications regarding eastern U.S. intraplate seismicity: Geological Society of America Abstracts with Programs, v. 21, no. 6, p. 185.

Amick, David, et al., 1991, The search for evidence of large prehistoric earthquakes along the Atlantic seaboard: Science, v. 251, p. 655–658.

3. Schwartz, D. P., 1988, Geologic characterization of seismic sources: Moving into the 1980's, *in* Von Thun, J. L., ed., Proceedings of Earthquake Engineering and Soil Dynamics 11, Park City, Utah: American Society of Civil Engineers Geotechnical Special Paper 20, p. 1–42.

USGS Working Group, 1988, Probabilities of large earthquakes occurring in California on the San Andreas fault: U.S. Geological Survey Open-File Report 88–398, 62 p.

4. Dolan, J. F., et al., 1995, Prospects for larger or more frequent earthquakes in the Los Angeles metropolitan region: Science, v. 267, p. 199–205.

5. Stein, R. S., and Ellsworth, W. L., 1995, Earthquakes; from California to Kobe: Nature, v. 373, p. 388.

Kerr, Richard A., 1995, An unnerving preview of a Northern California quake?: Science, v. 267, p. 445.

6. Atwater, B. F., 1987, Evidence for great Holocene earthquakes along the outer coast of Washington State: Science, v. 236, p. 942–944.

McCaffrey, R., et al., 1995, Forearc deformation and great subduction earthquakes; implications for Cascadia offshore earthquake potential: Science, v. 267, p. 856–859.

Wuetrich, B., 1994, It's official: Quake danger in Northwest rivals California's: Science, v. 265, p. 1802-1803.

Wheeler, Russell L., et al., 1994, Elements of infrastructure and seismic hazard in the central United States: U.S. Geological Survey Professional Paper P1538-M.

7. J. Unruh, 1996, oral communication.

8. Geophysics Study Committee, 1984, Explosive volcanism: Inception, evolution and hazards: Washington, D.C., National Research Council, National Academy Press, 176 p.

9. Tayag, J. C., et al., 1994, Volcanic disaster mitigation in the Philippines—Experience from Mt. Pinatubo: Disasters, v. 18, p. 1–15.

Pearce, F., 1993, Pinatubo points to vulnerable climate: New Scientist, v. 138, no. 1878.

Newhall, C. G., 1992, Volcanic hazards video tape and Pinatubo: Bulletin of Volcanology, v. 54, p. 4441.

10. Hufford, G. L., 1994, Alaska volcano-debris-monitoring system; new technologies to support forecasting volcanic-plume movement, *in* Casadevall, T. J., ed., Volcanic ash and aviation safety (proceedings of the first international Symposium on Volcanic Ash and Aviation Safety): U.S. Geological Survey Bulletin B2047, p. 239–244.

11. Ely, L. L., et al., 1993, A 5000-year record of extreme floods and climate change in the southwestern United States: Science, v. 262, p. 410–412.

12. Keller, E. A., 1992, Environmental geology: New York, MacMillan, 521 p.

Harp, E. L., 1995, Seismic instrumentation of landslides—Building a better model of dynamic landslide behavior: Seismological Society of America Bulletin, v. 85, p. 93–99.

Brabb, E. E., 1991, The world landslide problem: Episodes, v. 14, p. 52–61.

Schaefer, S. J., and Williams, S. N., 1991, Landslide hazards: Geotimes, v. 36, p. 20–22.

Holzer, T. L., 1989, State and local response to damaging land subsidence in United States urban areas: Engineering Geology, v. 27, p. 449–466.

13. Finkl, C. W., and Pilkey, 0. H., 1991, Impact of Hurricane Hugo; September 10-20, 1989: Journal of Coastal Research, v. 8, 356 p.

Pilkey, O. H., 1991, Coastal erosion: Episodes, v. 14, p. 46–51.

Norris, R. M., 1990, Sea cliff erosion—A major dilemma: Geotimes, v. 35, p. 16–1 7.

14. Milnes, A. G., 1985, Geology and radwaste: New York, Academic Press, 328 p.

Mattson, Steven R., et al., 1989, Geology and hydrogeology of the proposed nuclear waste repository at Yucca Mountain, Nevada, and surrounding area, *in* Vineyard, Jerry D., et al., Geological Society of America 1989 field trip guidebook: Missouri Division of Geology and Land Survey Special Publication 5, p. 9–44.

15. Owen, Susan, et al., 1995, Rapid deformation of the south flank of Kilauea Volcano, Hawaii: Science, v. 267, p. 1328–1332.

Moore, James G., et al,, 1995, Giant blocks in the South Kona Landslide, Hawaii: Geology, v. 23, p. 125–128.

16. Back, William, and Stephenson, D. A., editors, 1979, Contemporary hydrogeology: New York, Elsevier.

17. Oliver, J., 1992, COCORP probes continental depths: Geotimes, v. 38, no. 6, p. 21–22.

Brown, L. D., 1990, COCORP, crustal structure, and hydrocarbon exploration, *in* Pinet B., and Bois, C., eds., The potential of deep seismic profiling for hydrocarbon exploration: Paris, Editions Technip, p. 135–140.

Yoos, T. R., et al., 1991, The Cordilleran foreland thrust belt in northwestern Montana and northern Idaho from COCORP and industry seismic reflection data: American Association of Petroleum Geologists Bulletin, v. 75, p. 1089–1106.

18. Hausen, Donald M., et al., editors, 1990, Gold '90; proceedings of the symposium (Feb. 26–March 11, 1990, Salt Lake City, Utah): Littleton, Colorado, Society for Mining, Metallurgy, and Exploration, 564 p.

Nicholson, K., 1994, Fluid chemistry and hydrological regimes in geothermal systems; a possible link between gold-depositing and hydrocarbon-bearing aqueous systems, *in* Parnell, J., ed., Geofluids: Origin, migration and evolution of fluids in sedimentary basins: Geological Society of London Special Publication 78, p. 221–232.

19. Paull, Charles K., et al., 1995, Methane-rich plumes on the Carolina continental rise: Association with gas hydrates: Geology, v. 23, p. 89–92.

Dillon, William P., et al., 1995, Resource and climate implications of natural gas hydrates, *in* Carter, L. M. H.,

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SAGE REMARKS

Alex Glover, Chief Geologist, Mideast Division, Vulcan Materials Co.

To Be or Not To Be

That is the question! Do we want to continue being employed as geoscientists? Do we want to keep our state geological surveys? Do we want to keep the U.S. Geological Survey? Do you want to keep your university geoscience job? Does your company want to keep doing business in mineral extraction or consulting? Or do we want to be snuffed out like the U.S. Bureau of Mines and some state surveys that are already gone or have one foot in the grave?

If the answer to the last question is no, then we should think seriously about doing more to promote geoscience education in the K–12 (kindergarten through twelfth grade) arena. It is there that the general public learns about what we do and why geology is important to their lives.

Children grow up with mostly positive attitudes about things presented to them, and some become legislators who will control the destiny of our profession. Abraham Lincoln said, “With public sentiment [support], nothing can fail. Without it, nothing can succeed,” and an ancient Chinese proverb is: “If you plan for a year, plant rice. If you plan for ten years, plant trees. If you plan for 100 years, educate your children.”

If geoscience as we know it is to survive, then we need to “geo-educate” our children now, for their future and ours. As David Kearns, CEO of Xerox Corporation said, “Education is not a problem in our country. It is the solution to all the others.”

In 1989 my company, Vulcan Materials, initiated a structured earth science program at its Mideast Division in order to accommodate the various requests for field trips to the company quarries. This program grew and grew to what now involves presentations at a centrally located classroom and museum along with the quarry tour. Presentations have been given to more than 50,000 children within the Mideast Division (Virginia and North Carolina) alone, and more than 8,000 children visit the earth science center yearly. Most programs are conducted by retired chief geologist Joe Guttierrez, for whom the center is named. Joe averages a class a day—two or three on some days. The kids love it! Joe loves it! The company gains, the community gains, and all win. Not only is earth science, especially in the form of geology, presented, but also many aspects of mining and how mining can be managed properly to be environmentally friendly. The kids leave well informed and excited about where materials come from, how mining works, what geologists do, and how all of these are integrated to enhance their quality of life. For the company, the program has without a doubt been the most successful, yet least costly, community service project to date and has promoted a most favorable public attitude.

In a 2,000 person nationwide survey by the Roper Public Opinion Group in 1993, respondents were asked their opinion of 22 different industries. Mining ranked next to last. Further study found that when the 49% of those polled who said they didn’t know anything about mining were ignored, mining rose to ninth place, or one place above average. This study (*Mining and Engineering Journal,* December 1993) documents the differences between educated versus uneducated publics and the impact of those differences.

Geoscience professionals and their organizations or institutions will also gain as the general public knows what they do, why they do it, and how important it is for the work to continue because of the impact on society.

So the next time someone or some group requests a presentation from us, think not of how busy we are (as always) but of how we cannot afford not to do it! And remember, if we don’t tell children (who grow up to be the general public) why geoscience is important and what we do, then who will? Imagine the case in which no one knows the importance of geoscience—including those with the opportunity to eliminate our jobs. ■

Research *continued from p. 20*

ed., Energy and the environment; application of geosciences to decision-making: U.S. Geological Survey Circular Cl108, p. 68–70.

Howell, David G., 1995, The future of energy gases [abs.]: American Association of Petroleum Geologists Bulletin, v. 79, p. 588.

20. Ringwood, T., 1982, Immobilization of radioactive wastes in SYNROC: American Scientist, v. 70, p. 201–207.

Malow, Guenter, and Ewing, R., 1981, Nuclear waste glasses and volcanic glasses; a comparison of their stabilities, *in* Moore, J. G., ed., Proceedings of the third international Symposium on the Scientific Basis for Nuclear Waste Management, Volume 3: New York, Plenum Press, p. 1089–1106.

Cooper, G. I., et al., 1994, An assessment of experimental glass corrosion by comparison with ancient analogues: Mineralogical Magazine, v. 58A, p. 193–194.

Wronkiewicz, D. J., et al., 1994, The development of glass-crystal composite waste forms for the disposal of nuclear and hazardous waste: Geological Society of America Abstracts with Programs, v. 26, no. 7, p. 470.

21. Jannasch, H. W., 1995, Microbial ecology—Life at the sea floor: Nature, v. 374, p. 676–677.

Mathur, E. J., et al., 1991, The DNA polymerase gene from the hyperthermophilic marine Archaebacterium *Pyrococcus furiosus* shows sequence homology with Alpha-like DNA polymerases: Nucleic Acids Research, v. 19.

22. Dowdeswell, J. A., et al., 1995, Greenland ice core records and rapid climate change: Royal Society of London Philosophical Transactions, v. 352A, p. 359–371.

Mayewski, P. A., et al., 1993, Greenland ice core signal characteristics—An expanded view of climate change: Journal of Geophysical Research—Atmospheres, v. 98, p. 12,839–12,847.

Harris, R. M., et al., 1995, Climate change on the Colorado Plateau of eastern Utah inferred from borehole temperatures: Journal of Geophysical Research, v. 100, p. 6367–6381.

23. Robock, Alan, et al., 1995, GCM evaluation of a mechanism for El Nino triggering by the El Chichon ash cloud: Geophysical Research Letters, v. 22, p. 2369-2372.

Walker, Daniel A., 1995, More evidence indicates link between El Niños and seismicity: Eos, v. 76, p. 33, 34, 36.

24. O’Brien, S. R., et al., 1995, Complexity of Holocene climate as reconstructed from a Greenland ice core: Science, v. 270, p. 1962–1964.

Dowdeswell, J. A., et al., 1995, Green ice core records and rapid climate change: Royal Society of London Philosophical Transactions, v. 352A, p. 359–371.

25. Gehrels, T., editor, 1995, Hazards due to comets and asteroids: Tucson, University of Arizona Press, 1300 p.

Sharpton, V., et al., editors, 1990, Global catastrophes in earth history: Geological Society of America Special Paper 247, 631 p.

26. Randel, W. J., et al., 1995, Ozone and temperature changes in the stratosphere following the eruption of Mt. Pinatubo: Journal of Geophysical Research—Atmospheres, v. 100, p. 16,753–16,754.

Kerr, R. A., 1993, Global change—Ozone takes a nose dive after the eruption of Mt. Pinatubo: Science, v. 260, p. 490–491.

Handler, P., 1989, The effect of volcanic aerosols on global climate: Journal of Volcanology and Geothermal Research, v. 37, p. 233–249.

Stommel, H. M., and Stommel, E., 1983, Volcano weather: The story of 1816, the year without a summer: Newport, Rhode Island, Seven Seas Press. ■

The National Geologic Mapping Reauthorization Act of 1996: It's a Small Bill, But There Are Those Who Love It

Peter F. Folger, *1995–1996 GSA Congressional Science Fellow*

Not all maps are created equal. Those who have placed Brunton to outcrop and thence Rapidograph to topographic map know the anxiety and, occasionally, the thrill of producing a geologic map out of no more than sweat, a steady hand, and a lot of thought. Arguably, the geologic map can be considered a meshing of science and art, replete with valuable information yet retaining the imprint of the individual mapper, along with that individual's insight, creativity, and occasional oversights. As such, the geologic map should be considered invaluable to most earth science endeavors. In 1992, even Congress realized how important geologic maps are: "Congress finds and declares that ... geologic maps are the primary data base for virtually all applied and basic earth-science investigations." The 1992 National Geologic Mapping Act (now Public Law 102-285) recognized the societal importance of geologic maps, and formally established a cooperative mapping program between the U.S. Geological Survey (USGS) and the states.

In that same act, Congress also found that geologic mapping was swiftly becoming a lost art: "... during the past 2 decades, the production of geologic maps has been drastically curtailed." What has caused this decline?

I submit that question for all earth scientists, and I suggest that it is not trivial. I further suggest that in contrast to many of the fruits of scientific endeavor, geologic maps are tangible products that can be immediately useful to a variety of nonscientists. That fact, while obvious to us, cannot be overemphasized in the halls of Congress. In fact, geologic maps, as useful results of federally sponsored geology, made enough of an impression during passage of the original 1992 act that 23 senators cosponsored the bill. The 104th Congress differs from its predecessors, however, and reauthorization of the National Geologic Mapping Act as currently written is not guaranteed. Republicans in Congress are pursuing the goal of transferring some federal functions to the states and private sector where they might be better suited. When it comes to geologic mapping activities, however, the legislative initiative to emphasize mapping by federal and state governments and parallel efforts to privatize mapping activities may be at cross-purposes.

The National Geologic Mapping Reauthorization Act, introduced by Senator Larry Craig (R—Idaho) as S. 1731 and by Representative Ken Calvert (R—California) as H.R. 3198, would renew the original 1992 law. The act is administered by the U.S. Geological Survey and consists of three main parts: FedMap, EdMap, and StateMap. FedMap is strictly the USGS mapping program and supports both USGS mapping and activities such as geophysics, paleontology, geochronology, and other disciplines that contribute information to mapping efforts. EdMap aims to develop programs to teach university earth-science students fundamental principles of geologic mapping. StateMap authorizes matching funds for competitive contracts with state geologic surveys to map 7-1/2 minute quadrangles in the states. State advisory boards identify priority areas within their state and submit proposals to the USGS that reflect those needs. Of the three programs, StateMap has received the most attention in a Congress that favors delegating federal programs to the states. Adroitly, the USGS shifted priorities within the program to boost spending on the StateMap portion from $1.1 million in FY95 to $4.4 million in FY96. Congressional support of that priority is reflected by the $4.8 million authorization in FY97 for StateMap in this year's bill. In addition, the StateMap fraction of funding under the overall program is planned to increase slightly each successive year under the reauthorization bill.

The dollar amounts devoted to the state cooperative mapping projects are truly tiny compared to overall spending for federally funded science programs. I have overheard staff members of the Senate Budget Committee jokingly refer to such small numbers as "decimal dust." Nonetheless, these cooperative programs are very important to the states and are aggressively supported by the Association of American State Geologists (AASG), which represents the states' interests. Moreover, the cooperative federal-state program strikes a responsive chord with the 104th Congress. The states' proposals reflect "local" priorities, and state-employed geologists do the mapping and strive to be cost-effective, but the final product is reviewed and approved by the USGS, ensuring that it meets stringent standards. Finally, each completed quadrangle becomes part of a national digital geologic map database at the 1:100,000 scale.

The AASG points out that geologic maps available to the public at the 7-1/2 minute scale cover only 20% of the United States. This counters any notion that the job of mapping the country is done. Indeed, the rich information contained in geologic maps will become more important as our population crowds into areas with potential for landslides, earthquakes, floods, and volcanic eruptions and as our dependence on scarce ground-water resources continues to grow. Testimony on the reauthorization received at a hearing convened in the House Subcommittee on Energy and Natural Resources on April 23 indicated no opposition to the bill, and both the House and Senate bills enjoy bipartisan support in Congress. With such a recognized need, the beginnings of a successful program, and bipartisan congressional support, what can possibly go wrong?

Welcome to your U.S. Congress. As passed by the House of Representatives, bill H.R. 2491, the seven-year balanced budget reconciliation act of 1995, contains a section entitled "Department of Interior Surveying and Mapping Efficiency and Economic Opportunity Act of 1995." The legislation aims to privatize, wherever possible, the mapping and surveying functions within the Department of Interior that are duplicated within the private sector. The private mapping industry worked hard to ensure that this language was included in H.R. 2491, and Don Young (R—Alaska), chairman of the powerful House Resources Committee, was receptive to their efforts. At first glance, this legislation fits nicely within the Republican Party goals of privatizing federal functions that duplicate or compete with the private sector. Many alert earth scientists, however, pointed out that the definition of mapping and surveying in the provision includes geologic mapping performed by agencies within the Interior Department and any other department. Two timely articles appeared in *Geotimes*, in December 1995 and June 1996 that identify these problems.

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In fact, the bill instructs the Interior Department to use its mapping personnel "… to perform only those surveying and mapping activities that are governmental in nature ... and to perform basic research." This raises important questions regarding geologic mapping: Is it basic research? What mapping activities are inherently governmental? Moreover, it appears that the intent of this provision is at odds with the reauthorization of the National Geologic Mapping Act. As sponsors of the reauthorization legislation, Senator Craig and Representative Calvert, both conservative Republicans, clearly signal their support for a strong federal and state role. These twin efforts to privatize mapping activities and reauthorize the Mapping Act each reflect a theme of the 104th Congress: to reexamine the role of the federal government in American society. The long-term implications of these two pieces of legislation, however, are very different.

The privatization language was not included in the balanced budget bill that was finally sent to President Clinton, and he vetoed the bill anyway. Nonetheless, with both congressional and administration support, the geologic mapping act reauthorization bill is expected to move toward passage this session. As such, it is perceived as a good "vehicle" for additional amendments, and proponents of mapping privatization may yet attempt to attach their provision. That is common practice simply because so few bills make it through the legislative process on their own. As with other controversial riders, the privatization amendment could seriously slow or stop the bill's progress, and that concerns bill proponents.

In a Congress battling over "big ticket" items on the legislative agenda, like raising the minimum wage, or eliminating the 4.3-cent-per-gallon gas tax, geologic mapping is indeed a minor issue in the eyes of most members of Congress. Yet whether it is popular on its own merits or because it serves as a means to an end, there are those who love it. ■

Peter F. Folger, 1995–1996 GSA Congressional Science Fellow, serves on the staff of Senator Pete V. Domenici (NM). *The one-year fellowship is supported by GSA and by the U.S. Geological Survey, Department of the Interior, under Assistance Award No. 1434-95-G-2651. The views and conclusions contained in this report are those of the author and should not be intepreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.*

Mile-High GSA Chorale and Concert at 1996 Annual Meeting

GSA will offer a performance of John Rutter's moving Requiem at the annual meeting this fall, in Denver, on Tuesday, October 29.

Those wishing to sing with the Denver Mile-High GSA Chorale should contact Carla Montgomery, Geology Department, Northern Illinois University, 312 Davis, DeKalb, IL 60115, (815) 753-9402. You must be an active, accomplished singer who reads music. Spouses and guests with comparable talent are also welcome.

In addition, we seek instrumentalists or vocalists among the GSA family who are interested in performing pieces that would complement the chorale program either as solos or accompanied by the supporting ensemble. If you are interested in such an opportunity, please contact Greg Bush, Mile-High GSA Chorale Conductor, (303) 592-1714 (mornings), or (303) 670-2349 (home office).

PUBLICATIONS NEWS FROM THE GSA

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PHANEROZOIC FAUNAL & FLORAL REALMS OF THE EARTH: THE INTERCALARY RELATIONS OF THE MALVINOKAFFRIC AND GONDWANA FAUNAL REALMS WITH THE TETHYAN FAUNAL REALM

by A. A. Meyerhoff, A. J. Boucot, D. Meyerhoff-Hull, J. M. Dickins, 1996

Biogeographical data comprise a largely neglected but potentially powerful tool for deciphering the tectonic evolution of the Phanerozoic Earth. This is true because the borders of biogeographical units are natural barriers, some of them tectonic in origin. The problem addressed in this study is that the boundaries of plates proposed by geophysicists and geologists do not always match the boundaries of biogeographical realms and lower rank units worked out by paleontologists and biostratigraphers. In this volume, biogeographical data has been compiled from early Paleozoic to Mesozoic sections worldwide, with emphasis on the broad geographical zone, or – intercalary zone – that separates the middle Paleozoic Malvinokaffric Realm and late Paleozoic and younger Gondwana Realm from the warm realms of northern origin. Within this intercalary zone, northern and southern taxa occur within the same strata, or even within the same bed. The data make it clear that biogeographers, paleontologists, stratigraphers, structural geologists, tectonophysicists, and geophysicists need to work together now to bring the powerful tool of biogeography into tectonic reconstructions and tectonic models.

MWR189, 78 p., hardbound, indexed, ISBN 0-8137-1189-4, $40.00; GSA Members $32.00

PALYNOLOGICAL CORRELATION OF MAJOR PENNSYLVANIAN (MIDDLE AND UPPER CARBONIFEROUS) CHRONOSTRATIGRAPHIC BOUNDARIES IN THE ILLINOIS AND OTHER COAL BASINS

by R. A. Peppers, 1996

Major chronostratigraphic boundaries in the Middle and Upper Carboniferous of the Illinois Basin, Western Interior Coal Province, Appalachian Coal Region, western Europe, and the Donets Basin in Russia are correlated by use of palynomorphs. Correlations are based on comparison of the first and last appearances of spore species and significant changes in relative abundance of taxa in coal beds in the Carboniferous equatorial belt. The major palynological changes at the Middle-Upper Pennsylvanian boundary are discussed in detail. The study evaluates new as well as published palynological data. Some studies of fossil plants that provide useful chronostratigraphic information also are included where appropriate. Major divisions used in the various classification systems of Carboniferous strata are discussed. This investigation reinforces some previous biostratigraphic correlations and offers different interpretations of other correlations.

MWR188, 118 p., hardbound, 1 pocket insert, ISBN 0-8137-1188-6, $55.00; GSA Members $44.00

RECONSTRUCTING THE HISTORY OF BASIN AND RANGE EXTENSION USING SEDIMENTOLOGY AND STRATIGRAPHY

edited by K. K. Beratan, 1996

The Mojave and Basin and Range structural provinces (southwestern United States) experienced a complex Neogene extensional history. Extreme southwest-directed extension in the Mid-Tertiary was accommodated by large, low-angle normal fault systems (detached faults), resulting in formation of metamorphic core complexes. Lesser amounts of extension during the late Tertiary and Quaternary were accommodated by north-south–trending, high-angle normal faults, forming elongated, fault-bounded mountain ranges separated by broad valleys. Sedimentary and volcanic strata deposited during extension preserve a record of the structural events by recording changes in paleotopography through time. This volume highlights recent advances in the study of these synextensional strata. The variety of approaches includes, field-based descriptive stratigraphic analysis, high-precision radiometric dating, detailed lithofacies analysis of depositional environments, seismic stratigraphy, computer modeling of basin geometries, biostratigraphy, and detailed field-based structural mapping. This volume grew out of a symposium held at the 1993 Cordilleran & Rocky Mountain Sections meeting.

SPE303, 224 p., paperback, indexed, 1 plate, ISBN 0-8137-2303-5, $78.50, GSA Members $62.80

AVALONIAN AND RELATED PERI-GONDWANAN TERRANES OF THE CIRCUM–NORTH ATLANTIC

edited by R. D. Nance and M. D. Thompson, 1996

Along the southeastern margin of the Appalachian-Caledonide orogen lies a collection of suspect terranes traditionally associated with the eastern (Avalonian/ Gondwanan) margin of the early Paleozoic Iapetus ocean, but which record histories of Neoproterozoic subductions that predate the inception of the Iapetus cycle. Recent advances in our knowledge of these terranes have dramatically improved our understanding of Neoproterozoic tectonics and the Paleozoic evolution of the Appalachian-Caledonian orogen, and are proving central to the development of continental reconstructions for the critical Precambrian-Cambrian boundary interval. These advances are the result of the use of precise zircon geochronology and discriminative geochemical and isotopic studies, the application of sequence stratigraphy and faunal analysis to sedimentary overstep successions, and the interpretation of these data in terms of Neoproterozoic continental configurations and peri-Gondwanan paleogeography.
This volume documents these aspects with examples from all parts of the belt.

SPE304, 398 p., indexed, paperback, ISBN 0-8137-2304-3; List price : $95.00; Member price $76.00

THE LATE QUATERNARY CONSTRUCTION OF CAPE COD, MASSACHUSETTS: A RECONSIDERATION OF THE W. M. DAVIS MODEL

edited by E. Uchupi, G. S. Giese, D. G. Aubrey, and D. -J. Kim, 1996

Data from geologic and geophysical studies of Cape Cod and southeast coastal Massachusetts were used to reconstruct the geologic history of the region and to compare this construction with that proposed by W.M. Davis in 1986. The authors' support Davis' contention that Cape Cod was formed by glacial deposition during late Pleistocene and marine and eolian processes since. However, their geologic reconstruction of Cape Cod varies from that of Davis: they believe that the glacial lower Cape extended east of its present shore nearly double Davis' estimate and that it took more than twice the time Davis estimated to attain its present form. Davis also inferred that all detritus eroded on the east side was transported northward to create the Provincetown Hook, whereas the authors propose that prior to 9500 years ago this material was transported southward to fill a depression at the Cape's elbow; it was only during the last 6500 years that the material was transported northward to form the hook. This work also suggests that historical changes in Cape Cod are not limited to natural processes as Davis suggested, but that past and present human activities, such as construction of harbors and the Cape Cod Canal, dredging of channels and mooring areas, devegetation, mining, timber harvesting, clearing of land for agriculture and unrestricted grazing, played a significant role in creating the present morphology of Cape Cod.

SPE309, 76 p., paperback. ISBN 0-8137-2309-4; List price $30.00; GSA Member $24.00

LATE HOLOCENE ALLUVIAL GEOMORPHOLOGY OF THE VIRGIN RIVER IN THE ZION NATIONAL PARK AREA, SOUTHWEST UTAH

by R. Hereford, G. C. Jacoby, V.A.S. McCord, 1996

The research described in Special Paper 310 focused on how variations of water and sediment load modify valley morphology. A specific goal was understanding the timing and causes of arroyo cutting—the catastrophic, widespread degradation of stream channels in the southwest United States beginning in the late 1800s. Large-scale surficial geologic maps portray the terraces and alluvial deposits. Dated by archaeologic context and by tree-ring methods, these deposits correlate in time with dated late Holocene alluvium of other streams on the southern Colorado Plateau. Relocated historic photographs show the channel before, during, and after arroyo cutting. Dendrohydrologic reconstruction of streamflow demonstrates that arroyo cutting occurred during unusually wet climate with large floods and was preceded by an interval of very dry climate.

SPE310, 46 p., paperback, ISBN 0-8137-2310-8; List price $25.00; Member price $20.00

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View the **Meetings** page for complete information on the 1996 GSA Annual Meeting in Denver. Use the live links to expand on the information that appeared in the June issue of *GSA Today*.

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In the **Education** section, read about GSA's educational programs, including **PEP** (Partners for Education), and Project Earth S.E.E.D. What is IEE? Find out in the **Institute for Environmental Education** section.

See our **Administration** section for information on GSA Medals and Awards, and other general information about GSA.

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The following members were elected to membership by GSA Council action during the period from September 1995 through April 1996 (* indicates transfer from Student Associate to Member).

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Cindy D. Bartlett
*Bax R. Barton
Colleen A. Barton
Stephen C. Bateman
*Graham M. Bates
Charles M. Bauer
*Ethan F. Baxter
*Mary E. Baxter
*Richard A. Beck
*Brandon D. Beierle
*Paul Belasky
*Karen G. Bemis
Chaim Benjamini
Matthew A. Benson
Felisa Bercowski
*Michael Berger
*Deborah Bergfeld
Johannes Berndsen
Troy P. Bernier
*John Bernt
Erin K. Beutel
*Kenneth A. Bevis
Prajukti Bhattacharyya
Marianne Binkin
*Glenn Bixler
Cheryl A. Bjoraker
Christopher J. Black
*David E. Black
Claude L. Blanchard III
Dawnika L. Blatter
*Imogene W. Blatz
Rebecca F. Blevins
Ronald L. Boatman
DelWayne R. Bohnenstiehl
Maeve A. Boland
*Alison J. Bolton
Polly A. Bouker
*Robin M. Bouse
*R. Larry Bowman
*Timothy K. Boyle
Robert J. Brady
Marcia L. Branstetter
Dean R. Brant
*John F. Bratton
F. Christoph Breitkreuz
*Dianne L. Brien
Tom H. Brikowski
Laura Q. Broh
*Axel Brommer
Brook E. Brosi
*Craig A. Brown
*Michelle L. Bruce
*J. Daniel Bryant
Kenneth J. Bryars
Kurt Bucher
W. Roger Buck
Mick Buckley
*Nancy Buening
*Thomas F. Bullard
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Emily Burns
William J. Burns
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David L. Butler
*Marya A. Butler
Kurt T. Byanski
Tracy C. Byrd
Donald R. Cahoon
*Jonathan Caine
*Arthur R. Calderwood
Phillip Calvin
Rion H. Camerlo
James K. Campbell
*Kathleen A. Campbell
*Matthew R. Campbell
Neil L. Campbell
Penelope Canan
Vincent M. Carbone
*Douglas S. Card
*Alice A. Cardenas
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Jon C. Carlson
Matthew T. Carrano
Martin Casey
*Teresa A. R. Castelhano
Heather L. Caudill
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Margaret E. Chai
Gavin W. Chan
Lui-Heung Chan
*Remi Charbonneau
*Paul D. Chasco
Habib A. Chaudhary
Mikhail V. Cherny
*Anne Chin
Chi-Van Chin
*Catherine A. Chmidling
*Reia M. Chmielowski
Marzena M. Chocyk-Jaminski
Dezhi Chu
Meredith D. Church
Donald L. Clark
*Douglas H. Clark
Mary S. Clark
*Scott K. Clark
George P. Clarke
*Leon J. Clarke
Thomas R. Clifton
Aron K. Clymer
*Dwight F. Coleman
*Maurice Colpron
*John E. Comstock
James N. Connelly
*Katherine A. Connors
Curtis A. Consolvo
James E. Cook
*Sandra K. Cook
Michael A. Cooley
*Frances G. Cooper
P. G. Cooray
Maureen K. Corcoran
Edward W. Correll
Catherine M. Corrigan
Paul K. Coski
Joseph E. Cotten, Jr.
Mamadou Coulibaly
John A. Craven III
Todd N. Creamer
David S. Cronmiller
Edgar K. Cross
*Warwick A. Crowe
Paul G. Cutlip
William B. Dade
Angela T. Daniels
James M. Daniels
Stefanie Dannenmann
*BarbaraAnn Darling
Michael R. Daugherty
Philip A. Davis
Alexander Y. Davydenko
*Amy Day-Lewis
*Laura De Santis
*Michael J. DeFrisco
Rebecca T. DeKeyzer
Fei-Wen Deng
*Jane F. Denny
Janice J. Dependhal
*Pauline Deutz
Paul J. Dial
Arne R. Diercks
Carlo Dietl
James P. Diffily
*Frank J. DiGnazio
James S. Dinger
Suvasis Dixit
*Ron M. Dixon
William R. Doar
Clark A. Dobbs
Robert W. Dobson
Daniel H. Doctor
Luis M. Domenech
*William J. Domoracki
*Bruce C. Dougan
*Matthew T. Drake
Robert J. Drimmie
Lihua Duan
Kevin A. Dumont
Mack S. Duncan
*Carol A. Dupuis
*Thomas R. Dwyer
Linda Jo Dyer
James L. Dyson
*Janet F. Dyson
David K. Eastwood
Rebecca M. Eby
Earl V. Edris, Jr.
Carol A. Edwards
*Michael A. Edwards
John R. Eggleston
*James M. Eidem
Tambra L. Eifert
*Sandrine A. Elinski
*Stephen L. Elliott
*William S. Elliott, Jr.
Martha C. Eppes
Marshall Eschetz
*Inge Ewing
Ryan D. Fairfield
*Claudia M. Falkner
*Raymond P. Fallon
*Riccardo Fantini
Kenneth A. Farley
Douglas J. Faulkner
*John M. Faustini
LeeAnn Feher
Robert P. Felder
*Robert J. Ferguson
Luca Ferrari
Brooke K. Fiedorowicz
Eric J. Fielding
Mark E. Finley
*Mark P. Fischer
*Jesse E. Fisher
Martin D. Floyd
*Natalie P. Flynn
*Godlove T. Fonjweng
*Robert E. Forsberg
*Brenda L. Fouch
*Robert S. Fousek
James E. Fox
*Umberto Fracassi
George C. Frederickson
Andrew B. Freed
Ann M. Fritz
Theresa L. B. Fritzel
Duane G. Froese
*Jeanne M. Fromm
*Gina M. Frost
Kelly Hobby Fuks
Sylvie L. Furlan
*Francis C. Furman
*Robert R. Gaines
*Carol S. Galand
David F. Gale
Judith A. Gale
*Tanwi Gangopadhyay
Marshall W. Gannett
Elena Centeno Garcia
*Glen T. Garland
Carolyn E. Garman
Jennifer M. Garrison
Nichole D. Gelardi
*Richard E. Gerber
Martha L. Gerdes
*Christine J. Gerdon
*Christopher N. Gerteisen
*Gary L. Gianniny
Mark T. Gibbs
*Thomas E. Gill
*Mary L. Gillam
Jeffrey J. Gillis
*Gary M. Gin
Scott D. Giorgis
*Brian K. Giroux
Edwin Gnos
Nicola J. Godfrey
*Karen A. Goldenberg
*David W. Goldsmith
*Edward J. Gona
*Carlos M. Gonzalez-Leon
Gerald S. Goodman
Ian T. Gordon
Sheryl L. Gordon
Richard K. Gorton
*Matthew C. Goss
Rob M. A. Govers
*George W. Grader
*Robert E. Graham
*Scott E. Graham
Meg C. Grantham
*Rhonda M. Grasso
Georg H. Grathoff
William D. Green
*David C. Greene
*Tracy P. Gregg
*Hermann Grill
Armand R. Groffman
Arne Gronlie
*Eric E. Grossman
Larry D. Guenther
*Laura A. Guertin
*Todd M. Gunsher
Dennis W. Haas
*Paul C. Hackley
Mark R. Hafen
*Ann M. Hagni
Brian A. Haley
*Todd Halihan
April S. Hall
*Brenda A. Halminiak
Monty A. Hampton
Paul A. Hanczaryk
*Jennifer S. Hango
David J. Hankins
Thomas C. Hanks
Jamie D. Hanlon
Christina N. Hansen
*Lori M. Hanson
*Cheryl Hapke
*Mustafa M. M. Hariri
*Daniel E. Harlov
Charles L. Harper
*Fiona Harper
*Michael J. Harrison
Judson W. Harvey
*Judith K. Haschenburger
*Stephen T. Hasiotis
Isamu Hattori
Peter D. W. Haughton
Jason E. Haugland
*Christoph A. Hauzenberger
*Laura A. Heberle
Tracey Hebert
*Andrew B. Heckert
*Daniel Heimgartner
Jan T. Heine
John G. Helms
Gideon M. Henderson
*Adam T. Henry
Niall D. Henshaw
*Harvey Henson, Jr.
Bruce E. Herbert
Darrin W. Herbst
*Stephen J. Herdman
Michael W. Hernandez
Salvador S. Hernandez
*Eileen A. Herrstrom
*Pennilyn Higgins
*Sean M. Higgins
Stefan J. Higgins
Steven S. Hill
Denise J. Hills
Scott P. Hippensteel
Lee M. Hirsch

Members *continued on p. 26*

New GSA Fellows

The following Members were advanced to Fellowship in May 1996.

Claude J. Allègre
John R. L. Allen
Jean M. Bahr
Daniel B. Blake
Joanne Bourgeois
Maryellen Cameron
Chris I. Chalokwu
Joan R. Clark
Clay M. Conway
Morgan J. Davis, Jr.
Edward E. Geary
R. Brooks Hanson
R. James Kirkpatrick
Kenneth P. Kodama
Paul K. Link
David B. Loope
Gretchen Luepke
Stephen Marshak
Gautam Mitra
Robert W. Ridky
Philip A. Sandberg
Marilyn J. Suiter
Lynn M. Walter
Peter W. Weigand

Members *continued from p. 25*

*M. L. Hirsh
Joshua J. Hirten
*Margaret M. Hiza
*David E. Hobbs
Rex A. Hodges
Michael F. Hoffmann
Bradley E. Hoge
Terri S. Hogue
*Kimberly S. Holland
*Edith K. Hollister
*Joshua W. Holloman
*Benjamin K. Holtzman
*Debbie L. Hopkins
Frank Horna
Ferenc Horvath
Stacy B. Howard
Stephen G. Howell
Feng Sheng Hu
Bernard E. Hubbard
*Trent D. Hubbard
*John R. Hubeny
Sam W. Huddleston
Glenn F. Huff
Enrique J. Hung
Allyne D. Hunter
Robert F. Hunter
David W. Hyndman
*Bradley R. Ilg
Ismoenandar Ilyas
Jasim Imran
*Alexander Iriondo
Kathryn A. Jacobs
Bruce E. Jaffe
Jon J. Jagello
*Joerk Jarick
Shanka Jayaganapathy
*Andreas D. Jazdanian
Albert D. Jefferson
Shannon M. Jett
David G. Jewett
Jiu J. Jiao
Kevin H. Johannesson
*Mary K. Johns
*David D. Johnson
*Jenda A. Johnson
Stephanie E. Johnson
*Thomas M. Johnson
John W. Johnston
Bobby W. Jones
Kimberly R. Jones
Mary Clare Jones
*James W. Jordan
*Leah H. Joseph
*Steven J. Jusczuk
*Thomas C. Juster
Klaus F. Kaiser
*Jeong-Won Kang
Eugeney B. Karabanov
P. Andrew Karam
*Simon A. Kattenhorn
*Nancy L. Katyl
*Christopher M. Keane
Kevin D. Keatts
*Myra Keep
John D. Keisling
Patrick E. Kelleher
*Karen Duttweiler Kelley
Bronwyn K. Kelly
*Oliver K. Kenen
Loisa Kerwin
*Richard A. Ketcham
Arshad A. Khan
*Carrie Kievman
Deborah L. Kilb
Jin-Wook Kim
Jong-Yeon Kim
Jun-Mo Kim
*Geoffrey S. King
*John W. King
Susannah Kitchens
Arno Kleber
Andre C. Klein
Darrell S. Klingman
Peter W. Knightes
Peter A. Knoop
*Jeffrey R. Knott
Michael E. Konen
Randy L. Korotev
Steven W. Korte
*John H. Kramer
Kurt A. Kraske
Dana R. Kreeger
*Ilan Kreisel
Mary Krick
*Michael A. Krol
Robert G. Kruppa
*Kelly A. Kryc
*Andrika J. Kuhle
*Mark A. Kulp
Eve L. Kuniansky
*Dwight D. Lamb
Rebecca A. Lange
*Nadine L. Langley
*Robert M. Langridge
*Phillip C. Larson
Tonja M. Larson
Roy E. Lassus, Jr.
Dawn L. Lavoie
Dae-Ha Lee
Eut-Hyeong Lee
*Jae Il Lee
*Seung R. Lee
*Steven E. Lee
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Christopher T. Lehmann
Christopher A. Lepczyk
*Stephen A. Leslie
*Elisabeth Levac
Taohong Li
Stephen R. Libbey
*Nathaniel A. Lifton
Li Lin
*Tomas K. Liogys
Jeffrey H. List
Junzhe J. Liu
Xianhua Liu
*Lila M. Lohr
Catharine London
Robert Lopez
*Linda M. Lortz
Linda L. Lotto
Roy B. Luck
Peter G. Luetkehans
*Wei Luo
*Danielle J. Luttenberg
*Mary Ann Madej
Ian P. Madin
Ruben G. Magakyan
*Todd D. Maguire
*Laura D. Mallard
Stephen M. Maloney
Terri L. Maloof
*Ned Mamula
Benjamin E. Siyowi Mapani
David R. Marchant
Paul E. Marin
Bryan G. Mark
Janice C. Marsters
Jerry W. Martin
Martha J. Martin
*Peter Martus
*Joseph A. Mason
Jason A. Mastrine
*Raimundo J. Matos-Perez
*Jeffrey M. Matthews
Mark H. F. Mauthner
*Michael B. Maxwell
Jared D. May
Bea Mayes
Michael A. Mayhew
Randolph A. McBride
William D. McCaffrey
Thomas L. McClain
Ellen M. McClure
Megan E. McCoy
*Jason T. McCuistion
Heather G. McElroy
*Brian P. McFarland
*Cathleen E. McGinnis
*Eileen M. McGowan
Curtis R. McKinney
Gerrard McMahon
Galadriel J. McNaught
Trudy A. Mechum
Lawrence D. Meckel
Anna K. Meegan
Matthew T. Mellon
Brian P. Menounos
Brian R. Merrill
Tad W. Messenger
Robert P. Meyer
Elizabeth V. Meyers
Jeremy D. Middleton
*Carolyn H. Mikell
*Elizabeth J. Miksa
*Gretchen L. Miller
Mary Stewart Miller
*Michael S. Miller
*Nathaniel R. Miller
*Scott R. Miller
John D. Mills
Susan Mills
Charles E. Mitchell
*Michael E. Mitchener
Andreas Moeller
*Robert R. J. Mohler
*Timothy G. Monaghan
Thomas Moore
*Melanie Moreno
*Meghan M. Morrissey
*Jared R. Morrow
Jennifer Mortick
Carol L. Mueller
Tamara C. Mullis
Walter C. Munly
*Jeffrey S. Munroe
Adam E. Murphy
*Allen B. Murray
*John J. Murray
*Keenan M. Murray
*Stephen C. Myers
Beth M. Nadeau
Gregory Nadon
*Robert S. Nail
Tamara J. Nameroff
James H. Natland
Philip S. Neuhoff
Klaus Neumann
*Matthew E. Neutra
Hal H. Newell
John G. Nickerson
Stelios Nicolaides
Daria L. Nikitina
*Robin E. Nimmer
Julia A. Nord
*Laura E. Norton
Jon S. Novick
Michael A. O'Neal
*Michael L. O'Neal
James A. O'Neill, Jr.
*Lori A. Oakes-Coyne
Adriana C. Ocampo
Anton E. Oleinik
Douglas H. Oliver
*Amalia M. Olivera-Riley
Jennifer J. Olson
Thomas D. Olszewski
*David E. Orr
Walter E. Osborne
Laurie J. Osher
James R. Ostdick
Marino Ostos
Patricia A. Painter
*Dorothy K. Pak
*Jozsef Palfy
*David H. Palmer
Richard D. Pancost
Kuppusamy Panneerselvam
Leland R. Pannell
*Lisa E. Park
*Amy E. Parker
*Ronald L. Parker
Michael B. Parsons
Andrew D. Passarelli
Keyur P. Patel
Donald A. Pattalock
*John A. Peck
Timothy J. Peck
Brian J. Peer
*Anne B. Peery
John M. Pekala
*Narender Pendkar
Rona Penn
*Sarah C. Penniston-Dorland
*Daniel J. Perez
*Dean R. Perry
*Suzanne C. Perry-Huston
*Mark J. Peters
*Shanan E. Peters
Karl Peterson
*Dawn M. Peterson-Arnold
William D. Petroutson
*Oleg V. Pinous
*Scott M. Pinsonnault
Charles G. Pippin
Timothy J. Piwowar, Jr.
Emil Platon
Mitchell A. Plummer
*Olaf G. Podlaha
Michael Polenz
Brian D. Polkinghorn
Paul E. Potter
Chris J. Poulsen
*Linda A. Powell
Vishwa Ranjan Prasad
Nicole E. Preuss
*Susan R. Prew
*Jonathan D. Price
Linda M. Price
*Mason A. Pritchett
Alexander A. Prokopenko
Christopher R. Pyke
Andrew I. Quarles Van Ufford
Sally S. Radford
Janina K. Rafalska
Margaret A. Rafter
Douglas E. Rambo
Barbara Ranson
R. Ragnar Rasmussen
*Jacqueline C. Rasmusson
*Jesse E. Rawling III
*Carolyn R. Rebbert
*Kathleen M. Reddy
Kevin L. Reed
James S. Reichard
*Paula J. Reimer
*Ella Reinhard
*Edvard G. Reinhardt
James Repka
*Michael W. Ressel
*Jennifer R. Reynolds
*Chul Woo Rhee
Amy L. Rhodes
Brian Richardson
Richard D. Ricketts
Moira K. Ridley
*Richard M. Risek
Scott M. Ritter
Joe H. Robbins
*Lonna M. Roberts
Bruce E. Robertson
*Kim R. Robeson
*Dawn M. Robinson
Rebecca S. Robinson
Sarah F. Robinson
Antonio B. Rodriguez
Reinhard K. Roessling
*Pete Roffers
*Raymond Rogers
*Jeffrey L. Ronck
Wei Rong
*Steven Roof
*Timothy P. Rose
Nina D. Rosenberg
Mark A. Rosin
Andrew R. Ross
*Joyanto Routh
Elizabeth L. Rowan
Thomas A. Roznovsky
*Jeffrey N. Rubin
Ian C. Russell
John H. Russell
Richard A. Rymerson
Deanne M. Sabarese
*James C. Sagebiel
Ata Sagnak
Paul M. Sak
*Peter B. Sak
*Sherry D. Samson
Peter A. H. Samuels
Rick J. Santa
Kim Sapp
Satavisa Sarkar
Jaydeep J. Sathaye
*Dorothy A. Satterfield
*Michael Schaaf
William T. Schaeffer
*Jeffrey P. Schaffer
*Steven H. Schimmrich
Geary M. Schindel
*Bennetta L. Schmidt
Matthew W. Schmidt
Shane R. Schmidt
*Mark D. Schmitz
John A. Schnedl
Christopher M. Schneider
Carl W. Schnell
Florian M. Schwandner
Carrie Schweitzer-Hopkins
Jennifer Diane Schweyer
Roberta Score
*Robert J. Scott
*Dogan Seber
Frederick C. Seeber
Dean M. Senner
Jason A. Sentivany
*Parvinder S. Sethi
*Abbas Seyedolali
Paul M. Shannon
Panka J. Sharma
Shannon C. Shaw
Kevin F. Shea
Mamdouh A. Shebl
Tai-Chyi Shei
Brian L. Sherrod
*Elizabeth R. Sherwood
*Todd C. Shipman
*Kurt A. Shoemaker
William J. Showers
Douglas L. Shrake
*Gregory S. Siek
Paul G. Silver
*David Kristjan Simpson
Eric O. Simpson
Chris Sinton
Steven P. Sittler
Eric A. Sivers
*Derek J. Sjostrom
Marta K. Sjovall
Robyn K. Skelton
Deborah M. Skilliter
*Suzanne M. Smaglik
*Erik W. Smith
J. Bailey Smith
Janice L. Smith
*Laryn M. Smith
*Loren H. Smith
*Scott D. Smith
Michael Smoliar
*Catherine M. Snelson
David S. Snipes
*Hilde Snoeckx
Jennifer N. Snow
Adewale A. Sobande
*Ed R. Sobel
Michael Sommer
*Rachel E. Sours-Page
*Robert J. Spang
Dan Spinogatti
Carol Stack
*Gregory P. Stanton
Stephen Stanton
*John-Mark G. Staude
Maureen B. Steiner
Mark W. Stelford
Daniel A. Stephen
Kevin P. Stephens
Gordon M. Stevens
Keith H. Stewart
*Michael A. Stewart
Ingrid Stober
Stephanie A. Stockman
Karen R. Stockstill
*Daniel F. Stoeckli
Richard E. Stotts
Margaret M. Streepey
Widodo Sudomo
Michael A. Sullivan
Richard Sullivan
V. Marie Sullivan
*Kathryn H. Swaggart
*Susan K. Swanson
Robert E. Swartwout
*John C. Tacinelli
Glen S. Tanck
Vikas Tandon
Anna K. Tary
*Ann M. Tattersall
*James B. Tautfest
*Calvin D. Taylor
*David L. Taylor
*Philip Teas
Andrew M. Templeton
Hui Teng
Mark A. Terrell
Berry H. Tew, Jr.
David T. Thesenga
*Lisa D. Thieme
Suzanne M. Thomas
*Paul A. Thorn
Kimberly M. Thorup
Melinda R. Tidrick

*Kennen S. Tillman
*Jeffrey W. Tolhurst
A. Kurt Tollestrup
Bridget H. Tompkins
Nalini Torres
Michael E. Torresan
*Mary K. Tozer
David L. Trexler
Mark J. Triebold
*Michael D. Tryon
*Hiroyuki Tsutsumi
Gregory E. Tucker
Andrei Tudoran
Robert J. Turner
*Leslie A. Turrini-Smith
R. Thayer Tutt, Jr.
Anne G. Udaloy
*Ashraf Uddin
Ingrid A. Ukstins
Nuran Unsal
Gerald A. Unterreiner
*Ruben D. Uribe
David W. Valentine
*Ricardo A. Valls
*Marcus R. Van Baalen
Orson Van De Plassche
Olivier Vanderhaeghe
*Robert D. VanGundy
*Bradley W. Vann
Stephen B. Vargo
*Francisco J. Vega
*Guadalupe Velazquez
*Margaret E. Venable
Natasa J. Vidic
Robert K. Vincent
Wesley J. Vins
Robert D. Voegele
Grant D. Wach
Bradley A. Wake
*Jessica R. Walcott
Brian P. Wallick
Cong Wang
*Erchie Wang
Jinhui Wang
Zhaosheng Wang
*Charles W. Ward
*David B. Ward
Jane R. Ward
Arthur J. Warner
Barry G. Warner
John J. Watkins
James S. Watson
*Alecia L. Wawrzynski
Michael D. Weaver
*Bambi Jo Webb
Andrew J. Webber
Gary R. Webber
*John C. Weber
*William A. Webster
*Jennifer A. Weekes
Arlo B. Weil
*Josef P. Werne
Timothy N. Whalen
*Chris E. White
*Elizabeth A. White
John C. White
William M. Whiting
*D. Michelle Williams
*Kirk D. Williams
*Ernst Willingshofer
Chris H. Willoughby
Denise E. Wilt
*Jennifer E. Winkler
*Pamela A. Winsky
Margaret Winslow
Christine L. Wiscombe
*James M. Wise
Richmond Wolf
*Brent B. Wolfe
*Anne M. Woods
Stephen R. Worthington
*Dawn J. Wright
*Eric E. Wright
Melinda C. Wright
Wayne R. Wright
*Changde Wu
Chia-Hsin C. Wu
*Jonathan G. Wynn
Thomas C. Wynn
Michael E. Wysession
Xiaogang Xie
Fangjian Xue
Feng Xue
Simmy Yau
Qiucheng Ye
Cornelia Yoder
*Chan M. Yoo
*Robert S. Young
Raul A. Ysaccas
George F. Zack
*Terri D. Zeman
Xi-Guang Zhang
Norey Zimmerman
Kris A. Zumalt
*Gretchen Zwart ■

New GSA Student Associates

The following Student Associates became affiliated with the Society during the period from September 1995 through April 1996.

Sherry J. Aarnes
Peter N. Adams
Kristin L. Addis
Carol J. Akins
MaryJo Alfano
G. Guillermo Almaguer
Nathaniel M. Anderson
Rita L. Andrews
Gideon S. Applegate
Timothy M. Armato
Matthew A. Arsenault
Steven N. Bacon
Brendon D. J. Bailey
Emily S. Banks
Andrew D. Barron
Andy C. Beck
Mark D. Behn
Jennifer A. Beison
Ken J. Bell
Billy W. Belt
Callan X. Bentley
Tamara C. Biegas
Adam E. Bielecki
Brandon D. Boggan
Stanley P. Bonis
Maxwell W. Borella
Matthew Bowman
Jeremy W. Boyce
Nathanael Brooks-English
Michelle D. Brower
Steven M. Brown
John H. Burris
Wendy M. Buser
Mark E. Campos
Melissa L. Carlisle
MarLung Chin
Elli D. Chouparova
Oliver B. Christen
Jodi A. Clark
Paula S. Clifton
Brett A. Conaway
Kimberly M. Connor
Scott P. Cooper
Celeste A. Cosby
Annette Cossitt
Shannon L. Couch
Janet M. Cowling
William V. Craft
Brian T. Croyle
Tim Cullison
Betsy L. Cunningham
Daniel Curewitz
James B. Davis
Matt R. Davis
John W. Day
Elizabeth A. Debiak
Mark S. Deggeller
Stacy J. Delzer
Gregory A. Demmin
Nikki L. Dennis
Jon M. DeYoung
Lisa C. Doornbos
Robin M. Dornfest
Kristen M. Dougherty
Donna W. Driskill
Owen W. Duckworth
Debra L. Duncan
Derek W. Duncan
Tracey L. Eastridge
David J. Eden
Jonathan T. Eden
Bryan A. Eklund
Dane C. Evans
Peter J. Evans
Michelle L. Fassell
Joseph J. Favat, Jr.
Theresa E. Fitzsimons
Jim Fleming
Andrew Flint
Suzanne R. Frattaroli
Michael J. Friedhoff
Brian Fugiel
Amy M. Gaffney
Neal A. Gage
Vicky A. Gallardo
Marion C. Gannaway
David S. George
Brian J. Gerike
Stacey L. Geyer
Gregory W. Gibbs
Philip C. Giordano
Jason D. Godbout
Damon Y. Godfrey
Cory J. Godwin
Jeffrey S. Grandy
Amy Gray
Christopher A. Greenhoot
Cynthia G. Greenlaw
Kyra A. Grundeman
Alisa A. Haase
Anthony G. Hall
Cynthia R. Hall
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August *BULLETIN* and *GEOLOGY* Contents

GEOLOGICAL SOCIETY OF AMERICA
BULLETIN
Volume 108, Number 8, August 1996

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GEOLOGY

VOLUME 24
NO. 8
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AUGUST 1996

Forum

CALENDAR

Only new or changed information is being published in *GSA Today*. A complete listing can be found in the **Calendar** section on the Internet: **http://www.geosociety.org.** Send notices of meetings of general interest, in format above, to Editor, *GSA Today,* P.O. Box 9140, Boulder, CO 80301, E-mail: editing@geosociety.org.

1996 Penrose Conferences

October 1996

October 8–14, **Exhumation Processes: Normal Faulting, Ductile Flow, and Erosion,** Island of Crete. Information: Uwe Ring, Institut für Geowissenschaften, Universität Mainz, Becherweg 21, D-55099 Mainz, Germany, 49-6131-392164, fax 49-6131-394769, E-mail: ring@mzdmza.zdv. unimainz.de.

April 1997

April 24–30, **Paleocene/Eocene Boundary Events in Time and Space,** Albuquerque, New Mexico. Information: William A. Berggren, Department of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, (508) 289-2593; fax: 508-457-2187, E-mail: wberggren@whoi.edu.

Fall 1997

Faults and Subsurface Fluid Flow: Fundamentals and Applications to Hydrogeology, New Mexico. Information: William C. Haneberg, New Mexico Bureau of Mines and Mineral Resources, New Mexico Institute of Mining and Technology, 2808 Central Ave., SE, Albuquerque, NM 87106, (505) 262-2774, fax: 505-255-5253, E-mail: haneberg@mailhost.nmt.edu.

1996 Meetings

September

September 19–20, **Mineral Dusts—Their Characterization and Toxicology** Symposium, Washington, D.C. Information: Meetings Dept., SME, P.O. Box 625002, Littleton, CO 80162-5002, (800) 763-3132, (303) 973-9550, fax 303-979-3461, E-mail: smenet@aol.com, Internet: http://www.smenet.org.

November

November 14–16, **Seismic Hazards in the Las Vegas Region,** Las Vegas, Nevada. Information: Jim Werle, Converse Consultants, 731 Pilot Rd., Ste. H, Las Vegas, NV 89119, (702) 269-8336, fax 702-269-8353, E-mail: converse@enet.net.

November 20–22, **2nd Annual Strategic Environmental Research and Development Program Symposium,** Vienna, Virginia. Information: Erin Cannelli, Labat-Anderson Inc., 8000 Westpark Dr., Ste. 400, McLean, VA 22102, (703) 506-1400, ext. 512, fax 703-506-0946, E-mail: Erin_Cannelli@ laib.labat.com.

1997 Meetings

January

January 6–8, **High-resolution Geophysics Workshop,** Tucson, Arizona. Information: Ben K. Sternberg, LASI, MGE Dept., Bldg. #12, University of Arizona, Tucson, AZ 85721, (520) 621-8376, fax 520-621-8330, E-mail: hires97@mge.arizona.edu.

May

May 8–9, **Institute on Lake Superior Geology 43rd Annual Meeting,** Sudbury, Ontario, Canada. Information: Tracy Livingston, Resident Geologist's Office, Ontario Geological Survey, Sudbury, Ontario P3E 6B5, Canada, (705) 670-5741, fax 705-670-5681, E-mail: meyerw@gov.on.ca.

July

July 1–9, **International Association of Meteorology and Atmospheric Sciences—International Association for the Physical Sciences of the Oceans** joint assembly, Melbourne, Australia. Information: IAMAS/IAPSO Secretariat, Convention Network, 224 Rouse St., Port Melbourne, Victoria 3207, Australia, phone 61-3-9646-4122, fax 61-3-9646-7737, E-mail: mscarlett@ peg.apc.org.

July 28-August 1, **Second International Conference on Geoscience Education,** Hilo, Hawaii. Information: M. Frank Watt Ireton, GeoSciEd II, American Geophysical Union, 2000 Florida Ave., NW, Washington, DC 20009, E-mail: fireton@kosmos.agu.org.

August

August 17–21, **PaleoForams '97,** Bellingham, Washington. Information: Charles A. Ross, Dept. of Geology, Western Washington University, Bellingham, WA 98225-9080, (360) 650-3634, fax 360-650-3148, E-mail: rossjrp@ henson.cc. wwu.edu.

August 30–September 5, **Large Meteorite Impacts and Planetary Evolution,** Sudbury, Ontario, Canada. Information: B. O. Dressler, Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058-1113, (713) 486-2112, fax 713-486-2162, E-mail: dressler@lpi.jsc.nasa.gov.

GSA SECTION MEETINGS

Call for Papers — 1997

NORTHEASTERN SECTION

March 17–19, 1997 • Sheraton Valley Forge Hotel, King of Prussia, Pennsylvania

Abstract Deadline: **November 12, 1996**

Submit completed abstracts to:
Allan M. Thompson, Department of Geology, University of Delaware, Newark, DE 19716-2541, (302) 831-2585, thompson@bach.udel.edu

SOUTH-CENTRAL and ROCKY MOUNTAIN SECTIONS

March 20–21, 1997 • University of Texas, El Paso, Texas

Abstract Deadline: **November 25, 1996**

Submit completed abstracts to:
Elizabeth Y. Anthony, Department of Geological Sciences, University of Texas, El Paso, TX 79968-0555, (915) 747-5483, anthony@geo.ltp.edu

SOUTHEASTERN SECTION

March 27–28, 1997 • Auburn University, Auburn, Alabama

Abstract Deadline: **December 2, 1996**

Submit completed abstracts to:
Charles E. Savrda, Department of Geology, Auburn University, Auburn, AL 36849-5305, (334) 844-4893, savrdce@mail.auburn.edu

NORTH-CENTRAL SECTION

May 1–2, 1997 • The Concourse Hotel, Madison, Wisconsin

Abstract Deadline: **January 9, 1997**

Submit completed abstracts to:
Bruce Brown, Wisconsin Geological & Natural History Survey, 3817 Mineral Point Rd., Madison, WI 53705, (608) 263-3201, babrown1@facstaff.wisc.edu

CORDILLERAN SECTION

May 21–23, 1997 • Kona Surf Resort and Convention Center, Kailua-Kona, Hawaii

Abstract Deadline: **January 24, 1997**

Submit completed abstracts to:
Fred MacKenzie, Department of Oceanography, University of Hawaii–SOEST, 1000 Pope Road, Honolulu, HI 96822, (808) 956-6344, fredm@soest.hawaii.edu

1997 SECTION MEETING
ABSTRACT FORM REQUEST

To: GSA Abstracts Coordinator, P.O. Box 9140, Boulder, CO 80301-9140 or E-mail: ncarlson@geosociety.org

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1996

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October 28–31
Colorado Convention Center

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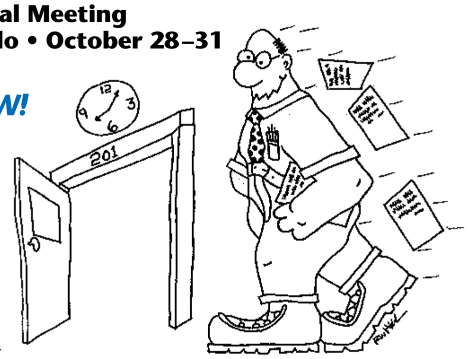

Registration information and full course descriptions were published in the June issue of *GSA Today*. To register, contact Edna Collis, Continuing Education Coordinator, GSA headquarters, (303) 447-2020, ext. 134; E-mail: ecollis@geosociety.org.

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The University of Oklahoma has a tenure-track position for a structural geologist in the School of Geology and Geophysics; pending University approval. Entry-level applicants are preferred, but in exceptional cases other levels may be considered. Preference will be given to those with interests in experimental and/or theoretical approaches as applied to the field to solve problems in structural geology. Numerical modeling is considered an essential tool. The Ph.D. is required at the time of appointment. The successful candidate must have commitment to both undergraduate and graduate (M.S. and Ph.D.) education, and equally develop an externally-funded research program.

The structural-research facilities within the school, beyond standard equipment, include access to the interdisciplinary, state-of-the-art rock mechanics laboratory which is part of the University Rock Mechanics Institute. This laboratory has a fully automated acoustic emission system, three, MTS 3kb load cells and frames as well as in-house designed high pressure equipment. The School is part of the College's Geoscience computing Network and the position holder will have a work station that uses ABAQUS, among other systems, for numerical modeling.

Applications, including resume, publication lists, college transcripts, statement of research interests, and names, addresses, and phone numbers of at least three references should be sent to Dr. R. D. Elmore, School of Geology and Geophysics, University of Oklahoma, Norman, 73019. Salary will be competitive and commensurate with experience. Application review will begin October 1, but the position will remain open until filled. University of Oklahoma is an equal-opportunity/affirmative action employer. Women and minorities are encouraged to apply. The university has a policy of being responsive to the needs of dual-career couples.

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QSC seeks strong researcher at the doctoral level with the desire and ability to develop funded research program in an area of either paleoenvironmental interpretation of fluvial stratigraphy and landforms, fluvial mechanics and sediment transport, paleoflood hydrology and flood geomorphology, watershed management and anthropogenic impacts to riverine environments, or coupled field-based fluvial studies and modeling. Opportunities exist for participation in graduate programs at the University of Nevada, Reno and the University of Nevada, Las Vegas. Successful candidate will posses a doctorate in geology, physical geography or a related discipline; demonstrated interest and abilities in the application of geomorphic principles toward resolving environmental issues related to fluvial systems as well as enhancing the management and restoration of fluvial landscapes; excellent communication skills as evidenced by peer-reviewed publications, conference and symposia presentations; evidence of successful development of research proposals and performance of research; and evidence of ability to secure grant and contract funding. Salary competitive and commensurate with qualifications. DRI offers an excellent benefits package. Position will be in either Las Vegas or Reno, Nevada. For further information, contact Dr. Nick Lancaster, Search Committee Chairman at (702) 673-7304 or E-mail nick@maxey.dri.edu. Closes: 11/4/96. Submit vitae, statement describing research interests and names, addresses and telephone numbers of 4 references to: Recruitment Office, Desert Research Institute, University & Community College System of Nevada, P.O. Box 19040, Las Vegas, NV 89132-0049. DRI is an Affirmative Action/Equal Opportunity Employer, hiring only U.S. citizens and persons authorized to work in the U.S.

STRATIGRAPHY / BASIN ANALYSIS

The Department of Geological Sciences of Rutgers, The State University of New Jersey (New Brunswick) seeks to fill an anticipated tenure-track position at the Assistant Professor level in the field of Stratigraphy and Basin Analysis beginning in September 1997. Exceptionally accomplished applicants at more senior levels will be considered.

We seek candidates with proved research capability in integrating geochemical, geophysical, and stratigraphic data. While the subdiscipline is open, we desire expertise in isotopic stratigraphy, magnetostratigraphy, biostratigraphy, or cyclostratigraphy to complement current faculty strengths. The successful candidate should interact with ongoing regional and inter-regional studies; these include current projects on the rift, passive margin, and foreland basins represented in the New Jersey region and their global counterparts. Our goal is to establish and maintain a gas mass spectrometry or magnetostratigraphy/multi-sensor track laboratory in collaboration with the new faculty member. In addition to developing an innovative, forward-looking research program, a solid commitment to undergraduate and graduate teaching is required.

A curriculum vitae, statement of research interests, and the names of four references should be sent by 15 November, 1996 to Dr. Kenneth G. Miller, Chair of the Search Committee, Department of Geological Sciences, Rutgers University, Piscataway, NJ 08855-1179. Rutgers University is an equal opportunity/affirmative action employer.

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1997

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

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

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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 1997 Salt Lake City Annual Meeting or the 1998 Toronto Annual Meeting.

Proposals must be received by December 1, 1996. Selection of courses for 1997 will be made by February 1, 1997. For those planning ahead, we will also consider courses for 1998 at that time.

For proposal guidelines or information, contact:

Edna Collis, Continuing Education Coordinator,
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AVALONIAN AND RELATED PERI-GONDWANAN TERRANES OF THE CIRCUM-NORTH ATLANTIC

edited by R. D. Nance and M. D. Thompson, 1996

Along the southeastern margin of the Appalachian-Caledonide orogen lies a collection of suspect terranes traditionally associated with the eastern (Avalonian/Gondwanan) margin of the early Paleozoic Iapetus ocean, but which record histories of Neoproterozoic subductions that predate the inception of the Iapetus cycle. Recent advances in our knowledge of these terranes have dramatically improved our understanding of Neoproterozoic tectonics and the Paleozoic evolution of the Appalachian-Caledonian orogen, and are proving central to the development of continental reconstructions for the critical Precambrian-Cambrian boundary interval. These advances are the result of the use of precise zircon geochronology and discriminative geochemical and isotopic studies, the application of sequence stratigraphy and faunal analysis to sedimentary overstep successions, and the interpretation of these data in terms of Neoproterozoic continental configurations and peri-Gondwanan paleogeography. This volume documents these aspects with examples from all parts of the belt.

SPE304, 398 p., indexed, paperback, ISBN 0-8137-2304-3,
List price $95.00, Member price $76.00

THE LATE QUATERNARY CONSTRUCTION OF CAPE COD, MASSACHUSETTS: A RECONSIDERATION OF THE W. M. DAVIS MODEL

edited by E. Uchupi, G. S. Giese, D. G. Aubrey, and D.-J. Kim, 1996

The authors of this reconstruction of the geologic history of Cape Cod and southeast coastal Massachusetts support W. M. Davis's contention that Cape Cod was formed by glacial deposition during the late Pleistocene and by marine and eolian processes since. However, their geological reconstruction of Cape Cod varies from that of Davis: they believe that the glacial lower cape extended east of its present shore for nearly double Davis's estimate and that it took more than twice the time Davis estimated to attain its present form. Davis also inferred that all detritus eroded on the east side was transported northward to create the Provincetown Hook, whereas Uchupi et al. propose that prior to 9500 years ago this material was transported southward to fill a depression at the cape's elbow; only during the past 6500 years was the material transported northward to form the hook. This work also suggests that historical changes in Cape Cod are not limited to natural processes, as Davis suggested, but that past and present human activities, such as construction of harbors and the Cape Cod Canal, dredging of channels and mooring areas, devegetation, mining, timber harvesting, clearing of land for agriculture, and unrestricted grazing, have played a significant role in creating the present morphology of Cape Cod.

SPE309, 70 p., paperback, ISBN 0-8137-2309-4,
List price $30.00, Member price: $24.00

LATE HOLOCENE ALLUVIAL GEOMORPHOLOGY OF THE VIRGIN RIVER IN THE ZION NATIONAL PARK AREA, SOUTHWEST UTAH

by R. Hereford, G. C. Jacoby, and V. A. S. McCord, 1996

The Virgin River, in the spectacular canyons of Zion National Park near the southwest margin of the Colorado Plateau, is well suited for geomorphic research; it has a relatively wide alluvial valley and is free flowing, retaining the pre-settlement discharge regime. The research described in Special Paper 310 focused on how variations of water and sediment load modify valley morphology. A specific goal was understanding the timing and causes of arroyo cutting—the catastrophic, widespread degradation of stream channels in the southwest United States beginning in the late 1800s. Large-scale surficial geologic maps portray the terraces and alluvial deposits. Dated by archaeologic context and by tree-ring methods, these deposits correlate in time with dated late Holocene alluvium of other streams on the southern Colorado Plateau. Relocated historic photographs show the channel before, during, and after arroyo cutting. Dendrohydrologic reconstruction of streamflow demonstrates that arroyo cutting occurred during unusually wet climate with large floods and was preceded by an interval of very dry climate.

SPE310, 46 p., paperback, ISBN 0-8137-2310-8, List price $25.00, Member price $20.00

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