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INSIDE

The Edwards Aquifer: A Resource in Conflict

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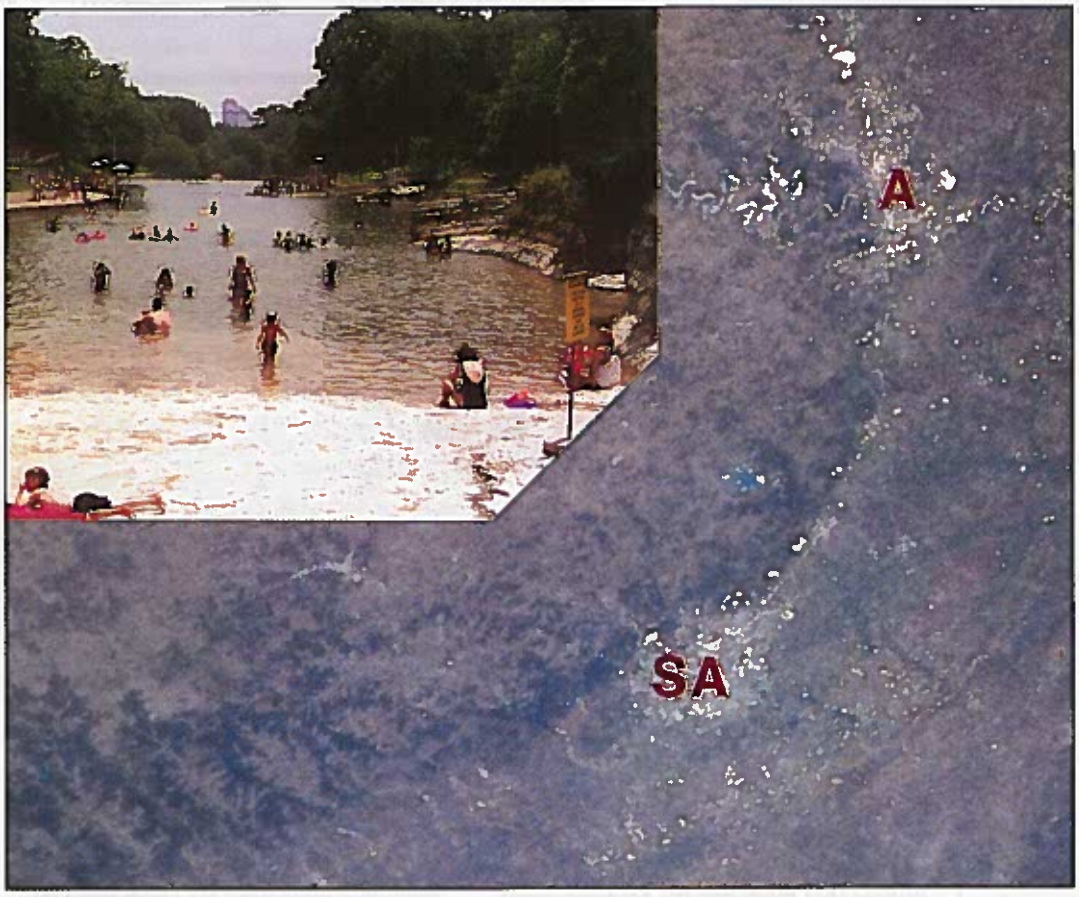

Figure 1. Space shuttle photograph of central Texas showing prominent physiographic features (see also Figs. 2, 3, and 5) that dictate patterns of recharge and flow in the Edwards aquifer. The landscape break shown by the color change across a southwest-northeast arc from San Antonio (SA) to Austin (A) formed as a consequence of en echelon, down-to-the-southeast normal faults of the Balcones fault zone. Urbanization of land (indicated by the light gray colors) around Austin, San Antonio, and the area in between has increased rapidly in the previous decade. North is to the top of the photograph. Austin–San Antonio distance is 120 km. Shuttle photo #NASA STS-62-97-143 (March 1994). Inset: The Barton Springs swimming pool in Austin, Texas, exemplifies the conflicting interests regarding the aquifer's waters. The pool is supplied by springs that discharge from submerged orifices in fractured limestone, which is visible on the right bank. The pool and surrounding park are important recreational resources. This spring system is the sole environment for the rare Barton Springs salamander, which is a federally listed endangered species. The rising skyline of the City of Austin is visible in the background. Water demands and conflicts will increase with increasing urbanization.

ABSTRACT

The Edwards aquifer of central Texas is an extensive, karstified flow system developed in rocks deposited on a Cretaceous limestone platform. Development of the aquifer was controlled by changes in sea level, large-scale hydrodynamic and tectonic processes in the Gulf of Mexico, and local climatic and geomorphic processes. The aquifer is a vital water resource and provides a diverse set of habitats, including those for several endangered species that live in its major spring systems. Because of its unique stratigraphic, hydraulic, and hydrochemical properties, the Edwards aquifer is a natural laboratory that is well suited for hydrogeologic studies. Because of numerous economic, social, and political interests in the use of the water and because of the rapid rate of population growth (and urbanization) of its watersheds, the aquifer is also a source of political conflict. Competing interests for its waters have stimulated an ongoing debate over how the aquifer would best be utilized. Historical water-balance analysis demonstrates that major water shortages will develop with the recurrence of historic decadal droughts. Future decisions regarding the aquifer's use will therefore have significant socioeconomic and environmental ramifications. These decisions should be based upon accurate hydrogeological data. The general nature of how the aquifer functions is understood, but more detailed interpretations are needed. Application of ground-water flow models based on field data and natural geochemical tracers have the potential to reduce uncertainties in the details of how the aquifer functions now and will function in response to potential future developments.

INTRODUCTION

There is a saying in Texas—"whiskey is for drinking, water is for fighting." Fighting over water resources involves legal, political, and economic interests. Much attention is focused on the Edwards aquifer, which is one of the most prolific aquifers in North America, providing water for more than two million people. It provides all the water used by the City of San Antonio and by numerous smaller municipalities, industry, and agriculture. Individual well yields can be tremendous; a City of San Antonio well drilled in 1941 had a natural flow of 16,800 gallons/minute (1.06 m^3/s; Livingston, 1942), and a well drilled in 1991 is reportedly the world's greatest flowing well, with a natural discharge of 25,000 gallons/minute

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Ralph H. Howe
Bluff, Utah
June 1997

Dorothy Lewis
Queensland, Australia
April 23, 1997

Henry G. Thode
Hamilton, Ontario
June 1997

Notice of Council Meeting

Meetings of the GSA Council are open to Fellows, Members, and Associates of the Society, who may attend as observers, except during executive sessions. Only councilors, officers, and section representatives may speak to agenda items, except by invitation of the chair. Because of space and seating limitations, notification of attendance must be received by the Executive Director prior to the meeting. The next meeting of the Council will be Tuesday afternoon, October 21, 1997, at the Annual Meeting in Salt Lake City.

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(1.58 m^3/s; Swanson, 1991). The Edwards aquifer also provides important recreational resources in stream waters and in the parks that surround major spring orifices that discharge the aquifer's water. The streams that flow over the aquifer and are fed by its springs provide needed fresh water to the south Texas Gulf Coast bays and estuaries, which are the nurseries for shrimp, redfish, and other species of coastal and marine wildlife.

The aquifer has been the subject of recent litigation, notably regarding the maintenance of natural flow to certain spring systems and the preservation of the threatened and endangered species that dwell in them. This conflict has developed because the communities and region that overlie and rely upon the Edwards constitute one of the fastest growing urban corridors in the United States (Fig. 1). During 1996, undeveloped land in Williamson County, north of Austin, was being subdivided for homes and businesses at the rate of one acre every three hours (*Austin-American Statesman*, 1996). Significant decisions will have to be made about these water resources in the coming decades. These decisions should be based more on accurate scientific data and less on political exigencies. Hydrogeological facts about the Edwards aquifer and related natural (including biological) resources must be effectively conveyed to those drafting policy and making decisions about future resource utilization.

The Cretaceous rocks that form the aquifer are present over much of Texas, either in outcrop or in the subsurface. These units also extend into northern Mexico (Lesser and Lesser, 1988). There are three aquifers in these rocks (Fig. 2): the Edwards-Trinity (Plateau) aquifer, the Edwards (Washita Prairie) aquifer, and the Edwards (Balcones fault zone) aquifer. The last is the most prolific and is what most people consider the Edwards aquifer (and that to which we refer in this paper). It stretches in a band (usually <64 km wide) from the Rio Grande river near Del Rio east through San Antonio, then northeast through Austin, and ends near

Edwards Aquifer *continued on p. 3*

Legislative Alert: House Moves To Eliminate Tax Exemption for Graduate Student Tuition Waivers

The U.S. House of Representatives recently passed H.R. 2014, which modifies the federal tax code. One provision of this bill would eliminate the current tax exemption for graduate students who receive tuition waivers from their universities. If this provision becomes law, graduate teaching and research assistants would have to pay taxes on the value of their tuition waivers, starting with 20% of the waivers' value in 1998, and rising incrementally to 100% in 2002. The tuition waivers, in other words, would be treated as taxable income.

Senate tax legislation, S. 949, does not eliminate the tuition waiver exemption. This and other differences between House- and Senate-passed tax bills must be ironed out in a conference committee meeting. For updated information on the status of the tax legislation, visit the American Geological Institute's Web site: www.agiweb.org and click on "Government Affairs."

In response to passage of H.R. 2014, GSA President George A. Thompson has written the following letter to House Ways and Means Committee Chairman William Archer:

The Honorable William Archer,
Chairman, Committee on Ways and Means,
United States House of Representatives, Washington, DC 20515

Dear Chairman Archer:

For the past 50 years, the U.S. Congress has been a steadfast supporter of the nation's system of scientific research and education. This system is the envy of the world, and the source of the talent and innovation that will fuel our nation's welfare in the coming century. Congress is to be commended for maintaining its historical commitment to research and education even while struggling to get the nation's fiscal house in order. In this light, I want to point out that recent provisions of House-passed tax reform legislation, H.R. 2014, threaten to undermine this commitment and our investment in training the nation's next generation of scientists and engineers. In specific, the provision that would eliminate Section 117(d) of the tax code—the exclusion of tuition waivers or reductions from taxable gross income—could have a serious negative impact on the nation's ability to attract the best and brightest students into our graduate science programs. I write to strongly urge that Section 117(d) be restored to the final tax bill during House-Senate conference.

As President of the Geological Society of America, a 15,000 member organization dedicated to the pursuit of world class scientific knowledge about the Earth, I am acutely aware of the challenge that we face in striving to maintain the preeminent status of the nation's research effort. The key element to meeting this challenge is the quality of our next generation of scientists. Ability in science—not ability to pay—must remain the prime criterion for entry into our graduate programs. Elimination of the tuition waiver exclusion could seriously compromise our capacity to fulfill this criterion.

In considering this issue, I urge you to keep in mind some very special aspects of our graduate science education system. Graduate education in science is a process that requires deep personal commitment over many years of hard work and meager pay. Our best graduate students typically receive stipends of less than $15,000, and they are often in their late twenties or early thirties when they complete their studies. If these students must accept an additional tax burden on tuition waivers—which may be worth as much as $20,000 per year—the economics of graduate training in science may become untenable for those without independent financial means. This is particularly the case because the salaries that scientists receive after finishing graduate school are far less than those for graduates of law, business, and medical schools. While a future doctor, lawyer, or corporate executive can justify the high cost of professional training based on anticipated future earnings, scientists do not have this luxury. Thus, if we ask our graduate students to accept a considerable real increase in tax burden (and, in many cases, an increase in personal debt, as well), we may well find that our most promising future scientists opt for more economically viable careers in the professions.

In the coming century, every aspect of the nation's well being—from economic competitiveness in the global marketplace, to the preservation of health in an aging population, to the development of energy resources and protection of the environment—will depend on the ability and ingenuity of our scientists. Short-term revenue losses resulting from the tax exclusion for tuition waivers will be paid back in spades by the long-term benefits of our investment in the next generation of world class scientists.

Sincerely,
George A. Thompson, President
[Geological Society of America]

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the town of Salado in Bell County. The boundaries of the Edwards aquifer (Fig. 3) are (1) the northern and western limits of the outcrops (except in the west, where it is continuous with the Edwards-Trinity Plateau aquifer; (2) the Rio Grande; and (3) the bad-water line, which separates the fresh-water zone (potable waters) from the bad-water zone (brackish or saline waters with >1000 mg/l total dissolved solids). Of particular interest is the aquifer between the ground-water divides near Brackettville (east of Del Rio) and Kyle (just north of San Marcos) because this is the largest segment of the aquifer and includes San Antonio.

There have been many studies of the Edwards aquifer. The aquifer's water balance and how it functions are basically known, but the lack of knowledge about many details disturbs those who need to make decisions and wish to maintain a broad consensus of support. As stated by Tilford (1994), "geological facts and fantasies will be called on to support both proponents and critics" of any water resources project, and "unknowns are powerful tools," whether or not warranted, in the hands of these groups. In this paper, we review the hydrogeology of the aquifer (its stratigraphy, structure, and relatively unique hydraulic parameters) and major issues facing the many users of the aquifer, and we suggest some areas where hydrogeological research should have both practical and scientific implications.

STRATIGRAPHY AND STRUCTURE

The aquifer is in carbonate rocks that were deposited in shallow subtidal to tidal-flat facies on an extensive marine platform approximately 100 m.y. ago. This stratigraphic package formed as part of an extensive series of shallow-water carbonate-evaporite platforms that encircled the margin of the ancestral Gulf of Mexico during a major marine transgression in the Early Cretaceous. Subsequent lowering of sea level, rapid burial of the deep sections of the Gulf of Mexico basin, tectonic uplift along the margins, and erosion and karstification have played important roles in the development of the aquifer (see Fig. 4 for representative stratigraphic sections). Detailed hydrostratigraphic relationships

Edwards Aquifer *continued on p. 4*

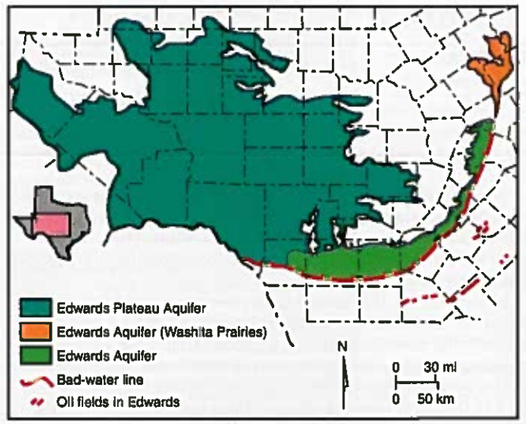

Figure 2. Edwards aquifers of Texas.

Edwards Aquifer *continued from p. 3*

are given in Rose (1972), Maclay and Small (1986), and Pavlicek et al. (1987), among many others.

Some confusion still persists over differences between hydrostratigraphic and stratigraphic nomenclature. It is not always recognized, for instance, that although the Edwards aquifer is present in the San Antonio area, the Edwards Limestone is not! The Edwards aquifer is a hydrostratigraphic unit that generally includes all rocks above the Glen Rose Limestone and beneath the Del Rio Clay, except where the latter has been eroded and aquifer crops out. The aquifer thickens to the south and southwest from about 60 to 275 m.

Both the upper and lower confining units are continuous and widespread. In the Glen Rose, layers of limestone and marl alternate and form a local aquifer with a low vertical permeability. The Del Rio Clay is a very efficient confining layer. It consists of low-permeability smectitic shales with occasional shell-fragment beds. Where exposed at the surface, the Del Rio Clay is a gray, sticky, expansive clay and is well known for causing foundation and slope-stability problems. The geologic formations of the aquifer (Fig. 4) have highly variable hydrogeologic properties. Organic, reeflike buildups of an unusual suborder of bivalves called rudistids are common in the aquifer unit. These provide significant primary porosity. The Regional Dense Member of the Person Formation is relatively unkarstified and functions as a semiconfining unit. The Leached and Collapsed members of the Person Formation and the Kirschberg Evaporite Member of the Kainer Formations tend to be the most permeable units because of secondary permeability caused by dissolution.

The structure is simple regionally, but it can be quite complex locally. Subdued arches and synclines are oriented nearly normal to the strike of the aquifer. The early Miocene, en echelon normal faults of the Balcones fault zone dip toward the Gulf of Mexico. Throws vary, reaching a maximum total displacement of >500 m along the San Marcos Arch (Fig. 5). The result is a series of blocks of Edwards aquifer rocks that are partly to completely offset. Some of these blocks are unconfined and some are confined. The San Marcos Arch has been a persistent high during the late Mesozoic and Cenozoic, and the carbonates that lie above it are more highly dolomitized. Finally, the aquifer has been affected by several uplifts. The first, in the Cretaceous, resulted in karstification before deposition of the Georgetown Formation (Fig. 4); this was followed by several episodes of erosion and karstification. The major uplift, in the early Miocene, led to both major faulting and modern karstification.

The stratigraphic and structural features serve to (1) control the distribution of recharge features, primary and secondary porosity, permeability, and water chemistry and (2) make the Edwards one of the most highly productive aquifers in North America. Even though the aquifer is commonly treated as a single hydrostratigraphic unit, its properties are highly variable both laterally and vertically. This variability, coupled with the intricacies and variability created by karstification, leads to considerable complexity within the aquifer.

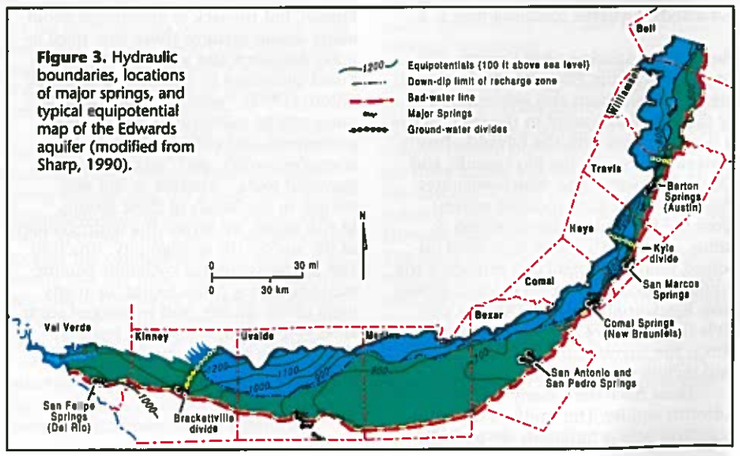

Figure 3. Hydraulic boundaries, locations of major springs, and typical equipotential map of the Edwards aquifer (modified from Sharp, 1990).

HYDROGEOLOGY

The Edwards aquifer receives approximately 80% of its recharge through losing (influent) streams that flow over its unconfined parts. Most of the remaining recharge is from direct precipitation on aquifer outcrops. Minor amounts of recharge come from the movement of saline ground waters across the bad-water line, from leaky water mains and sewage lines in urbanized areas, and from cross-formational flow from underlying units. A cross-formational flow component is locally important especially to the north, where the aquifer thins, and it may be identified by chemical and isotopic signatures (Clement and Sharp, 1988; Oetting et al., 1996). Recharge from streams is highly variable because it depends primarily upon the duration and intensity of stream flows. Figure 6 shows historical trends in recharge to and discharge from the aquifer. Average recharge over the period of record has been 682,800 acre-feet/year (26.63 m^3/s), but the highest recorded recharge was 2,486,000 acre-feet/year (96.95 m^3/s) in 1992, and the lowest recorded was 43,700 (1.70 m^3/s) in 1956 (Edwards Underground Water District, 1993). Discharge is by springs and wells, and well discharge has increased in the 60 years of record to meet the growing needs of the population and irrigation. Well discharge is inversely correlated with years of high recharge (and precipitation).

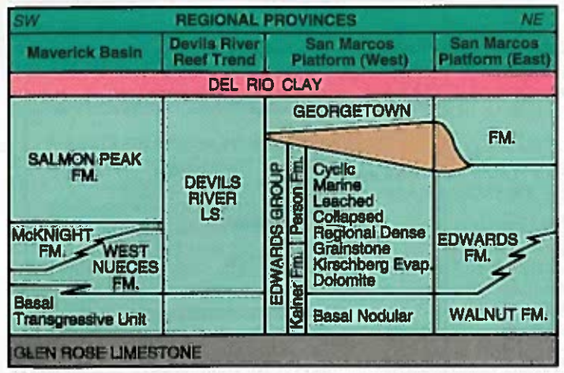

Figure 4. Stratigraphic formations that make up the Edwards–Balcones fault zone aquifer. Member names are shown for the Person and Kainer Formations.

Nevertheless, the current needs of the regions that depend upon the aquifer exceed the historical water availability during the drought of 1947–1956. When a similar decadal drought occurs, it will be a considerable hardship to the region. In order to plan for the combination of an extended period of low recharge with the rapid urbanization of the area, authorities must consider use restrictions and water-supply plans, as discussed below, and ways to raise revenue to institute them, including (unpopular) higher water rates or (equally unpopular) higher taxes.

The general flow systems are understood, but local hydrogeological details are complex. Faulting and subsequent dissolution along fractures create a very heterogeneous and anisotropic permeability distribution. The orientation of the maximum permeability is subparallel to the strike of the rocks and fracture trends. All waters recharged east of the ground-water divide near Brackettville flow east, where they discharge to wells or at the large springs. These include San Pedro and San Antonio springs in San Antonio, Comal Springs and Hueco Springs, near New Braunfels, and San Marcos Springs in San Marcos. In the confined part of the Edwards, the flow is nearly parallel to the strike of the aquifer. San Marcos Springs is the lowest natural discharge point of the aquifer (570 ft/174 m above mean sea level). Just north of San Marcos, a ground-water divide near Kyle separates the San Antonio system of the aquifer from the Barton Springs system, which ultimately discharges to the Colorado River in Austin.

Maclay and Small (1986) and Maclay and Land (1988) recognized several domains of highly variable transmissivity. Faulting has juxtaposed different hydrostratigraphic units in the aquifer, so that some fault blocks are almost isolated. Other blocks are connected, to varying degrees, with the adjacent ones, because of the variable hydraulic characteristics of the different members within the aquifer and variation in the throw of faults. The faults may serve as barriers to flow between blocks and simultaneously serve as conduits to flow along the fracture planes. Only guesses can be made regarding the detailed hydraulic characteristics of the fracture systems. There are extensive cave systems that support a strikingly diverse subsurface ecosystem that includes two species of blind catfish (Longley, 1981). Flow-system delineation by tracer tests demonstrated complexities unusual even in karst systems (N. Hauwert, 1996, personal commun.). Consequently, even though several numerical models have been developed, they only simulate the general characteristics of the system. It is often proposed at public hearings that the aquifer can be overdrafted during drought because large recharge events will replenish the aquifer. This would avoid both the costs of a huge regional water distribution system and use restrictions, and would allow the current users of the aquifer to continue to use this very high quality, cheaply produced water for current and projected needs. However, this scenario is rendered tenuous by unknown potential effects of severe overdrafting on water quality, water availability, and habitats (especially those of endangered species living in the two largest spring systems).

GEOCHEMISTRY: BAD WATER, FRESH WATER, AND EFFECTS OF URBANIZATION

Major and trace element concentrations and isotopic variations in Edwards ground waters provide clues to the sources of dissolved ions in the waters and the

Edwards Aquifer *continued on p. 6*

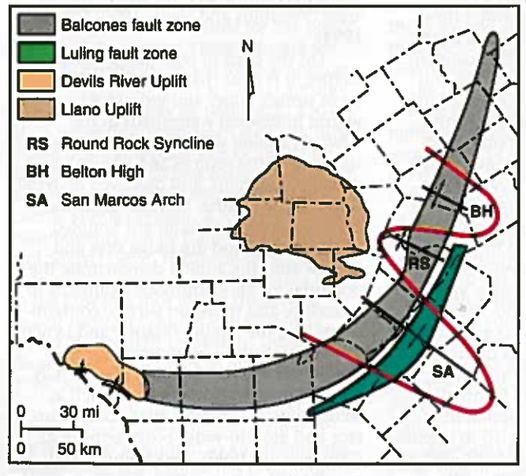

Figure 5. Structural trends in the Edwards aquifer (modified from Sharp, 1990).

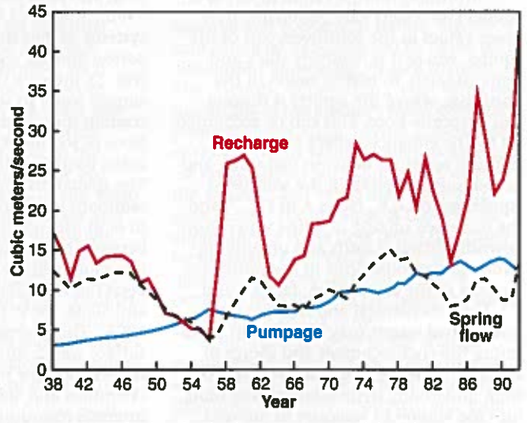

Figure 6. Water budget for the San Antonio part of the Edwards aquifer. Five-year linearly weighted averages of recharge and discharge from wells and springs (data from Edwards Underground Water Conservation District, 1992, written commun.). Note: 1,000 acre feet per year = 1.38 cfs = 0.039 m^3/s.

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processes that govern the chemical evolution of the waters. As demonstrated by Sharp and Clement (1988), the bad-water line marks the convergence of two flow systems (Fig. 3). The first is characterized by very high permeabilities and flow rates and by low-salinity, oxidizing Ca-HCO_3 waters. The second flow system is relatively stagnant and is characterized by higher salinity, reducing waters of several hydrochemical facies. Consequently, this chemical boundary (the bad-water line) also reflects a physical change in the hydrogeological regime. Downdip from the aquifer toward the Gulf of Mexico, Edwards aquifer–equivalent rocks are important oil reservoirs. Natural oil seeps occur in outcrops of aquifer rocks along the Balcones fault zone. Hydrocarbons and associated oil-field brines influence bad-water zone chemistry in the central part of the Edwards aquifer. Integrated Sr isotopic and major and trace element variations indicate that a wide range of processes are involved in the origin and evolution of different bad-water hydrochemical facies in the Edwards (Fig. 7; Clement and Sharp, 1988; Oetting et al., 1996). These processes include (1) incongruent dissolution of gypsum, (2) recrystallization of calcite, (3) ion exchange with clays, (4) sulfate reduction, (5) fluid mixing involving at least five end-member ground-water compositions, and (6) interaction with igneous intrusions. Regional and local variations in hydrogeologic parameters that may govern the extent to which these processes occur include the mineralogy and thickness of the aquifer, the extent of flow along fractures, and the composition of saline ground waters in Edwards rocks downdip and in underlying hydrostratigraphic units.

Strontium isotope values in Edwards aquifer bad waters vary regionally, from lower values in the southwest part of the aquifer, where it is relatively thick and evaporite-rich, to higher values in the northeast, where the aquifer is thinner and evaporite-poor. This can be accounted for by the enhanced effect of mineral-solution reactions between bad-water and host-aquifer minerals in the southwest aquifer region (i.e., facies A in Fig. 7) and the increased mixing of saline waters from downdip Edwards units and underlying hydrostratigraphic units in the northeastern part of the aquifer (i.e., facies E and E'). The geochemical and isotopic signatures of bad waters may be useful in monitoring the encroachment and source of Edwards brines or cross-formational flow from underlying hydrostratigraphic units into the aquifer in response to drought or increased pumpage. The saline water encroachment problem is particularly pertinent in densely populated areas that rely solely on the Edwards, such as San Antonio, where fresh ground water is withdrawn from wells near the bad-water line.

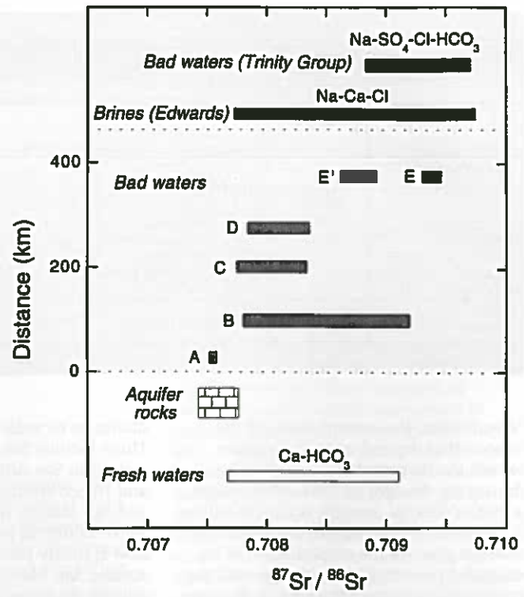

Figure 7. Strontium isotope variations in the Edwards aquifer system. All $^{87}Sr/^{86}Sr$ values are for waters and rocks from the Edwards, except for those of the Trinity Group bad waters, which are from underlying stratigraphic units. Low $^{87}Sr/^{86}Sr$ values of aquifer carbonate and evaporite rocks reflect their Lower Cretaceous marine origin. Major ion compositions are used to define six Edwards bad-water hydrochemical facies, A through E', that are also geographically distinct, as represented by distance along a southwest-northeast transect along the bad-water line from Kinney to Bell County. These bad waters change in the southwest-northeast sequence: facies (A) Ca-SO_4 waters; (B) Ca-Mg-SO_4 (low Na-Cl); (C) Ca-Mg-SO_4 (high Na-Cl); (D) Na-Cl; (E) Na-SO_4-Cl; (E') Na-Cl-SO_4-HCO_3. The geochemistry of Edwards bad waters portray regional controls on ground-water evolution, as discussed in the text. Only Edwards bad-water samples are referenced to the ordinate. Although fresh waters in the Edwards aquifer (ground water, surface water, and precipitation) have a wide range in $^{87}Sr/^{86}Sr$ similar to bad waters and brines, fresh-water isotopic variations appear to reflect more local controls such as flow paths and residence time in the aquifer. Data are from Oetting (1995), Oetting et al. (1996), and sources cited by them.

In contrast to the regional bad-water compositional patterns, geochemical and Sr isotope variability in the fresh-water aquifer appears to be a function of variations in smaller scale factors such as flow routes and ground-water residence times in the karst aquifer, soil type and thickness, and land use (e.g., Banner et al., 1996). Studies of local fresh-water flow systems within the Edwards, such as the Barton Springs segment in the Austin area (Fig. 3), indicate that ground water and surface water in some parts of the aquifer contain higher than normal concentrations of sediment, hydrocarbons, pesticides, bacteria, nitrate, and heavy metals. The spatial distribution of elevated contaminant levels in ground water relative to land use indicate some correspondence between contamination and those parts of the aquifer where urban development has been heaviest (Slade et al., 1986; Veenhius and Slade, 1990; Hauwert and Vickers, 1994). This correspondence is enhanced in surface waters during periods of increased runoff and flow resulting from storms (Veenhius and Slade, 1990). Conflicting interests regarding the development of the aquifer's watersheds has led to intense scrutiny of the scientific methods used in such water-quality studies (see Addendum to Hauwert and Vickers, 1994). Future studies of the effects of development on water quality in the Edwards will need to constrain natural compositional variability and flow paths (using tracers), as well as changes in land use and impervious surface coverage. The amount and distribution of impervious cover are key measures for assessing and predicting the effects of urbanization on water quality in watersheds in Austin and other metropolitan areas (Veenhius and Slade, 1990; Schueler, 1994).

On the basis of regional geochemical studies, it is clear that more focused studies of surface water and ground water within individual watersheds in the Edwards aquifer will improve our understanding of the sources and transmission of water, sediment, and dissolved material through the aquifer. Mineralogical and chemical studies of sediment sampled from recharge and discharge sites and from within the aquifer demonstrate the potential for allochthonous sediments to introduce and transport surface contaminants into the aquifer (Mahler and Lynch, 1996). Integration of hydrogeological, geochemical, and biological studies may reveal critical habitat controls, such as solute sources, on biota that occupy surface and ground-water ecosystems (e.g., Carney et al., 1996). Geochemical and geochronological studies of calcite deposits in Edwards caves can provide insight about the relation between climate variability and ground-water flow and composition on a range of temporal scales (e.g., Banner et al., 1996).

ENDANGERED SPECIES

A significant drop in natural (spring) discharge occurred during the period from 1947 to 1956 (see Fig. 6). The two largest spring systems are Comal and San Marcos springs. Comal Springs ceased flow for more than four months in 1956, and San Marcos Springs discharge dropped to about 50 cubic feet per second (cfs) (1.42 m^3/s). Since then, several organisms living in these springs have been listed under the Endangered Species Act of 1973. At San Marcos Springs, these are (1) the San Marcos salamander *(Eurycea nana)*, (2), a fish, the fountain darter *(Etheostoma fonticola)*, and (3) the Texas wild rice *(Zizania texana)*. A fourth species, the San Marcos gambusia *(Gambusia georgei)* has not been observed for several years. This fish may be extinct, but it is still listed. At Comal Springs, fountain darters had been present before 1956, but they could not be found in 1974 (Schenck, 1975). Fountain darters from San Marcos Springs were reintroduced to the Comal Springs system between February 1975 and March 1976 (U.S. Fish and Wildlife Service, 1984). There is now a significant population of the darters at Comal Springs (Crowe and Sharp, 1997). Several other species at Comal Springs may be candidates for listing as endangered species. These include the Comal Springs salamander (*Eurycea* sp.) and the Comal Springs riffle beetle *(Heterelnis comalensis)*.

A lawsuit was filed in 1991 by the Sierra Club against the U.S. Fish and Wildlife Service and other agencies in order to maintain adequate spring flows for the preservation of these species. This has resulted in the establishment of minimum springs flows required for the preservation of the species. These minima are 100 cfs (2.83 m^3/s) at San Marcos Springs and 200 cfs (5.66 m^3/s) at Comal Springs. The latter limit may be reduced to 150 cfs (4.25 m^3/s) if the ramshorn snail, an introduced tropical species, can be controlled. This snail is a voracious herbivore and can significantly alter the ecosystem of the Comal Springs system. A review of these requirements can be found in McKinney and Sharp (1995). Historical data, however, clearly demonstrate that spring flows in the Edwards (not just at these two largest springs) cannot be maintained under the drought conditions similar to those of the mid-1940s to mid-1950s, even if the demand for water was still that low.

The Barton Springs salamander *(Eurycea sosorum)* was recently listed by the federal government as an endangered species. This salamander has been found only in Barton Springs in Austin (Fig. 1), and its population is smaller than that of the San Marcos salamander. Protection of endangered species requires protection of the spring system environments against contamination and loss of flow—a difficult task in a region of increasing urbanization.

LEGAL-POLITICAL-ECONOMIC MANAGEMENT PROBLEMS

Texas has an intriguing system of water law. Surface waters are owned and allocated by the state. Any extraction of water from a stream or its underflow (Meinzer, 1923; Larkin and Sharp, 1992), except for domestic or livestock use, must be approved by the state. On the other hand, ground water belongs to the land owner who can produce it by the "rule of capture." The owners of the land above the Edwards aquifer consequently have a legal right to pump as much water as they can as long as they use it beneficially, don't use it in a malicious manner, or negligently cause subsidence. However, continued pumping during times of drought will reduce spring flows and violate the Endangered Species Act. In addition, the communities of New Braunfels and San Marcos gain considerable revenues from the recreational users of the Comal and San Marcos rivers, which are fed almost solely by the springs. The Edwards Aquifer Authority was created by the Texas legislature in January 1993, to regulate withdrawals in order to protect spring flows and thereby protect the endangered species of Comal and San Marcos springs. However, resolutions to the conflicts are not cheap, readily available, or agreeable to all parties.

First, population growth is intensifying water demands. Second, there are no potential alternative water resources that can provide high-quality, abundant water as cheaply as the Edwards aquifer. Third, there are few, if any, sites for potential high-yield reservoirs in the area, and downstream users of streamflow, such as the city of Corpus Christi, object to actions that will diminish the flows that replenish their reservoirs. In addition, some levels of fresh-water flow to the coast are required to maintain the ecological health of the estuaries of the south Texas Gulf Coast. The state of Texas and the users of the Edwards aquifer waters are not immune to the financial consequences of who will be allocated or supplied with water. Coupling these considerations with the complexities of interbasin or interstate regional water transfer makes clear the difficulties associated with future water-resource development in this area, even though it overlies one of the most prolific aquifers in the world.

Solutions to all water shortages involve one or more of the following types of actions: (1) increasing water supplies, (2) decreasing water demands, or (3) better management and more efficient use of existing resources. How much water is stored in, discharges from, and recharges the aquifer is generally known, as is how the water is being used (53% municipal, 36% agricultural, 3% industrial, 8% rural domestic and livestock; Technical Advisory Panel, 1990). Potential management actions will benefit from a better understanding of the hydrogeology of the Edwards aquifer. If the detailed hydrogeology were better understood, for instance, then we should be better able to: (1) target well-field locations to maximize production and minimize adverse effects; (2) manage well production with respect to which river basin is contributing recharge; (3) evaluate more precisely methods of spring-flow augmentation which could be used to maintain minimal flows during drought; (4) predict more accurately how waste water recovery (and injection?) systems will function in the aquifer; and (5) predict more accurately the effects of urban development, construction, and point-source pollution. In particular, as the watersheds in the urban areas increase the amount of impervious cover and sewage lines (which inevitably leak), what will be the eventual effects on water quality?

PROMISING RESEARCH

Analysis of the Edwards aquifer situation suggests that detailed hydrogeological studies could have significant economic applications as well as providing new insights into the processes that form the aquifer, the processes now occurring in the aquifer, and how to develop more meaningful numerical simulations. Detailed precise answers are sought by the various groups contesting uses of the Edwards waters, but our hydrogeological and hydrostratigraphic knowledge is of a regional and conceptual nature. Significant financial decisions will be based upon our current knowledge, or lack thereof. The scientific questions include: What are the details of the aquifer's hydrogeologic property distribution?; What is the extent of flow between various fault blocks?; Can we predict travel paths and times within the aquifer?; and What flow equations are suitable? For instance, is Darcy's Law applicable, or is the flow better described by turbulent flow models? Can we quantify with any reasonable degree of certainty how siting of the pumping wells would affect spring flows?

Uncertainties exist in the analysis for methods of springflow augmentation and artificial recharge. Artificial recharge structures have been proposed, and some have been constructed with some success (HDR, 1993). Not all sites or areas are

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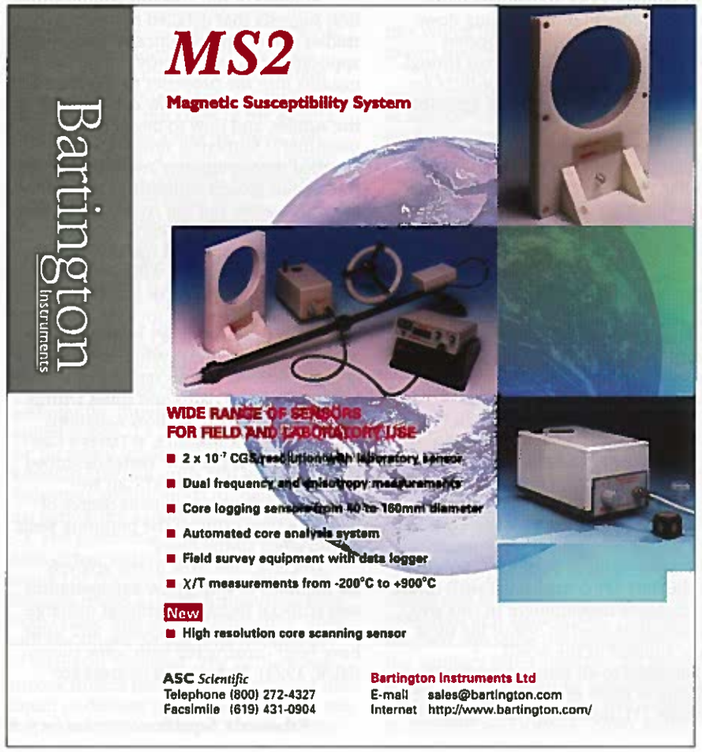
equally conducive, because the permeabilities and the connections between various faulted blocks are irregular. What are the best mechanisms and where are the best sites for enhanced or artificial recharge? Uliana and Sharp (1996) and McKinney and Sharp (1995) examined potential methods for spring-flow augmentation. They noted that geological mapping and tracer tests are required near the large springs before the feasibility of these methods can be assessed with confidence. Detailed hydrogeological mapping of the aquifer has not been accomplished despite numerous previous studies (Menard, 1995), but recent studies by Hovorka et al. (1993, 1995), Stein and Ozuna (1995), Small et al. (1996), and Hauwert (1997) are encouraging because they provide high quality conceptual and numerical data. Determining the effects of both natural processes and changing land use on water quality will require studies that cover a range of spatial and temporal scales.

Another important question requiring quantification is the effect on the downstream users of the proposed water resource developments relating to the aquifer. For instance, it is commonly assumed by the general public that all the water that issues from the springs flows into the Gulf of Mexico. The other extreme position is that even if all discharge from the springs were diverted, there would be very little effect on fresh water reaching the Gulf Coast. Water balance studies should be conducted to analyze these possibilities.

Scientific analyses are needed for the evaluation of water-supply proposals, which range from the simple to the grandiose, such as a massive regional transfer of water from east Texas or Louisiana to Houston, Austin, and San Antonio. For instance, would the environmental consequences of such a scheme be greater than those from periodic diminution of spring discharges below the take limit flows for endangered species? (Take limit flows are the established minima below which we cannot maintain the species' critical habitat.) What would be the effects of such transfers on the coastal systems or on river systems such as the Sabine, the Trinity, or the Brazos? Finally, political and economic studies are also required. For instance, curtailment of irrigated agriculture during droughts would reduce spring-flow diminution. What would be the legal, economic, social, and hydrologic effects of such an action?

The Edwards aquifer represents an important natural resource where geologic, hydrologic, biologic, legal, political, and socioeconomic factors are intertwined. The region will be developed and the aquifer will be stressed. A greater understanding of the aquifer's and the region's hydrogeology is required to use these precious water resources more efficiently in response to the changing combination of demands and constraints.



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Penrose Conference To Address Crustal Differentiation

A Geological Society of America Penrose Conference, "Processes of Crustal Differentiation: Crust-Mantle Interactions, Melting, and Granite Migration through the Crust" will be held July 4–11, 1998, in Verbania, Italy. The conveners chose this location because the Ivrea Zone is well exposed in the surrounding areas and these rocks represent a section of middle to lowermost continental crust in addition to basaltic underplate or upper mantle. This meeting will use the Ivrea Zone as a template in which to focus on major processes of continental growth; the chemistry and dynamics of partial melting in the lowermost crust and upper mantle (including crust-mantle interactions), segregation of melt from the lowermost crust, and migration and transfer of magma upward through the crust. Discussions will center on processes active from the middle crust into the upper mantle and on key questions that enhance understanding of the current state of the research. Specific questions to be addressed are the following:

- How does the crust respond, rheologically, to such continental growth processes as partial melting and magma transfer?
- What geochemical signatures can be used to indicate crustal growth during active deformation?
- What is the possible range in rates of melt segregation?
- What are the specific links between the petrologic and structural (kinematic and dynamic) expressions of melt migration?
- What do we really need to know to develop tests of models for melt segregation and migration?
- What kind of models are even testable?

The talks (a mixture of keynote and specific examples of current research) and discussions will be split into separate sessions representing the different levels in the crust and upper mantle and will address these questions and others.

Out of the six full days for the Penrose Conference, three days are for field excursions and three days are for inside activities. The first evening (July 4) and three days of the conference will be in the Hotel Castagnola, where several speakers will address crustal growth processes, but from the viewpoint of different expertise and methodologies. Subjects of the lectures and discussions will range from large-scale tectonic modeling and isotopic studies of field examples to experimental petrology and crustal rheology. Few lectures are planned, so that more time will be available for panel discussions, poster presentations, and group discussions.

The other three days of the conference will consist of field trips into the Ivrea Zone. The field days will be an integral part of this meeting, providing opportunities for direct observation of the different levels in the crust and for discussion. The mix of field observation and key speakers from different disciplines is intended to promote interdisciplinary interaction for a better understanding of the nature and growth of the continental crust. This approach also provides an excellent environment for active discussion and learning.

The main goal of the conference is to provide a current assessment of our understanding of growth and evolution of the continental crust by utilizing recent work from across a range of disciplines.

The conference is limited to 80 participants. Interested graduate students are encouraged to apply; some partial student subsidies will be available. The registration fee, which will cover lodging, meals, field trips, and all other conference costs except personal incidentals is not expected to exceed $700. Participants will be responsible for transportation to and from the conference. Further information on travel will be provided in the letter of invitation.

All participants will be encouraged to present a poster on current research relevant to the topic of the meeting, and significant time will be given to view them.

Co-conveners are: ***Tracy Rushmer,*** Dept. of Geology, University of Vermont, Burlington, VT 05405, (802) 656-8136, fax 802-656-0045, trushmer@zoo.uvm.edu; ***Michael Brown,*** Dept. of Geology, University of Maryland at College Park, College Park, MD 20742, (301) 405-4080, fax 301-314-9961, mbrown@geol.umd.edu; ***George Bergantz,*** Dept. of Geological Sciences, University of Washington, Seattle, WA 98195, (206) 545-4972, fax 206-543-3836, bergantz@u.washington.edu.

Application deadline is January 15, 1998. Invitations will be mailed to participants by February 15, 1998. Potential participants should send a letter of application to Tracy Rushmer (address above), including a brief statement of interests, the relevance of the applicant's recent work to themes of the meeting, and the subject of any proposed poster presentation. ■

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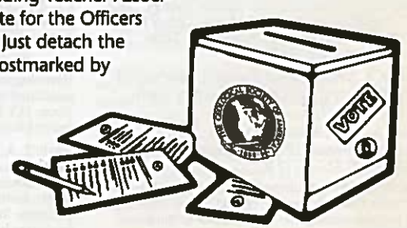

EDMAP Program: Training Tomorrow's Geologic Mappers

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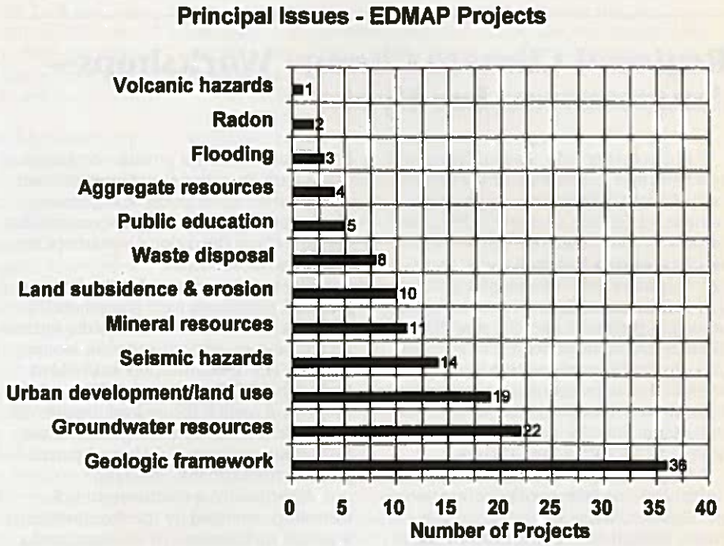
The National Cooperative Geologic Mapping Program (NCGMP), administered by the U.S. Geological Survey, has established a program to provide financial support for university graduate students who are doing thesis research that focuses primarily on geologic mapping. The EDMAP program was established as a component of the NCGMP by the National Geologic Mapping Act of 1992, which recognizes the importance of geologic mapping for our nation's well-being, and which stipulates that a portion of the funding for the NCGMP should be dedicated to training a new generation of geologic mappers. The other components that receive major funding are STATEMAP, requiring a 50-50 match with state funds, FEDMAP, and SUPPORTMAP. The latter two support mapping by USGS scientists and development of a national geologic map data base.

The EDMAP program involves a cooperative agreement between the USGS and a participating university in which costs related to field research are split 50-50. A faculty supervisor (principal investigator), together with up to three graduate students, submits a proposal that requests support for as many as three geologic mapping projects. The proposal is then submitted to the USGS through the usual college- or university-sponsored programs office. As part of the project, each student is expected to produce a new geologic map at a scale of 1:24,000 or larger, typically covering an area up to the size of a 7 1/2-minute quadrangle. EDMAP projects in every state must be consistent with the goals of that state's geologic mapping program and with the goals of the NCGMP, and a letter of support from a State Geologist, USGS Project Chief, or the NCGMP Coordinator must be part of the submittal.

Accountability is a hallmark of the EDMAP program: projects are funded on a year-by-year basis, and maps are submitted to the NCGMP at the end of each funding year. Each student may take up to two years to complete his or her mapping project, but an interim map that is reviewed for progress is required at the end of the first year as a prerequisite for second-year funding. The final product should be of "open-file" quality (uncolored ozalid or xerox copy) and include description of map units, explanation of symbols, correlation of units, and one or more cross sections. Digital geologic maps are encouraged but not required.

In the proposed budget, USGS funding should be matched or exceeded by university funding. The matching funds can include faculty salaries and university overhead. Both NCGMP and university funding should be restricted to field-related expenses such as housing, transportation, supplies, food, and field-season salaries. Limited laboratory expenses such as preparation of thin sections or computer time for digitization are also permitted. No faculty salaries will be paid by NCGMP funds, but university overhead (at off-campus rate) is permitted in the request. Proposals must nonetheless include a detailed mentoring plan that involves frequent visits by the faculty supervisor to the student(s) in the field.

EDMAP program announcements are sent out the first week in September, and proposals are due on December 1 of each year. A peer-review panel consisting of five university faculty, two State Geologists, and three USGS representatives review the proposals and meet in early January to determine awards and funding levels. Last year 38 proposals containing 56 mapping projects were submitted; funding requests totalling $732,336. The available USGS funds for FY 1997 total are $370,882. The panel recommended 32 proposals for funding; awards per student ranged from $6,000 to $12,000. Thirty-nine universities in the conterminous U.S. have participated in the program to date over a broad range of issues that are addressed by EDMAP projects (see chart).



Those interested in participation in the EDMAP program should contact Nancy Zeigler at the USGS in Reston, Virginia, (703) 648-6904; nzeigler@usgs.gov, for more information and a copy of the current Request for Proposal (RFP). Summaries of current EDMAP projects can be found on the NCGMP home page at http://ncgmp.usgs.gov, and a downloadable copy of the RFP for FY 1998 is available at that site.

The EDMAP program is unique among research grant programs in its emphasis on the development of geologic mapping skills and the production of new geologic maps. The program addresses the growing lack of these skills among geology graduates and provides funding for what many feel is a vital but poorly supported discipline within the geological sciences. ■

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. These reports present summaries of agency and interagency programs, track legislation, and present insights into Washington, D.C., geopolitics as they pertain to the geosciences.

Regional Climate Change Workshops—Ammunition For Kyoto

In December 1997, Kyoto, Japan, will host the Third Conference of the Parties to the United Nations Framework Convention on Climate Change (COP3). The purpose of the conference will be to formulate measures to curtail global warming. A primary goal is to adopt a protocol that defines target figures to reduce greenhouse gas emissions after the year 2000. About 5,000 participants from 190 countries, institutions, international organizations, and nongovernmental organizations (NGOs), as well as thousands of journalists will attend. The U.S. delegation will be headed by Vice-President Al Gore.

Originally formulated in 1992, the United Nations Framework Convention on Climate Change went into effect in March 1994. It has been ratified by more than 160 countries, including the United States. In 1995, the Intergovernmental Panel on Climate Change (IPCC) released a report that concluded that global warming was significantly impacting many aspects of the Earth system. The IPCC report recommends pursuing a wide range of actions to mitigate climate change, such as eliminating fossil fuel subsidies, increasing energy efficiency measures, preserving forests, and increasing reliance on renewable energy technologies, such as wind and solar power generation. Developing a strategy for mitigation and adaptation also appears to be the view of the Clinton Administration.

To provide input for formulating an official U.S. government strategy for the COP3 meeting and to understand the national-scale consequences of global change, the U.S. Global Change Research Program (USGCRP) is sponsoring a series of seven regional workshops. The workshops will examine the vulnerabilities of various regions of the United States to climate variability and climate change. It will also aggregate information across regions to support a national-scale scientific assessment.

The USGCRP was established under President Bush in 1989, and authorized by Congress in the Global Change Research Act (GCRA) of 1990. The program's fundamental purpose is to increase understanding of the Earth system and thus provide a sound scientific basis for national and international decision making on global change issues. The national-scale scientific assessments that will result from the regional workshops are authorized in the GCRA.

The regions selected for the first group of workshops were chosen on the basis of a combination of scientific interest and "near-term opportunities for hosting events." The first workshop was held at Fort Collins, Colorado, in late May, while the second, which focused on impacts on the western Arctic including Alaska, was held in Fairbanks in early June. I participated in the Fairbanks meeting.

Additionally, a southeastern U.S. workshop, attended by the vice-president, was held in Tennessee in late June, and a Pacific Northwest workshop was held in Seattle in mid-July. Three more workshops (Southwest, New England, and Mid-Atlantic), will be held in September. Each workshop has at least one local academic organizing institution and at least one coordinating Federal agency. Additional information about the workshops can be found on the USGCRP Coordination Office home page (http://www.usgcrp.gov).

Selection and invitation of participants is the responsibility of the regional organizers. The workshops are designed to include participation from the research and stakeholder community. The term "stakeholder" is used in the broadest sense. It includes individuals from federal, state, and local governments; universities and laboratories; industry, agricultural, and natural resource managers; nongovernmental organizations; and others.

Each workshop will focus on specific regional needs as well as issues common to all seven regions. For example, at the Alaska workshop, which was hosted by the University of Alaska, Fairbanks, and coordinated by the Department of Interior, we addressed what the impacts of changing climate would be on: infrastructure, fisheries, the coastal zone, land-based ecosystems, and nonrenewable resources.

For example, the primary concern in the "infrastructure" sessions was how a warming of as much as 1 °C per decade would affect shallow subsurface ice in the continuous permafrost zone. The group concluded that in the short term, melting of ice could result in the differential settling or collapse of roads, airport runways, buildings, and other infrastructure, including the Trans-Alaska Pipeline. In the long term, following the melting of shallow subsurface ice, construction in the Arctic would be significantly less expensive and less complicated.

Writing groups at each workshop will produce a report containing: (1) a description of the region's environmental, demographic, and economic conditions; (2) an identification of vulnerabilities to climate variability and climate change; (3) an identification of adaptation and resource management options; (4) a definition of research needs for improving estimates of regional vulnerabilities, understanding the consequences of climate variability and change, and analyzing viable response options; and (5) written input for the regional science assessment.

In spite of the fact that three workshops are still to be held, a meeting of technical experts was held July 29–August 7, at the Aspen Global Change Institute. Its purpose was to synthesize the results of the first four regional workshops and begin planning for the national science assessment. A National Workshop on Climate Change Impacts will be conducted in Washington, D.C., November 10–12. It will relate regional results to national-scale impacts and continue planning for the national science assessment. A second group of regional workshops, covering the remaining regions of the United States, will be conducted by mid-1998. The national science assessment is scheduled to be completed during 1999, and it will be the U.S. contribution to the IPCC Third Assessment Report.

This regional workshop process is not occurring in a vacuum. Both the environmental community and the industrial and business community are closely watching the outcome. Beginning in June, multiple-page newspaper ads, radio announcements, Internet messages and home pages, and detailed television reports began to appear. Their purpose was to try to rally support either for or against a strong U.S. position in Kyoto. For instance, the June 10 issue of the *Washington Post* contained a three-page advertisement signed by more than 130 presidents, chairmen, and CEOs of some of the largest companies in America, under the auspices of a group called the Business Roundtable. Their statement concluded, "We strongly urge the Clinton/Gore administration not to rush to policy commitments until the environmental benefits and economic consequences of the treaty proposals have

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LETTER

I read with great interest Eldridge Moores's 1996 GSA Presidential Address [*GSA Today*, v. 7, no. 1, p. 7]. As a former practicing geologist, frustrated by the difficulty in pursuing a career in geology, I have a special interest in his concerns.

I received my B.S. degree in geology in 1980 and my M.S. in 1983. I worked for a major oil company until 1990. When I was transferred from Bangkok to Los Angeles in 1990, I left the company after realizing that my salary was insufficient to allow me to live reasonably close to my downtown office. After earning a degree at the UCLA School of Law, I practiced law in Tucson for nearly two years before returning to Bangkok to practice law with a large New York-based firm.

The profession of geology is in a tragic state. My friends who are still with the major oil company have now lived with 13 years of layoffs. In the years since my departure, many innovative and highly qualified geologists have also left voluntarily, unable to raise families in the unstable environment facing the oil industry. Only a small number of my friends from the University of Arizona's large graduate program are still practicing geologists. Those who still practice struggle to do excellent jobs for companies that face uncertain futures. To supplement Moores's academic perspective, I offer the following industry-oriented problems facing geologists:

1. Geology suffers from its association with exploitative resource industries and development of marginal lands. Although popular thought may now be more pro-business than in the past, resource industries continue to suffer a poor public image. Geologists are regularly associated with strip mining, ground-water pollution, and sensational mishaps such as Malibu landslides, alleged conscripted labor in Burma, Bre-X, and the like. The public may justifiably question why, if geologists are so often associated with huge, moneymaking ventures or preventable disasters, they should receive generous subsidies from the government.

2. The public may associate geologists working on hazard abatement with the disasters they seek to mitigate or with the huge expenditures required to repair environmental damage. Environmental law seems to abstract underlying scientific issues into regulatory wrangling and wars among "potentially responsible parties." This may reduce industry's need for accurate geologic analysis.

3. The public may associate geology-related issues with impairment of land rights that can threaten even the ordinary homeowner. For example, the U.S. government has instituted a very sensible (if subsidized) approach to flood-plain regulation in the National Flood Insurance Program. The program has been designed to reflect statistical, scientific realities and impute the costs of flood-plain development to the risk taker (i.e., it's designed to avoid "rewarding" risk takers with postdisaster aid). Yet the program is popularly perceived as unwarranted government regulation and interference with property rights.

4. Geologists suffer in industry by the perception that they are the poor stepchildren of engineers. Industry may not value geologists because, in comparison with engineers, the supply of geologists is great and the demand is small. Further, in comparison with engineers, few geologists receive academic training efficiently oriented toward industrial applications. This approach to geology education, however justified, may contribute to industry's poor perception of the science and result in reduced support from industry. Further, industry management may neglect investment in geologists when resource exploration is more efficiently pursued in financial markets.

I recently observed negotiations related to a large infrastructure project. The geologic analysis of the site was poor, calculated only to produce a satisfactory "executive summary" for project investors. In the squeeze to make a living in an unfavorable environment, geologists may face compromises in the excellence of their work that will further contribute to the poor perception of geologists in industry.

Geology is indeed one of the most fascinating natural sciences—witness the popularity of the geology-oriented national parks. I appreciate Moores's observation of the "Eureka!" aspect of geologic thought and his perception that geological analysis differs from the purely analytic method of enquiry that prevails in many other sciences. For me, this provided an exceptional background for practicing law. It is too bad that it didn't more readily provide for a career in science.

Rob Risley
Bangkok, Thailand

Washington Report *continued from p. 12*

been thoroughly analyzed. Americans should have the opportunity to voice their opinions in this important debate."

Another group, the Global Climate Coalition (GCC), a similar organization of business trade associations and private companies "established in 1989 to coordinate business participation in the scientific and policy debate on the global climate change issue," has also issued a statement and paid for many radio ads in the Washington, D.C. area to lobby against severe limits on energy consumption. The statement by Gail McDonald, president of the GCC concludes, "President Clinton has a unique opportunity in the coming days to demonstrate true leadership by encouraging the leaders of the G8 and representatives to the U.N. to carefully study the scientific and economic implications of any climate agreement before taking action. If he does not, he stands on the precipice of what may easily become the most economically devastating federal policy blunder of the decade."

Elsewhere, Internet traffic from pro-environmental NGOs carries banners stating, "Act Now! Environmentalists fear weak U.S. stance may hamper global warming talks." Much of their concern is based on statements by President Clinton, in recent speeches, that his Administration has indicated only an inclination to support stabilization, but not reductions, in heat-trapping gases by 2010–2015.

On June 23, a "Scientists' Statement on Global Climatic Disruption," aimed at the Kyoto meeting and signed by hundreds of members of the international scientific community was released. In it, the signatories state, "Human-induced global climatic change is under way. [We] ... observe that the further accumulation of greenhouse gases commits the earth irreversibly to further global climatic change and consequent ecological, economic and social disruption. ... [We] urge the United States [to] enter that meeting with a clear national plan to limit emissions, and a recommendation as to how the U.S. will assist other nations in significant steps toward achieving the joint purpose of stabilization." The GCC response shows how large the difference in philosophy is between the two sides. Whatever position the vice-president and the USGCRP take, they will fail to satisfy a large percentage of the stakeholders. According to GCC, "Those who organized this effort today (the Scientists' Statement), are doing little to advance our scientific knowledge of global warming but are doing a great deal to politicize this important issue through public relations gimmicks. Political petitions are no substitute for an open scientific debate and rigorous economic analysis."

Stay tuned for more information.

If you have comments or questions on this Washington Report or others contact Bruce Molnia, bmolnia@usgs.gov or bmolnia@erols.com, (703) 648-4120, fax 703-648-4227, Deputy Chief, International Programs Office of the Chief Geologist, U.S. Geological Survey, 12201 Sunrise Valley Dr., Rm. 3A312, 917 National Center, Reston, VA 20192. ■

SAGE REMARKS

Honey, I Shrunk the Class: Thoughts on Personalizing Large Lecture Classes

Jonathan Levy, Department of Geology, Miami University

Last year I was awarded the BIGGS award for early-career earth science teachers. For this I am deeply honored and grateful to all involved. Ed Geary, Educational Programs Coordinator for GSA, asked me to share some of my teaching philosophy and techniques. I consider myself new at this whole thing and am therefore cautious about giving any advice to teachers with much more experience than I have. I have given a good deal of thought to what contributes most to my teaching and have decided that one factor is my success in making large classes feel like small ones. Some of this is due to such intangibles as feeling at ease in front of large groups—i.e., being a bit of a ham. But there are some tactics that might be worth sharing, most of which I borrowed from others and all of which contribute to getting around the formal barriers set up in a traditional lecturer and student format. These tactics can be broken down into the Murray technique of learning students' names, cooperative learning techniques, and what my wife refers to as the Columbo technique. Allow me to explain.

POWER OF NAMES: THE MURRAY TECHNIQUE

When I began graduate school at the University of Wisconsin, my advisor suggested I take a statistics class. I dutifully signed up for one thinking it would be useful, but not terribly exciting. I was wrong. Not only was the class full of invaluable material, but it was also exciting and fun. Of course, what made it such a great experience was the talent of the professor, Murray Clayton, who would go on to become a teaching mentor for me. Since I was the nerdy, pesky type who asked a lot of questions and went to office hours, I was not surprised that Murray quickly learned my name. As the semester went on, however, I was surprised to find that Murray seemed to know everyone's name. How this was possible in a lecture class of roughly 130 students I did not know, but I did know that along with Murray's gracious, easy-going style, it helped transform the lecture into an intimate, seemingly small-class experience.

When I came to Miami University as an assistant professor in 1994, I asked Murray for any advice he could give me. The first thing he recommended was that I should learn all my students' names. I was more than a little dubious. Like many people, I have trouble remembering someone's name 30 seconds after an introduction. Still, I have had great success with the techniques that Murray recommended. I employ them each semester in the introductory class Environmental Geology, comprising about 95 nonscience majors. The rewards have been tremendous. Knowing students' names helps create a friendlier, less intimidating learning environment. The changes in students' attitudes and demeanor are obvious when you call them by name (either when their hands are raised or when they're not). They immediately feel less like mere numbers, and they feel that you care about their learning. As a result, they begin to care more about their own learning. Although I haven't performed any controlled experiments, I also believe that calling students by name encourages class attendance and participation in question-and-answer dialogs. When Murray told me his methods, he presented them as a magic trick and swore me to secrecy, but since he is a statistician and will probably never read *GSA Today,* I don't see the harm in sharing the information with you. If you see Murray, please don't tell him that I wrote this.

Step one is to become familiar with the class names, independent of their faces. Simply spending some time reading and reciting the class list helps associate students' first names with last names. Even in the first few weeks of the class you may be able to use this information, for example, when handing back papers. You may ask a student "What is your last name again? Summers. Right. Here you go, Mary Ann." To the students, this can appear as if you have magically already learned who they are. The most important aspect of learning to associate first and last names is that it prepares you for the next step.

Step two occurs on the day of the first exam. I have chosen not to generally take attendance or have a seating chart, but by this time, students tend to sit where they sit. There is typically very little shuffling around after the first two weeks. During the first exam I pass around an "attendance sheet." It's not really an attendance sheet. In fact, exam days are the only days where an attendance sheet provides redundant information. The funny thing is, no student has yet questioned why I need an attendance sheet on exam days (I guess they are a bit preoccupied). The sheet is passed up and down the rows. I am ever watchful to ensure that it is passed around in a logical order. I'm sure the students must write off my behavior as overly fussy as I frantically leap up to grab the sheet if it's passed the wrong way. For a class of 95 it takes about 20 minutes (with some diligence on my part to keep it moving) for the sheet to make the rounds. That leaves me 30 minutes to use the sheet as a seating chart and to associate as many names with faces as I can.

Associating names with faces is a matter of a combination of thinking up mnemonic devices and using simple rote memorization. It comes in very handy to have already associated first and last names because it might be either name that lends itself to an easy mnemonic. For example, Leon Jones in the third row might have red hair (or a bony face, for that matter). The fact that I am a fan of the musician Leon Redbone makes this name one I won't easily forget. Most, of course, are not so easy or so polite. For the protection of my former and future students (and myself), I will refrain from giving any real examples. Easy ones to remember are also embarrassingly goofy. Now that I have done this a few times, I find myself getting nervous on exam day. The pressure is on to quickly and creatively come up with good mnemonic devices. However, I also look forward to being able to call my students by name. On average, while not as good as Murray, I have found that by the end of the first exam, I have learned about half—40 to 50—of the names, some with mnemonics, others by rote memorization. Here's some more magic—learning half the names is enough to give the impression that you know all the names. I repeat the process during the second exam, concentrating on the faces I have yet to learn. By the end of the second exam, I will typically know 75 to 85 names out of around 95. The hardest to learn are the young men with the hats. During exams, their heads are down making it very difficult to see their faces and to associate their faces with their names. If they wore the same hats everyday, I'd be OK, but that seems not to be the case. On the same note, be wary of using hair styles in your mnemonics, for they can be too ephemeral. The boys (or men) that shave

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or grow their beards midway through the course also cause me grief.

Learning each student's name makes each one feel a bit more like an individual and someone whose efforts are appreciated. It's a bit of work, but judging from the number of students who comment on it at the end of the semester, it is time well spent.

USE OF COOPERATIVE LEARNING

After having gone through the effort to learn 92 names my first semester, I discovered that students who had sat next to each other three days a week for 15 weeks often didn't even know each other's names. This discovery, as much as anything, led me to think that something was missing from the learning community I was trying to foster. Of course, what I had stumbled upon was the rich and complex subject of cooperative learning. While knowing the names of most of the students establishes a direct and personal link between me and the students and makes the students feel more like individuals, it is only the first step in increasing individual accountability of student learning. The use of cooperative learning techniques is the next step in the process, and I have only begun to experiment with these techniques.

My first and simplest application of cooperative learning was to extend the Socratic method to self-formed groups instead of individuals (also known as Think-Pair-Share; Macdonald, 1995). I am, no doubt, not alone when I admit that, too often, I ask a question and am initially met with deadly silence. (While always tempted to answer the question myself and move on, I try to withstand the silent onslaught until a response is given, often with rephrasing and much coaxing). While the silence can sometimes occur when the question is too easy, student fear of a wrong response explains most of it. Once in a while, therefore, I encourage students to confer with one or two people sitting nearby and see if they are thinking along the same lines. The first couple of times I do this, I ask that they introduce themselves and tell their new partners a little about themselves. In addition to perhaps eliciting more responses, this tactic is usually viewed with some surprise and good humor and may help make the lecture seem less formal and intimidating. It might also lead to fostering friendships between students and more cooperation outside the classroom.

Recently I've begun experimenting with more sophisticated applications of cooperative learning. This experimentation occurred in an introductory hydrogeology class with about 35 to 40 juniors, seniors, and graduate students. About midway through the course, I was lecturing (in traditional style) on a topic that mainly involved interpretation of numerous figures showing the effect of various hypothetical geologic settings on groundwater flow. I found the material fascinating and perhaps naively thought the class would enjoy the lecture. I stood in front of the class showing overheads of the figures and explaining the relationships, only to observe the students getting more bored than I had ever seen them, including during involved equation derivations. During derivations, they are at least taking notes and are, therefore, somewhat involved with what I am doing. With the figures, however, all they could do was watch me make the interpretations. I realized that guided interpretation of these same figures in interactive groups would be a much more effective method of conveying an understanding of the material. I therefore designed activities based on the "jigsaw" technique as described, for example, by Tewksbury (1995). The class was divided into nine groups of four. Each group was assigned one of three figure-based problems to work on, so three groups were working on each problem, which involved drawing flow and equipotential lines and answering questions. I roamed around the room guiding the groups through their problems. What struck me most was that in some groups, the students had begun working on the problems individually, with no communication at all. They were so unaccustomed to working together that they did not initially know how to approach the assignment. With some gentle prodding, they began working together. After sufficient time for completion of the problems, the groups reshuffled so that new groups of four were formed with at least one representative from each of the three problems. Each new group member was responsible for teaching his or her problem to the other members of the new group. The idea is a simple one: teaching a concept requires a deeper understanding than is normally required for doing an assignment. To complete all the problems, students must pay attention to and ask questions of their fellow students. I closed the exercises with student oral presentations using overheads to make sure no major concepts were missed.

SAGE Remarks *continued on p. 16*

Educom Medal Award Winner Named

Michelle N. Lamberson is the winner of the Educom Medal for her pioneering work in World Wide Web resource development for undergraduate geoscientists. The Web site Lamberson has developed for the Department of Earth and Ocean Sciences, University of British Columbia, at http://www.science.ubc.ca/~eoswr/ includes course Web sites, interactive learning modules, exercises, discipline-specific databases, and developer tools.

The Educom Medal was established in 1994 to improve the quality of the undergraduate learning experience and to promote the effective use of information technology in higher education. Each year, Educom, a consortium of 600 colleges and universities, selects disciplinary societies as partners, whose representatives choose a winner. This year, Educom has chosen GSA as a partner in selecting an individual who has made a significant contribution to transforming undergraduate learning in geology through information technology.

Michelle Lamberson is a lecturer in the Department of Earth and Ocean Sciences and the Educational Technology Coordinator for the Faculty of Science at the University of British Columbia in Vancouver. She received her Ph.D. in geology at the University of British Columbia in 1993. She was a postdoctoral fellow at the University of Arizona, and she taught several geology courses at the University of British Columbia and the University of Victoria. She says she first looked at the World Wide Web in October of 1994 and saw its potential for improving the learning environment for visually oriented learners in geoscience. She was hired as a four-month postdoctoral teaching fellow to investigate the effectiveness of the Internet as a teaching and learning medium for geoscience students in January 1995, a role that evolved into her current position.

GSA President George Thompson will present the Educom Medal to Michelle Lamberson at the Presidential Address and Awards Ceremony at the GSA Annual Meeting in Salt Lake City, Utah, on October 20, 1997. Lamberson will then travel to the Educom Annual Meeting in Minneapolis, Minnesota, October 28–31, to participate in the Educom awards presentation and receive a check for $2,500, and a bronze desk statue.

SAGE Remarks *continued from p. 15*

I believe my ventures into cooperative learning, and especially the jigsaw method, have been very successful. Students seemed grateful for the experience (especially when similar problems were included on the final exam). In end-of-semester evaluations, students rated the exercises "excellent" (44% of respondents), "good" (44%), and "fair" (11%) compared to a normal lecture. Like many before me, however, I found that the exercises took much more time than I originally expected (actually, about twice as long). There is no doubt that using such methods results in getting through less lecture material. To work successfully, it requires students' coming prepared to class, having done the appropriate reading. I am, so far, just a dabbler in these techniques. I see them as a way of breaking up the normal lecture routine. They help create an atmosphere in which students are encouraged to participate as individuals and not anonymous listeners and note takers, and, therefore, share similar goals to learning student names. Next semester, I plan to extend these techniques to my large introductory class. Because the classroom I use does not lend itself to students moving around, modification will be necessary. The goals, however, will be the same: involve the students more actively and cooperatively in thinking about the course material.

COLUMBO TECHNIQUE

Along with emphasizing my getting to know the students and the students getting to know each other, a third component to breaking down traditional classroom barriers is to let the students know a bit about me and see me as a person, not just a lecturer. At grave risk of dating myself, I'm calling it the Columbo technique. You may or may not remember the TV series in which the detective Columbo used a combination of techniques meant to give the murderer a false sense of superiority and security before sending him or her to prison for life. OK, so that's not exactly my aim with the students, but I do mean to put them at ease and make even a large lecture hall a friendly environment. Like Columbo, I engage in somewhat self-deprecating humor, and I will embark on personal stories of travels or mishaps to get my geological points across. The key to Columbo's success was that he appeared to digress, when actually he was always on a direct course toward well-developed objectives. As I mentioned at the outset, my wife came up with the name, and that, of course, is part of the point. Part of Columbo's style was to bring his professional relationships to a personal level by telling stories regarding and giving cre-

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ative credits to his wife. For example, I enjoy telling the students that it was my wife, not me, who came up with a good mnemonic device (a first-letter analog) for remembering the names of the epochs of the Tertiary and Quaternary periods (people everywhere order many pizzas, piping hot). Geology, more than other disciplines, lends itself to the Columbo technique, because we get to show slides of exotic locations. I try to include slides that show me, my friends, and my wife, and students have often told me how much they enjoy this part of the lecture and how it helps involve them more in the material. Plus, as I admit to my students, who could ask for a better job than one in which you get to show your travel slides without being socially ostracized?

All the techniques outlined have the same general goal: to improve on the traditional lecture format in such a way as to more involve the student in his or her own education. They are not revolutionary in that they do not deviate much from an overall lecture format. Perhaps more can be achieved with further deviation from the lecture format and more sophisticated application of cooperative learning techniques. However, I believe that our knowing the students, the students knowing each other, and the students knowing us help make lectures more personal and draw students into discussions, activities, and their own learning.

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Tewksbury, B. J., 1995, Specific strategies for using the "jigsaw" technique for working in groups in non–lecture-based courses: Journal of Geological Education, v. 43, p. 322–326. ■

About People

GSA Fellow **John A. Cherry,** University of Waterloo, Ontario, Canada, has been awarded the William Smith Medal by the Geological Society (of London), for excellence in contributions to applied and economic aspects of geoscience.

Member **Robert Lamonica,** Trumbull, Connecticut, has been named executive vice president and chief operating officer by the groundwater and environmental engineering services firm, Leggette, Brashears & Graham.

The Association of Engineering Geologists has appointed a new executive director: GSA Fellow **Norman R. Tilford,** Texas A&M University.

GSAF UPDATE

Valerie G. Brown, Director of Development, GSA Foundation

FROM THE GROUND UP

In recent months, we've reported both on 1996 fund-raising results and on cumulative revenue during the Second Century campaign from 1992 through April of 1997. So what's the point of all this money?

The GSA Foundation has 67 gift funds. The funds originate from several sources—from individuals, many of them GSA members who create significant gifts or who donate in honor or memory of their GSA colleagues, from corporations that engage in the business of geology, from foundations that respect and support GSA's programs of education and outreach, and from government investment in the importance of geoscientific excellence.

The funds are applied to several purposes—above all, to education. Of the 67 funds, 35 are dedicated to assisting students of all ages to become intellectually or even professionally engaged in the geosciences.

Some of the applications are general in nature. The SAGE funds, for example, are directed to enhancing public understanding and appreciation of geoscience. This broad objective encourages unusual but valuable activities such as

- designing and presenting summer workshops for middle school teachers from all over the country needing to improve their command of earth science curriculum and technological teaching aids;
- recruiting GSA member volunteers to serve as expert mentors for schools, classrooms, or individual students in their communities;
- creating the Colorado Rock Park, a geological garden that will provide interactive instruction for visitors of all ages about the shape and structure of the state's natural environment and will establish a model for similar installations in other parts of the country.

These activities are supported by the full spectrum of donors.

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Digging Up the Past

I stepped on a boulder at the foot of a glacier during the 1960 IGC and learned about thixotropy—we both sank.

—*Virgil E. Barnes*

GSAF Update *continued from p. 16*

The Donald L. and Carolyn N. Biggs Excellence in Earth Science Education Fund was established in 1990 in memory of Donald L. Biggs. Upon the death of his wife, Carolyn, in 1991, her name also was incorporated. Income from this endowment is committed to the SAGE initiatives, serving as a permanent reminder of the generosity of the Biggs family and friends.

Several hundred individuals making annual gifts directed their use to SAGE programs.

BHP Minerals has made and renewed vital corporate gifts used, in part, as seed money for developing the Rock Park.

Grants from the **Boettcher Foundation, El Pomar Foundation,** and the **National Science Foundation** have enabled GSA to launch the science and technology workshops for teachers, a labor- and equipment-intensive project that wouldn't have been feasible without a major infusion of capital.

In short, the point of the money is fulfilling a mandate.

man' date, n. From the Latin *mandatum,* a charge, command, commission; lit., to put into one's hand; *manus,* hand, and *dare,* to give.

As recently noted in the journal *Science,* "The U.S. educational system was designed a century ago to prepare children to hold jobs and raise families in a world that relied primarily on physical labor. Because of the large role of agriculture and an abundance of natural resources, the nation could prosper even if many young people did not develop their full intellectual capacities.... Now we face a future in which we must increasingly turn to high-technology products as a source of economic security." To prepare for this world, excellence in scientific and technological education is of the highest priority.

Your gifts to GSA fuel our contributions to such education.

THIS MONTH'S BUMPER STICKER:

Take good care of the future, because that's where we're going to spend the rest of our lives. ■

Donors to the Foundation, May 1997

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Institute for Environmental Education

Assessing Environmental Justice: The Demographics of Hazardous Waste in Los Angeles County

James L. Sadd, J. Tom Boer, Manuel Pastor, Jr., Lori. D. Snyder, Occidental College, Los Angeles, CA 90041

The concept of environmental justice addresses potentially inequitable impacts of environmental hazards on society, as well as the need for equal public access to processes that can redress such impacts. We used Geographic Information System (GIS) and Global Positioning System (GPS) technologies to document the current geographic distribution of hazardous waste treatment, storage, and disposal facilities (TSDFs) in Los Angeles County, California. We examined this pattern to test if hazardous waste sites can be correlated with a variety of socioeconomic and demographic factors. Because an extensive permit and siting process is required for legal operation, environmental justice problems associated with hazardous waste facilities may be at least partly rooted in political process. For this reason, hazardous waste facilities have been a particular focus of environmental justice debate in other areas. In this study, we assumed that the presence of a TSDF poses some additional risk to nearby residents, particularly in case of fire, accidental explosion, earthquake, or illegal discharge.

All 82 permitted Los Angeles County TSDFs were used in this analysis, and differentially corrected GPS was used to confirm geocoded site locations. We assumed that the wide range in capacity among these facilities (0.01 to 140,000 tons annually) implies a significant range in potential health risk to nearby residents, and that this risk is greater near large capacity TSDFs (>50 tons per year; $n = 39$). For this reason, we also explored the impact of facility size on correlation with demographic characteristics. Data used in this study were obtained from the State of California, 1990 U.S. Census, Southern California Association of Governments, Los Angeles County Registrar/Recorder's Office, and commercial data sources. Analysis was conducted at the census tract level, and tracts listed as having no residents were eliminated from the analysis. The average tract area is 2.5 square miles, with a median of 0.5 square mile.

Using GIS (Arc/Info software), we compared demographic characteristics of census tracts that contain or are near a TSDF to the universe of all Los Angeles County tracts. To summarize demographic composition, we used 12 census variables: percentage minority residents (sum of African-American, Asian, Hispanic, and Native American), per capita income, median household income, median home value, median rent, percentage of population employed in industry, unemployment, percentage registered to vote (1992), population density, percentage with a high school education or less, percentage of tract area devoted to industrial use, and percentage devoted to residential use.

Four different aggregate tract subsamples were defined to explore different definitions of the community exposed to the potential hazard. TSD is composed of all tracts that contain at least one TSDF regardless of capacity. TSD50 includes tracts containing a large-capacity TSDF. TSD50/0.5 and TSD50/1.0 are two subsamples that include all tracts with boundaries within a 0.5 or 1.0 mile radius of a large-capacity TSDF. Demographic variables were summarized to produce mean and median values that describe the total population represented by the sum of tracts in each subsample. Using univariate statistical techniques to test the statistical significance of the implied visual results, we compared these data with similar tract-level demographic means or medians for all Los Angeles County census tracts.

This comparison of tracts with and without TSDFs reveals statistically significant differences by race, economic status, education, voting participation, and land use. In almost every case and in each of the four subsamples, the aggregate mean demographic profile for each of the twelve variables varies from the county mean at statistically significant levels, usually at the 99% confidence level. The manner in which these variables differ indicates substantial demographic inequity in TSDF location. A significantly larger percentage of people who live near Los Angeles County TSDFs belong to racial and ethnic minorities and are below the county average in terms of income, education, employment, and voting participation. Neighborhoods near TSDFs also lag behind the county mean in value of residential home and rental property, and the percentage of the land in these tracts occupied by industrial land use is four to ten times the county average. Demographic, economic, and land use differences tend to be greater for tracts containing large-capacity TSDFs, and evaluation of tracts within a one-half or one mile radius shows that these demographic differences persist over a wide area. "Minority"-dominated neighborhoods are much more likely to be located near TSDFs than primarily Anglo (non-Hispanic white) neighborhoods. The resident population of tracts with boundaries within 1 mile of a large-capacity site comprises 8.3% of the Anglo population, it also represents 22.0% of Los Angeles County's minority population. Therefore, more than one in five minorities live in a census tract located within 1 mile of a large-capacity TSDF in Los Angeles County, as compared to fewer than one in ten Anglos living in similar circumstances.

These results indicate a strong geographic correlation, but spatial and univariate analyses cannot separate the effects of each demographic characteristic and determine its relative importance in facility location. This is particularly problematic because many of the variables (e.g., minority and income) are themselves highly correlated, making it difficult to distinguish whether site location is the result of explicit income or ethnic discrimination, or perhaps a consequence of market-driven opportunity costs such as real-estate pricing and local job options (or some combination of both).

We also used a multivariate logit regression to attempt to tease out the separate effects of each variable while holding the others constant. Our findings include: (1) percentage minority and industrial land use are the dominant factors in large-capacity TSDF location; (2) per capita income has far less effect than the previous two variables; (3) the significance of percentage minority is greater with distance (to 1 mile) from TSDFs, while industrial use is highly significant regardless of distance; (4) per capita income first has a positive, then a negative effect on the probability of TSDF location as income level rises. While the last finding may seem anomalous to those who have thought income, not race, is the driving force behind the location of environmental hazards, this relationship is consistent with the assertion of demographic inequity and environmental "injustice," and it makes sense upon reflection. Some areas are too poor to have any economic activity, including a TSDF, while others are wealthy enough to resist TSDFs being sited nearby. The persistence of race across our tests suggests that environmental justice proponents have cause for their concerns, at least in the Los Angeles area. The overall pattern we find suggests that the communities most likely to "host" a TSDF are neighborhoods located near industrial activity and with a large residential concentration of working-class people of color—exactly the sorts of communities that, in our area, organize and challenge the location of urban environmental hazards under the "environmental justice" concept.

The complete version of this study will appear in the December 1997 issue of *Social Science Quarterly;* it is also available on the World Wide Web at http://www.oxy.edu/academia/acadepts/environ.htm. ■

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Late Paleocene–Early Eocene Events in Space and Time

Co-conveners:
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Spencer G. Lucas, *New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, NM 87104; lucas@darwin.nmmnh-abq.mus.nm.us*
Lowell Stott, *Department of Geology, University of Southern California, Los Angeles, CA 90089; stott@usc.edu*
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Although it has been known for more than a century that a major turnover occurred in the terrestrial mammalian fauna near the Paleocene-Eocene epoch boundary, it is only relatively recently that apparently simultaneous, equally important evolutionary turnovers among marine invertebrates and protists have been recognized. Subsequent to the discovery of a sharp late Paleocene extinction event in deep sea benthic foraminifera—the most notable evolutionary event among marine taxa in the last 90 million years—sharp variations in the oxygen and carbon isotopic composition of uppermost Paleocene marine carbonates were identified. Late Paleocene–early Eocene variations in the isotopic composition of organic carbon of amplitude similar to those described from marine carbonates have now been described from teeth of late Paleocene land mammals and from upper Paleocene carbonate concretions in paleosols. In addition, marked sedimentologic features such as a decrease in grain size of atmospheric dust and an increase in kaolinitic content of marine deposits, in particular at high latitudes and on epicontinental shelves, have been documented. These findings have led to the upper Paleocene–lower Eocene stratigraphic record becoming the focus of considerable attention in earth science circles during the past few years and to the recognition that the latest Paleocene–earliest Eocene epochs constituted the most critical turning point in the Cenozoic history of our interstellar home.

In an attempt to delineate clearly the location and distribution in space and time of these changes, and to decipher the cause-and-effect relationships involved and which resulted in global warming, International Global Correlation Project (IGCP) 308 was initiated (1989; president: Marie-Pierre Aubry) and funded for a period of 5 years by IUGS and UNESCO. Simultaneously the Paleogene Subcommission of the International Commission on Stratigraphy (ICS) designated the Working Group on the Paleocene/Eocene Boundary to search for and provide documentation on stratigraphic sections that might serve as potential standard bearers for the boundary between the Paleocene and Eocene series, the so-called Global Boundary Point and Section (GSSP) and its "golden spike." In this context, IGCP 308 has also been active in seeking to provide the appropriate criteria by which the Paleocene-Eocene epoch boundary may be characterized and the Paleocene-Eocene series boundary recognized and correlated.

In view of the large database that has accumulated on the subject of the P-E boundary interval, it was considered appropriate to convene an international conference that would enable specialists who have been engaged in IGCP Project 308 studies to meet and review the information 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. The Penrose Conference was held April 24–29, 1997, at the Rio Grande Inn, Albuquerque, New Mexico, cosponsored by GSA and the New Mexico Museum of Natural History. Fifty-five scientists (including 10 graduate students receiving partial support from GSA) attended the meeting. Among the more outstanding problems that formed the focus of the meeting were the following.

1. 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.

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

3. Assessment of marine and terrestrial stratigraphic correlations with a view

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to providing a rigorously tested and high-resolution chronologic framework for a historical geology of this important time in Earth history.

4. Assessment of various bio-chemo-magnetostratigraphic events currently used and favored in depicting the P-E series boundary with a view to establishing the main criterion (or criteria) to be used to define it when the GSSP is proposed or selected.

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 for recommendation to the International Union of Geological Sciences (IUGS).

Each day of the four-day meeting was devoted to specific topics.

Day 1: Setting the Framework in Terms of Lyellian Stratigraphy

W. A. Berggren reviewed the original definition and subsequent history of Paleocene and lower Eocene (chrono)stratigraphic units, recent modifications to lithostratigraphic nomenclature in northwestern Europe, and the implications of a revised (short) chronology for the northwestern European P-E boundary interval ash series (vs. the conventional "long" chronology). He presented a relative chronology of the main events that span the 2 m.y. Paleocene-Eocene boundary interval. Until such time as a GSSP is chosen, the P-E boundary is defined at the base of the Leper Clay Formation (Belgium), stratigraphically equivalent to the NP10a/b calcareous nannoplankton boundary, within planktonic foraminiferal Zone P6b and with an estimated age of 54.37 Ma.

Robert Knox reviewed the original stratigraphic units included in the lower Eocene of England, emphasized Prestwich's (1854) remarkably precise stratigraphic cross section of the Thanet Sands and London Clay formations depicting the "surface of ravinement," which corresponds precisely to the unconformable sequence boundary separating the two units as recognized today. Knox continued with an overview of the modern (re)definition of stratigraphic units of the Lambeth and Thames Groups, correlations with the (subsurface) North Sea lithostratigraphic units and sequences and causal connections between observed faunal and floral and lithic changes and atmospheric and climatic events.

Medard Thiry and Isabelle Cojan presented overviews of the ^{13}C stratigraphy of the Paris and Aix-en-Provence basins, respectively. Organic carbon (pedogenic nodules) have yielded a record in the Paris Basin that appears to indicate a revised scheme of correlation within the lacustrine-fluviatile (Sparnacian) formations of the Paris Basin and to allow, to a first approximation, correlation with the terrestrial record in North America (Wasatchian land-mammal "age" [LMA] of the Bighorn Basin) and the marine (deep sea) record. A significant feature of this study is the implication that the *Conglomérat de Meudon* (typical of the "Sparnacian" of northwestern Europe) is slightly younger than the base of the Wasatchian (Wa_0) of the Bighorn Basin. Cojan reviewed the geologic setting and history of studies of the Upper Cretaceous (Maestrichtian) and Paleocene lacustrine sediments of the Aix-en-Provence Basin. The ~350-m-thick section contains a record of several Paleocene magnetozones and of the long-term carbon isotope trend seen in marine records. Unfortunately, a fault in the section renders it uncertain whether the "excursion" seen in these records reflects the major

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PUBLICATIONS NEWS FROM THE GSA

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THE NATURE OF MAGMATISM IN THE APPALACHIAN OROGEN
edited by A. K. Sinha, J. B. Whalen and J. P. Hogan, 1997
The thermal evolution of mountain belts is commonly recorded in the distribution, origin, and ages of magmatism. In this volume, 20 contributors present the latest petrological, isotopic, and geochemical evidence to highlight the contribution of igneous rocks to the evolution of the Appalachian orogen in both Canada and the United States. These papers emphasize the use of modern geochemical and petrologic data to discriminate the sources yielding magmas, and thus the nature of the crust and mantle. The wealth of data available in this work provides a significant stepping-stone to more rigorous interpretation of the assembly and origin of the Appalachian orogen.
MWR191, 438 p., indexed, ISBN 0-8137-1191-6, $135.00, Member price $108.00

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 and others, 1996
MWR189, 78 p., hardbound, indexed, ISBN 0-8137-1189-4, $40.00; Member price $32.00

PLIOCENE CARBONATES AND RELATED FACIES FLANKING THE GULF OF CALIFORNIA, BAJA CALIFORNIA, MEXICO
edited by M. E. Johnson and J. Ledesma-Vázquez, 1997
The Gulf of California is a stimulating laboratory in which to test the interplay between tectonics and eustasy with respect to the erosion of rocky shorelines. Not since GSA Memoir 43 on the results of the 1940 E.W. Scripps Cruise to the Gulf of California has there been assembled so expansive a collection of research papers on the Gulf Coast Pliocene of Baja California. This volume takes up facies relations, paleogeography, and tectonics where the classic exploration style of the 1950 Memoir leaves off. The result of collaboration by Mexican and American geologists and marine biologists associated with the Sociedad Geológica Peninsular, the topics embraced by this well-integrated collection fall under three themes. One concerns the origin of carbonate sediments, giving new emphasis to coralline red algae as rhodoliths. Another deals with rocky shorelines as an ideal boundary marker for the mapping of facies and the determination of relative sea-level changes. The third theme involves insights on Pliocene stratigraphy through Holocene patterns of sedimentation and neotectonics.
SPE318, 180 p., indexed, ISBN 0-8137-2318-3, $57.00, Member price $45.60

AN 800,000-YEAR PALEOCLIMATIC RECORD FROM CORE OL-92, OWENS LAKE, SOUTHEAST CALIFORNIA
edited by G. I. Smith, J. L. Bischoff, 1997
A need for more lacustrine records that document late Quaternary climates in the now-arid western North America led to a U.S. Geological Survey–funded core-drilling project on Owens Lake, southeast California. The resulting 323-m-long core records lake fluctuations since 800 ka. This volume describes how they are revealed by variations in the CO_3 and organic-C percentages, pore-water isotopic content, composition of clay-sized materials, magnetic susceptibility, and fossils (diatoms, ostracodes, mollusks, fish, and pollen). Sediment ages are based on ^{14}C data, measured mass-accumulation rates, and paleomagnetic variations. The recorded wet and dry climatic cycles are about 100 ka long. Although their distribution in time is similar to those of deep-sea and other records that largely reflect paleotemperatures, the maxima and minima of the wet and dry cycles differ in age from correlative inflections in paleotemperature records by an average of 15 ka.
SPE317, 172 p., indexed, ISBN 0-8137-2317-5, $60.00; Member price $48.00

PERMIAN STRATIGRAPHY AND FUSULINIDA OF AFGHANISTAN WITH THEIR PALEOGEOGRAPHIC AND PALEOTECTONIC IMPLICATIONS
edited by E. Ja. Leven, C. H. Stevens, D. L. Baars, 1997
An excellent overall study of the Permian Stratigraphy and fusulinid faunas of Afghanistan. All of the major stratigraphic sequences there are correlated with those of the adjacent Pamirs and are described, as are one new genus and 41 new species and subspecies of Permian fusulinid.
SPE316, 138 p., ISBN 0-8137-2316-7, $45.00; Member price $36.00

THE THIRD HUTTON SYMPOSIUM ON THE ORIGIN OF GRANITES AND RELATED ROCKS
M. Brown, P. A. Candela, D. L. Peck, W. E. Stephens, R. J. Walker, E-an Zen, 1996
The invited papers in this volume, from the Third Hutton Symposium on the Origin of Granites and Related Rocks, summarize the latest ideas concerning crustal anatexis, melt segregation, magma transfer, and granite emplacement into lower- grade upper-crustal rocks.
SPE315, 225 p., indexed, ISBN 0-8137-2315-9, $78.00, Member price $62.40

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event recorded in marine and terrestrial records in Chron C24r elsewhere.

Jan Hardenbol presented an overview and regional (Transatlantic) correlation network (Gulf and Atlantic Coastal Plains, northwestern European basins) of the P-E boundary stratigraphic interval in a sequence stratigraphic framework and discussed the recently completed Cenozoic Global Sequence Stratigraphic Correlation Chart(s) prepared for inclusion in the forthcoming SEPM volume on sequence stratigraphy of European basins.

Marie-Pierre Aubry presented evidence for the incompleteness of stratigraphic records across the P-E boundary interval using an integrated magneto-bio- isotope-stratigraphic approach. She emphasized that most stratigraphic sections only represent or record "windows on time," with overlap and exclusion of temporal records from site to site, and discussed the need to conduct "temporal analysis of stratigraphic sections" to achieve sound temporal correlations between sections.

Will Clyde reviewed the magnetostratigraphy of the classic (most complete) North American P-E terrestrial section, the Bighorn Basin. The Tiffanian-Wasatchian LMAs span the ~3 m.y. Chron C25n to C24n interval in a 2000+-m-thick stratigraphic record wih the ^{13}C excursion identified at the base of the Wasatchian (Wa_0) LMA approximately in mid–Chron C24r. Several dubious or uncertain normal-polarity magnetozones in Chron C24r may correspond to the cryptochrons of Cande and Kent (1995) and be suitable for global correlation, but positive identification or correlation is not possible at present.

Oral presentations were complemented by a poster dealing with the late Paleocene palynology of Siberia presented by Alina Yakovleva.

Day 2: Paleoceanography and Paleoclimatology of the P-E Boundary

Lowell Stott opened the morning session with a review of carbon and oxygen isotopic changes recorded through the mid-Paleocene to lower Eocene marine records. He pointed out that the distinct isotopic events documented near the Paleocene-Eocene boundary are superimposed on long-term changes in the temperature of the ocean and long-term changes in their carbon isotopic composition. Even though the cause(s) of these changes are not known, they provide the backdrop for the events near the boundary.

Ashish Sinha reviewed the systematics of carbon isotope exchange reactions between the major carbon reservoirs. The equilibrium carbon isotope exchange reactions between the ocean and terrestrial biosphere via atmospheric CO_2 are used by stratigraphers to predict what the pattern of terrestrial carbon isotopic variability should be relative to the marine carbonate record. The marine pelagic carbonate records show large changes indicating substantial reorganization of carbon between the major reservoirs during the late Paleocene and early Eocene. These patterns of change, including a marked negative carbon isotope excursion near the P-E boundary are the focus of investigations that are attempting to correlate terrestrial and marine sections across the P-E transition interval. Sinha reviewed his own work in the Paris Basin and the London Basin, for which there is now a detailed carbon isotope stratigraphy from the pedogenic soils that characterize these classic sections. The pattern of carbon isotope change recorded in the pedogenic samples matches closely the model predicted values derived from the marine carbonate records. This includes a distinct negative carbon isotopic excursion near the base of the Argiles Plastique of the Paris Basin and the Reading Beds of the London Basin, an excursion that correlates with the marked marine carbonate excursion near the P-E boundary.

There are also notable points in the terrestrial records where the terrestrial carbon isotopic values are more positive than the model would predict. Sinha addressed several potential explanations for these anomalous values. Preservation is one possible explanation, but diagenesis would not likely produce temporally and spatially consistent patterns throughout both the Paris and London basins. Second, the incorporation of C4 plant material, which is isotopically more positive than that of the C3-type plants, is unlikely, because the majority of C4-type plants are thought to have first appeared in the fossil record in the Miocene. Sinha presented a third intriguing possibility stemming from new experimental work. Using data from growth experiments, he pointed out that carbon isotope fractionation in C3 plants is related to CO_2 concentrations in the atmosphere. The experimental work indicates that there is a systematic increase in the fractionation of ^{13}C and ^{12}C with increasing CO_2 concentrations. The anomolously low ^{13}C values in the Paris and London basins could, therefore, point to relatively lower pCO_2 levels in the earliest Eocene.

James Zachos discussed the pattern of carbon isotope change recorded in several marine and terrestrial sections and their implications for (1) chemostratigraphy and stratigraphic completeness, and (2) testing models of the LPTM (late Paleocene thermal maximum) event. In particular, he raised the possibility, based on a comparison of carbon isotope records from tropical (ODP Site 865) and high-latitude (ODP Site 690) pelagic sections, that some Paleocene-Eocene NP (calcareous nannofossil) zones in the high southern latitude sections may be time transgressive. He also presented new records from new deep-sea sequences in the Caribbean that contain laminated clay and volcanic ash at or near the boundary interval. These sequences provide important new insights into events near the boundary. In particular, the presence of a distinct drop in $CaCO_3$ percent during the excursion is consistent with a rapid shoaling of the ocean lysocline as predicted from the methane disassociation model of Dickens et al. (1996, 1997). Moreover, the availability of laminated sequences in the Caribbean sections, particularly those containing ash, should provide a very detailed high-resolution record of changes across the interval, as well as a precise dating of the event(s). Zachos also discussed the high-resolution soil nodule carbon isotope records of Koch et al. (1992, 1995) from the Bighorn Basin paleosol sequences, which show that the C-isotope excursion and LPTM coincided with the earliest Eocene mammalian origination event.

Doug Hammond reviewed models that call on methane release from clathrates to explain the large carbon isotopic excursion near the P-E boundary. Other reservoirs containing isotopically light carbon, such as the terrestrial biosphere or the mantle are unlikely sources, given mass balance considerations. Hammond then presented model results in which the ODP Site 690 carbonate record was used to model the dynamics of methane cycling between the deep ocean, the upper ocean, and the atmosphere. The elimination of the surface-to-deep-water ^{13}C gradient seen at this site during the excursion calls for rapid inputs of methane to the upper ocean and a reduction in oceanic mixing rates. The solid-gas phase boundary at upper ocean pressures is near 12 °C. It is interesting that the excursion in the carbon isotope records coincided with the warming of the deep sea to about 12 °C and may help explain why there was apparently a sudden release of methane at that particular time.

Karen Bice reviewed the status of general circulation modeling of the boundary interval. There remain several problems in model-data comparisons. These include the underestimation of high-latitude sea-surface and bottom-water temperatures, even given atmospheric carbon dioxide and oceanic heat transport values elevated relative to the modern values. Ocean simulations indicate that the modeled thermohaline circulation is dependent on ocean geometry and freshwater fluxes to the sites of potential deep-water formation. For the early Eocene, these include the Northern Tethyan margin and the

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circum-Antarctic ocean. A minor North Atlantic deep-water source is possible, especially for the intervals during which the North Sea basin was flooded. The prediction of a warm, saline deep-water source in the Northern Tethys is dependent on the treatment of continental runoff in the model.

Paul Koch presented a model for the application of soil iron-oxide oxygen isotope ratios to reconstruct terrestrial temperature variations across the P-E boundary. According to Koch, the composition of the soil Fe oxides (hematite) is determined primarily by the $\delta^{18}O$ composition of the soil (meteoric) water in which it forms with a small temperature-dependent fractionation. Since the composition of meteoric water varies primarily as a function of surface temperature, the oxide $\delta^{18}O$ composition can be used to estimate past changes in temperature. The primary advantage of Fe oxides is that they are highly resistant to diagenesis, unlike calcite and other geologic materials. To demonstrate the feasibility of this approach, Koch presented preliminary data for samples collected from the upper Paleocene–lower Eocene paleosol sequences of the Bighorn Basin. These preliminary data indicate a large depletion in $\delta^{18}O$ values in the early Eocene following the WaO interval. Although such a trend might be caused by changes in more than one factor, Koch showed that one possible interpretation, that there was a significant decline (~4 °C) in MAT following the LPTM event, is consistent with previous findings based on an independent proxy (paleobotanical) of MAT for this region.

Tim Bralower presented new data from two recently drilled Caribbean cores, ODP sites 999 and 1001, each of which contains an expanded sedimentary record of the LPTM event. Preliminary lithologic and geochemical records from these sites show evidence of environmental changes including dysoxic bottom-water conditions and minor warming of surface waters. The most prominent feature, however, is the presence of multiple ash layers, including one at the onset of the LPTM warming episode in both cores. These ashes provide compelling evidence that volcanism may have directly influenced climate change. According to Bralower, these Caribbean eruptions may have triggered the LPTM event by causing high-latitude warming on millennial time scales via carbon dioxide emissions, and shorter term tropical and subtropical cooling via sulfur dioxide emissions. This combination of climatic effects led to an abrupt shift in the source of intermediate waters to low-latitude regions. The flow of warmer waters to intermediate depths, in turn, triggered the dissociation of methane hydrates in continental-rise sediments.

Thierry Adatte discussed the paleoclimatic, oceanographic, and ecologic changes associated with P-E boundary events as recorded in the deep Tethyan basin. He presented lithologic, clay assemblage, and stable isotopic data from several marine sequences, including the Spanish sections Zumaya, Caravaca, and Alademilla. In general, all sites show the C-isotope excursion and REE. Several of the sites show pronounced increases in phyllosilicate clay content, primarily kaolinite, coincident with the excursion. The increase in kaolinite is often accompanied by a relative decline in smectite. At Alademilla, the clay transition is marked by an increase in palygorskite. The kaolonite is thought to reflect an increase in humidity and chemical weathering, and the palygorskite is interpreted as an indicator of more arid conditions.

Wilfried Winkler spoke on the sedimentary and climatic aspects of the late Paleocene–early Eocene in northern Spain. The climatic reconstructions were based on detailed sedimentologic, clay assemblage, and bulk-rock stable isotope time series from Zumaya. One of the more prominent features of this record is a large increase in the relative concentration of kaolinite coincident with the C-isotope excursion and REE. According to Winkler, this depositional event reflects a significant increase in precipitation and chemical weathering. This event was accompanied by a large reduction in regional productivity.

Birger Schmitz presented new isotope and trace element data from three shallow marine Tethyan sequences, Ben Gurion, Gebel Duwi, and Gebel Aweina, Egypt. The lithology and geochemistry of the sediments indicate that deposition in this region was strongly influenced by local coastal upwelling. A C-isotope excursion of between –3‰ and –4‰ is recorded at each section. In addition, there is evidence of increased productivity at the P-E boundary interval. The most dramatic change occurs at G. Duwi where barium accumulation rates increase severalfold within the excursion interval. According to Schmitz, this change reflects a fundamental shift in the intensity of the trade winds at this time. In addition, at G. Duwi the change in productivity appears to be permanent.

John Flynn and Lisa Tauxe presented a talk analyzing all the principal magnetostratigraphic data sets from both marine and terrestrial strata spanning the P-E boundary interval, and applied two measures to assess reliability. The P-E boundary (under any of the potential definitional criteria) lies within Chron C24r. The most robust terrestrial magnetostratigraphies come from the northern Bighorn Basin, Ellesmere Island, and the San Juan Basin. There is poor consistency among ODP and DSDP sites, reliability of the magnetics is low for many marine sequences, and at a few sites there appear to be problems with biostratigraphic datums (relative to magnetochrons). In particular, there are significant inconsistencies at ODP Site 690B. The best marine magnetostratigraphic sequences appear to be Contessa Road and ODP Site 752, while ODP Site 690 and DSDP Site 577 may provide important additional data. Steven Schellenberg outlined a research project designed to quantify variations in P-E bottom-water paleotemperature. Current estimates based on oxygen isotopes may contain small errors due to salinity (ice-volume) effects. Schellenberg intends to use an independent proxy, the Mg/Ca ratios of deep-sea ostracodes, to reconstruct bottom-water temperature. If successful, this procedure would also allow him to deconvolute the ice-volume contribution to the oxygen isotope record.

Day 3: Biotic Events across the P-E Boundary Interval

The third day focused on biotic events across the P-E transition. The 13 talks were divided into seven on terrestrial mammals, two on paleoflora, three on foraminifera, and one on calcareous nannoplankton. Two posters were also presented, one on mammals and one on nonmarine gastropods.

The talks on mammals concentrated on the Holarctic continents—Europe, Asia, and North America—which formed a single paleobiogeographic province during the P-E transition. A significant reorganization of the placental mammalian fauna took place during the P-E transition and marks the beginning of the Wasatchian land-mammal "age" (LMA) in North America and the beginning of the Neustrian (="Sparnacian") LMA in Europe. This reorganization includes the first appearance of perissodactyls, artiodactyls, and euprimates in North America, and of these groups as well as rodents, carnivores, and bats in western Europe. In North America, this reorganization (also called the "mammalian origination event" or MOE) is best recorded in the Bighorn Basin of Wyoming, which preserves the most complete terrestrial record of the P-E transition.

Philip Gingerich reviewed that record, emphasizing the distinctiveness of the oldest Wasatchian mammalian fauna (Wa0 Zone) from earlier Clarkforkian mammal faunas. He suggested that the LPTM allowed boreal dispersal of Holarctic mammals leading to the MOE. Opening of the North Atlantic during Wa1 time led to increasing endemism and divergence of the North American and Eurasian mammal faunas. (Several mammalogists present at the conference informally agreed that the mammal event should be called a "mammal dispersal event" rather than a "mammal origination event" in view of the evidence and of known processes of mammal evolution.)

Spencer Lucas presented a comprehensive correlation of Holarctic mammals of the P-E transition. He equated the MOE at the beginning of Wasatchian and Neustrian time and emphasized that it predates the beginning of the Ypresian Stage (= base of Leper Clay in Belgium), which currently defines the base of the Eocene. The MOE correlates closely, though perhaps not exactly, to the C-isotope excursion. The mammalian turnover at the beginning of the Bumbanian LMA in Asia may, however, postdate the MOE as indicated by close-correlation using species of the pantodont *Coryphodon*.

Jerry Hooker divided the Neustrian LMA in Europe into zones and attempted to correlate these zones precisely to intervals of the North American Wasatchian LMA. He argued that the MOE in Europe was a more profound reorganization than in North America, and that most of the Neustrian first appearances were immigrants from North America.

Marc Godinot discussed the P-E transition mammalian assemblages from southern France, Spain, and Portugal. On the basis of their stage of evolution, he argued that these mammals predate the beginning of the Neustrian and represent an endemic, Tethyan center of origin. He thus argued, contra earlier speakers, for a strong immigration of mammals from Europe to North America during the P-E transition.

Suyin Ting reviewed the Asian mammal record of the P-E transition, recognizing three LMAs (ascending): Nonshangian, Gashatan, Bumbanian. She correlated the beginning of the Bumbanian and Wasatchian-Neustrian and emphasized the contrasting endemism of Nonshangian mammals and cosmopolitanism of Gashatan and Bumbanian mammals.

Will Clyde used the Bighorn Basin mammal record to delineate how taxonomic turnover at the beginning of the Wasatchian LMA affected mammalian community composition. Overall diversity increased at the beginning of the Wasatchian, largely due to extensive immigration of herbivores, carnivores, and frugivores into the Bighorn Basin. The immigrants continued to diversify through the Wasatchian, during which mammalian species richness was more evenly distributed.

Chris Beard reviewed the early Wasatchian mammals from the Tuscahoma Formation in Mississippi which provide a direct nonmarine-marine cross-correlation to nannoplankton Zone NP9. Judith Schiebout's poster focused on the mammalian succession of the P-E transition in Big Bend National Park, Texas, which has a magnetostratigraphy that correlates the beginning of the Wasatchian to Chron 24r, as is the case in other sections in Mexico, Wyoming, and Arctic Canada. Joe Hartman's poster documented the stratigraphic distribution of extensive assemblages of land snails in the western United States, identifying significant turnover events that provide biostratigraphic datums for correlation.

Scott Wing presented a broad overview of Holarctic paleofloras of the P-E transition. He distinguished a fairly homogeneous, widespread Paleocene flora dominated by temperate, deciduous lineages from early Eocene floras dominated by legumes and other subtropical and tropical species. The Bighorn Basin paleofloras do not indicate a major floral turnover at the Clarkforkian-Wasatchian boundary, although diversity did drop somewhat at that boundary and there were significant floral shifts during warming periods of the Wasatchian.

Peter Wilf focused on late Paleocene floras from the Rock Springs uplift of southwestern Wyoming, which, on the basis of leaf-margin analysis, suggest a mean annual temperature of 16 °C. He noted the strong present correlation between leaf size and rainfall and used that relation to estimate rainfall of 1.1 to 1.8 m/yr in southwestern Wyoming during the late Paleocene.

Ellen Thomas stressed the unusual nature of the extinction of benthic foraminifera that correlates closely to the C-isotope excursion. She linked the extinction to an overall drop in oceanic productivity (increased oligotrophy) but pointed out that there are different post-extinction patterns in different places, suggesting a complex event. In general, after the excursion the benthic foraminiferal fauna was dominated by a few, thin-walled species.

Richard Norris noted that global compilations of planktonic foraminiferal diversity show little change associated with the C-isotope excursion. Examination of the foraminiferal record at ODP site 865 in the central Pacific indicates that subbotinids were stable through the excursion (they were thermoclinal species), whereas acarininids and morozovellids diversified somewhat after it. However, the big diversity changes in planktonic foraminiferans took place later, during late Biochron NP12 and at the P10/P11 biochronal boundary.

Clay Kelly also looked at ODP site 865 using high-resolution sampling of the 5-m-thick interval around the C-isotope excursion. He identified a short-lived bottleneck in the evolution of *Morozovella velascoensis*, possibly caused by a deepening of the mixed layer and intensification of oligotrophy.

Marie-Pierre Aubry identified a profound turnover in calcareous nannoplankton during the P-E transition comparable to the turnover at the Cretaceous-Paleogene boundary. On the basis of the genus as the operational taxonomic unit, she identified three bursts of evolution in the calcareous nannoplankton—earliest Paleocene, early late Paleocene and during the P-E transition. Dominant Paleocene forms became extinct during the transition, and numerous new genera appeared within a 1 m.y. interval from mid–Biochron NP9 to the NP10a/b biochronal boundary.

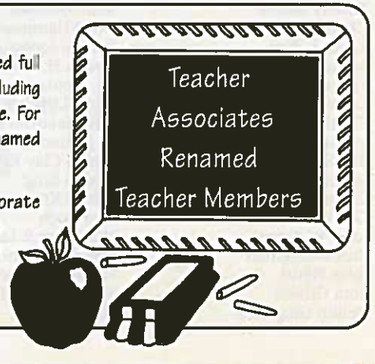
Day 4: Special Studies on Potential P-E Boundary GSSPs

ICS regulations require that GSSPs be defined on land-based marine sections. Thus, shallow marine to bathyal sections located in different countries have been studied with the goal of finding the "ideal" GSSP for the P-E boundary. As our work progressed, however, we became aware that the concept of an "ideal section" is rather utopian. At the same time, we understood that what matters is not so much to find the GSSP, but to determine how sections in different geologic and tectonic settings correlate with one another. Thus, following an introduction by Hanspeter Luterbacher regarding the ICS guidelines for the definition of a GSSP, the morning session was devoted to the stratigraphic analysis of upper Paleocene–lower Eocene sections concurrently stud-

Penrose Conference *continued on p. 24*

At its May meeting, the GSA Council granted full Member privileges to Teacher Associates, including the right to hold office and the right to vote. For this reason, Teacher Associates will now be named Teacher Members, effective immediately.

Teacher Members will receive a 1997 Corporate Ballot and the Society encourages them to vote for 1998 Officer and Councilor candidates.



Penrose Conference *continued from p. 23*

ied by different groups of IGCP Project 308.

Birger Schmitz primarily discussed the carbon isotopic record in sections from Egypt, Israel, Spain, and Austria, emphasizing the interval in which the carbon isotope excursion occurs. He showed that the expanse of the interval in which the excursion occurs varies between sections, independently of their completeness. Thus, some sections are definitely better suited as a GSSP than others if the excursion is used to characterize the boundary. The Awaina section in the Nile Valley (near Luxor, Egypt) is currently seen as the best section to serve as a GSSP, but the unstable political situation there is preventing an official proposal.

Ernie Mancini and Nick Tew described the Tuscahoma and Bashi formations in terms of sequence stratigraphy. These are siliciclastic deposits that represent a span of ~7 m.y. The section that best illustrates the Tuscahoma-Bashi contact is currently inaccessible except by boat or helicopter. The lowstand sands at the contact between the two formations is, however, seen at the Red Hot Truck Stop, where a land-mammal fauna was discovered (discussed by Chris Beard; see Day 3).

Tom Gibson discussed the upper Paleocene (Vincentown Formation)–lower Eocene (Manasquan Formation) record of the east Atlantic coast (New Jersey), which he believes to be continuous across the P-E boundary. Using tau values on benthic foraminifera, he discussed regional paleodepth changes.

Richard Fluegeman presented the results of biostratigraphic studies of several sections in Cuba collected in 1993 by an international field party. The collecting was aimed at integrated magneto-bio-isotopic analyses. The rock quickly proved to be unsuitable for magnetostratigraphy, and chemostratigraphy was possible only on bulk samples. Only one section yielded good biostratigraphic results, providing rare direct correlation between calcareous (calcareous nannofossils and planktonic foraminifera) and siliceous (radiolarian) microfossils. These results were further documented by Fluegeman in a poster.

Christian Dupuis discussed sequence stratigraphic subdivision of sections near Tunis, and attempted correlation with sections located in the western part of the Paris Basin along the coast of Normandie-Picardie. He showed that whereas there seems to be clear correlation between some sequence boundaries, others are present only in the Paris Basin.

Marie-Pierre Bolle and colleagues discussed the suitability of the Ermua and Trabakua sections in northern Spain as GSSPs. These have been officially proposed by Spanish colleagues as boundary stratotypes. On sedimentologic grounds, Bolle and co-workers indicated that other Spanish sections would constitute more appropriate GSSPs, a proposition that was further documented in a poster.

Laurel Bybell gave a short explanation, complemented with a poster, of the differences in taxonomic concepts which lead to disagreements between authors about the location of the NP9/NP10 zonal boundary. This continuing debate is relevant to the relation between the NP9/NP10 zonal boundary and the C-isotope excursion.

In a poster session, Piotr Gawenda and Wilfried Winkler presented evidence for tectonic complications at the P-E boundary in the Zumaya section (Spain); Eustoquio Molina presented correlations between the main Spanish sections; Simonetta Monechi documented the calcareous nannofossil stratigraphy of Spanish sections, and Katharina Perch-Nielsen presented that of sections in Egypt.

The afternoon session resumed with a discussion on the best criteria to use to characterize the Paleocene-Eocene Epoch boundary based on a presentation by Marie-Pierre Aubry of the pros and cons of the seven criteria that are worth considering (from younger to older: FAD *T. digitalis;* LAD *M. velascoensis;* FAD *T. bramlettei;* benthic foraminiferal extinction; carbon isotope excursion; Chron C245n/C24r magnetic reversal boundary; top of the Thanet Beds). The use of the FAD of *Tribrachiatus digitalis,* which approximately dates the base of the Ypresian Stage would result in stable stratigraphic nomenclature as emphasized in the guidelines by Hedberg. The C-isotope excursion is seen as the best criterion for correlation because it has been identified in the terrestrial as well as in the marine record. It also correlates with the benthic foraminiferal extinction event recorded in the bathyal and abyssal realms. If the C-isotope excursion is selected to recognize the P-E boundary worldwide, the boundary would be placed at the sharp mammalian turnover (the MOE) that occurred between the Clarforkian and Wasatchian (North America) and Cernaysian-Neustrian (Europe) ages.

Discussion centered on the part of the excursion that should be chosen to delineate the boundary and the possible pitfalls in the procedure. A paper by Gerald Dickens emphasized that there was as yet no demonstration that methane degassing through clathrate dissociation occurred (the best possible evidence being the excursion itself) and warned that dissociation would have occurred at different times in different locations. However, geochemists at the conference remarked that diachrony would be on the order of a few thousand years at most. Also, Doug Hammond gave a presentation on carbonate dissolution and reminded us that lack of carbonates (as in most Spanish sections) does not necessarily imply dissolution.

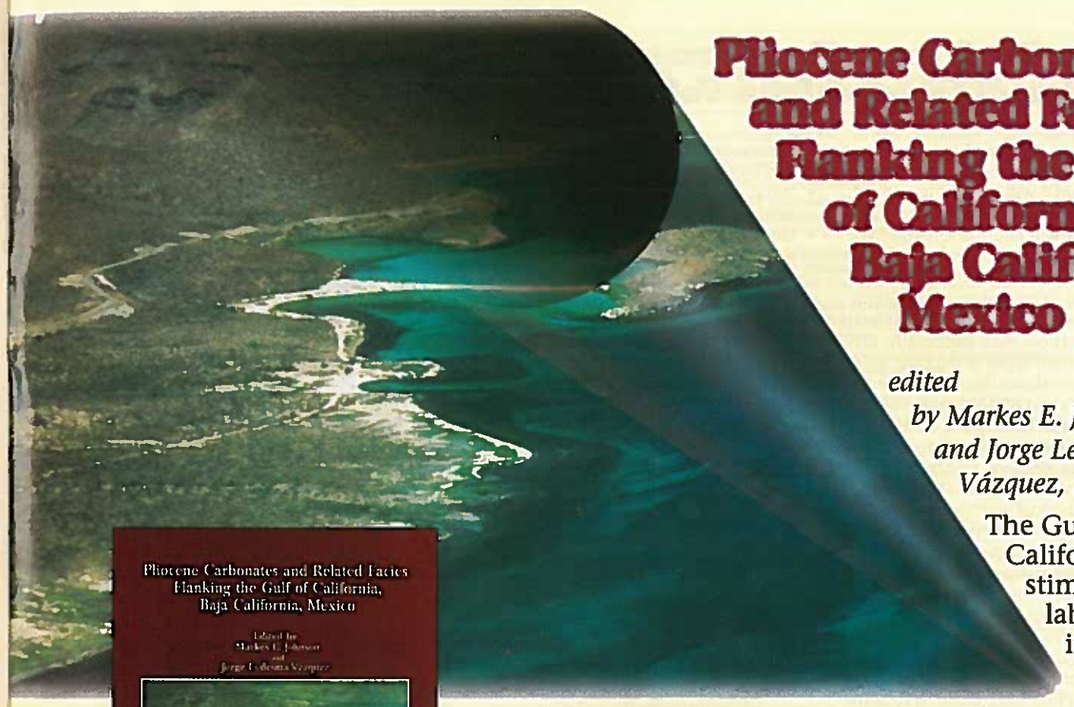
The conference ended with a full appreciation that reconstructing the geological history of even as short a time interval as that of Chron C24r (~2.55 m.y.) requires a multidisciplinary approach and the study of many different sections around the world. As geologists, we have a tendency to look for the "best section," but we are beginning to understand that any section, how unpromising it may look, contributes some of the evidence that contributes to the whole story. We believe that this conference gave all a better respect for the complexity of the stratigraphic record.

Penrose Conference Participants

Thierry Adatte
Chris Beard
Karen L. Bice
Marie Pierre Bolle
Timothy Bralower
Laura Bybell
Charles Chapin
William C. Clyde
Rodolfo Coccioni
Isabelle Cojan
Christian Dupuis
Gae Eisenhardt
John W. Estep
Rick Fluegeman
John Flynn
Tom Gibson
Phillip Gingerich
Marc Godinot
Doug Hammond
Jan Hardenbol
Joseph H. Hartman
J. J. Hooker
Brian T. Huber
Alina Iakovleva
H. Jochen-Kuss
Daniel Clay Kelly
Adrian King
Robert Knox
Paul Koch
Hanspeter P. Luterbacher
Ernest A. Mancini
Simonetta Monechi
Thierry L. A. Moorkens
Hiroshi Nishi
Richard D. Norris
Frederic Quillevere
Stephen Schellenberg
Judith A. Schiebout
Birger Schmitz
Ashish Sinha
Berry H. (Nick) Tew
Medard Thiry
Deborah J. Thomas
Ellen Thomas
Suyin Ting
Katharina von Salis
Peter Wilf
Scott Wing
Wilfried Winkler
Thomas E. Yancey

ACKNOWLEDGMENT

We thank Lois Elms (Western Experience, Inc., and long-standing coordinator of GSA-sponsored Penrose Conferences) for arranging the logistics of this meeting. ■



Pliocene Carbonates and Related Facies Flanking the Gulf of California, Baja California, Mexico

edited by Markes E. Johnson and Jorge Ledesma-Vázquez, 1997

The Gulf of California is a stimulating laboratory in which to test the interplay between tectonics and eustasy with respect to the erosion of rocky shorelines. Not since GSA Memoir 43 on the results of the 1940 E.W. Scripps Cruise to the Gulf of California has there been assembled so expansive a collection of research papers on the Gulf Coast Pliocene of Baja California. This volume takes up facies relations, paleogeography, and tectonics where the classic exploration style of the 1950 Memoir leaves off. The result of collaboration by Mexican and American geologists and marine biologists associated with the Sociedad Geológica Peninsular, the topics embraced by this well-integrated collection fall under three themes. One concerns the origin of carbonate sediments, giving new emphasis to coralline red algae as rhodoliths. Another deals with rocky shorelines as an ideal boundary marker for the mapping of facies and the determination of relative sea-level changes. The third theme involves insights on Pliocene stratigraphy through Holocene patterns of sedimentation and neotectonics.

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The Geological Society of America

Penrose Conference To Address Evolution of Ocean Island Volcanoes

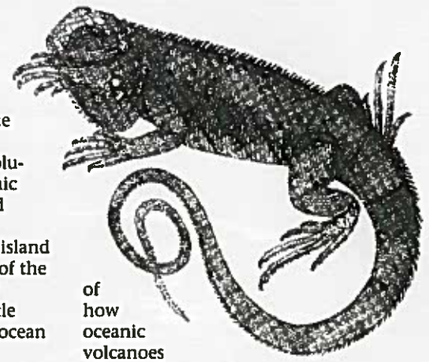
A Geological Society of America Penrose Conference, "Evolution of Ocean Island Volcanoes," will be held June 4–12, 1998, in the Galápagos Islands, Ecuador. The Charles Darwin Foundation and IAVCEI are cosponsors.

Volcanism associated with ocean islands changes in several ways with time. In most archipelagos, the eruptive styles of individual volcanoes vary temporally, giving rise to different types of deposits as the volcano emerges above the sea, reaches a peak in activity, and dies. At most volcanoes, the variation in eruptive style is accompanied by systematic changes in the petrologic, trace element, and isotopic compositions of the magmas. These changes at individual archipelagos lend critical insight into geodynamic processes such as the interaction between mantle plumes and their surroundings, the amount and rate of melt production, and the degree of chemical heterogeneity of the mantle source. Despite their common characteristics, different archipelagos display utterly distinct evolutionary styles, which suggests that differences in tectonic setting or plume dynamism, or both, can lead to variations in the evolutionary development of individual ocean islands.

PURPOSE

The purpose of the conference is to convene a broad spectrum of specialists who have worked on different aspects of many different islands to compare common patterns, highlight unique styles of evolutionary change, and assess models for the causes of the patterns of evolutionary change. The major questions to be addressed by the conference are:

- How do different volcanoes in different island chains evolve volcanologically, petrologically, geochemically, and tectonically?
- What are the common and unique patterns at different volcanoes?
- How do the different styles of evolution relate to differences in tectonic setting, ocean basins, sources, and strengths of the hotspots?
- How does the evolution of ocean island volcanoes help constrain models of the deep earth (e.g., mantle plumes)?
- Are there alternatives to the mantle plume theory that better explain ocean island volcanism?



of how oceanic volcanoes change with time.

LOCATION

The conference will be held in the Galápagos Islands, Ecuador, a locale virtually synonymous with evolution. Participants will depart Quito, Ecuador, on June 4, 1998, and fly to San Cristobal Island, where they will be picked up by the tourist ships *Corinthian* and *San Jacinto*. For the first five days of the conference, we will be touring from these boats, examining Galápagos volcanoes in various stages of evolution; talks and discussion sessions will occupy mornings and evenings. The preliminary itinerary for the field trip will take the conference from the oldest part of the archipelago (San Cristobal and Espanola islands) to active volcanoes (Sierra Negra and Santiago). There will be abundant opportunity to observe and photograph the wildlife for which the archipelago is renowned. On June 8, the participants will disembark to Puerto Ayora, Santa Cruz Island, home of the host institution, the Charles Darwin Research Station. Three days of oral presentations, poster sessions, and discussions will focus on current research and future directions that will lead to holistic models of how oceanic volcanoes change with time.

Owing to the field-intensive aspect of this Penrose Conference, participants must be reasonably fit (able to walk 2 miles and ascend 1000 feet in the sun) and tolerant of equatorial heat. The conference facilities have no air conditioning. The boat and hotel facilities are superb yet informal.

LOGISTICS

The conference will be limited to 60 participants, who will be selected to represent a broad range of disciplines and with knowledge of diverse geologic settings. We will be able to subsidize travel for several strongly qualified graduate students. The registration fee, which will cover boat travel, lodging in Puerto Ayora, and meals exclusive of dinners in Puerto Ayora, is expected to be about $1180. We expect group airline fares to be available from Miami for approximately $750.

CONVENERS

Co-conveners are ***Dennis Geist***, Dept. of Geology, University of Idaho, Moscow, ID 83844, dgeist@uidaho.edu, fax 208-885-5724, phone (208) 885-6491; ***Karen Harpp***, Dept. of Chemistry, Lawrence University, Appleton, WI 54912, Karen.Harpp@lawrence.edu, fax 414-832-6962, phone 414-832-6729; ***Wendy Bohrson***, Dept. Geological Sciences, University of California, Santa Barbara, CA 93106, bohrson@magic.geol.ucsb.edu, fax 805-893-2314, phone (805) 893-8782. E-mail inquiries are preferred by all of the co-conveners.

DEADLINE

Application deadline is January 15, 1998. Formal invitations will be mailed by February 15, 1998. Three paper copies of applications, sent to Dennis Geist, should include a brief curriculum vitae (e.g., NSF form 1362), a cover letter indicating your interest and experience, and the subject of proposed poster presentations. ■

PENROSE CONFERENCE
PROPOSALS ENCOURAGED

The Penrose Conferences, named in honor of R. A. F. Penrose, Jr., a benefactor of the Geological Society of America, were established in 1969 by the Society as a further step in its service to the science of geology. The conferences provide the opportunity for exchange of current information and exciting ideas pertaining to the science of geology and related fields. They are intended to stimulate and enhance individual and collaborative research and to accelerate the advance of the science by the interactions and development of new ideas.

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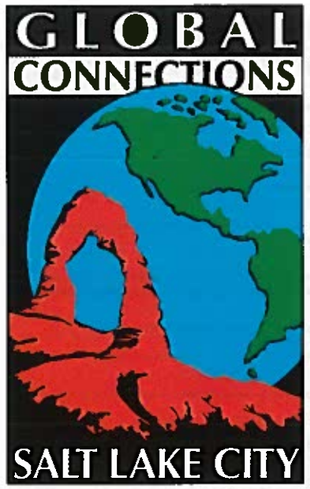
AUGUST 1997



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for Salt Lake City 1997 GSA Annual Meeting
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Special instructions for submitting an abstract for the Late-Breaking Research Sessions:

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- Abstracts must be submitted using the Web form; they may not be submitted on paper or by e-mail: http://www.geosociety.org.
- Space will be limited and selection will be based on scientific merit.
- The author will be asked to provide a brief explanation of why the abstract deserves consideration after the usual deadline for this meeting.
- The author may designate either oral and/or poster, although space limitations may require reclassification.
- Because of scheduling limitations, you may present only one volunteered paper in oral or poster mode. If you have already had a volunteered abstract accepted, please do not submit another.

Abstract Fee: For this meeting, a nonrefundable abstract fee of $50 must accompany each Late-Breaking Research abstract submitted. Our Web-template form will ask for credit-card information. We have installed one of the best known and most respected Secure Server systems for transmission of your credit-card data to fully protect your confidential information.

Schedule: Abstracts will be reviewed by the Annual Program Committee. Electronic acceptance notices will be sent out the first week in October giving the place and time of presentation. Late-Breaking Research Sessions (oral and poster) will be held on Thursday, October 23, 1997.

Publication: The abstracts will not be published in the abstract volume, although they will be published on the Web along with the Web abstracts and paper copies will be made available on site.

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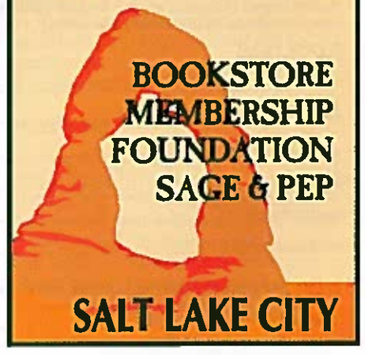
in addition to the regular exhibit hours, the Services area will be open again on Thursday, from 9:00 a.m. to 2:00 p.m.



1998

Toronto, Ontario, Canada
October 26–29
Metro Toronto Convention Centre
Sheraton Toronto Centre Hotel and Towers

General Chair: ***Jeffrey J. Fawcett,*** *University of Toronto*

Technical Program Chairs:
Denis M. Shaw, *McMaster University,*
Andrew Miall, *University of Toronto*

Due date for symposia and theme proposals: ***January 2, 1998***

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

Pierre Robin, University of Toronto, Dept. of Geology, 22 Russell Street, Toronto, Ontario M5S 3B1, Canada, (416) 978-3022, fax 416-978-3938

Henry Halls, Erindale College, Mississauga, Ontario L5L 1C6, Canada, (905) 828-5363, fax 905-828-3717, hhalls@credit.erin.utoronto.ca

CALL FOR CONTINUING EDUCATION COURSE PROPOSALS

Due December 1, 1997

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 1998 Toronto Annual Meeting or the 1999 Denver Annual Meeting.

Proposals must be received by December 1, 1997. Selection of courses for 1998 will be made by February 1, 1998. For those planning ahead, we will also consider courses for 1999 at that time.

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

GSA SECTION MEETINGS — 1998

Call for Papers

NORTHEASTERN SECTION
March 19–21, 1998
Holiday Inn By the Bay, Portland, Maine
Abstract Deadline:
November 14, 1997
Submit completed abstracts to:
Marc C. Loiselle
Maine Geological Survey
22 State House Station
Augusta, ME 04333-0022
(207) 287-2801
marc.c.loiselle@state.me.us

SOUTHEASTERN SECTION
March 30–31, 1998
Charleston Civic Center, Charleston, West Virginia
Abstract Deadline:
November 21, 1997
Submit completed abstracts to:
Peter Lessing
WV Geological & Economic Survey
P.O. Box 879
Morgantown, WV 26507-0879
(304) 594-2321
lessing@geosrv.wvnet.edu

NORTH-CENTRAL SECTION
March 19–20, 1998
Ohio State University, Columbus, Ohio
Abstract Deadline:
November 14, 1997
Submit completed abstracts to:
David H. Elliot
Department of Geological Sciences
Ohio State University
125 South Oval Mall
Columbus, OH 43210
(614) 292-5076
delliot@magnus.acs.ohio-state.edu

CORDILLERAN SECTION
April 7–9, 1998
California State University, Long Beach, California
Abstract Deadline:
December 12, 1997
Submit completed abstracts to:
James C. Sample
Department of Geological Sciences
California State University
Long Beach, CA 90840
(562) 985-4589
csample@csulb.edu

SOUTH-CENTRAL SECTION
March 23–24, 1998
University of Oklahoma, Norman, Oklahoma
Abstract Deadline:
December 1, 1997
Submit completed abstracts to:
Judson Ahern
School of Geology & Geophysics
University of Oklahoma
100 E. Boyd St., Suite 810
Norman, OK 73019-0628
(405) 325-3253
jahern@ou.edu

ROCKY MOUNTAIN SECTION
May 25–26, 1998
Northern Arizona University, Flagstaff, Arizona
Abstract Deadline:
January 8, 1998
Submit completed abstracts to:
Wendell Duffield
U.S. Geological Survey
2255 Gemini Road
Flagstaff, AZ 86001
(520) 556-7000
wduffield@flag2.wr.usgs.gov

1998 SECTION MEETING ABSTRACT FORM REQUEST

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

Please send _____ copies of the 1998 GSA Section Meeting abstract form.

Name _____

Address _____

_____

City _____ State_____ ZIP _____

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infinitesimal properties ... cosmogenic nuclide systematics ...
paleoecosystems ... vector mapping ... geomicrobiology ...**

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Analysis of Veins in Sedimentary Rocks—An Introduction for Structural Geologists ❖ Techniques of Geostatistical Estimation and Simulation Applied to Environmental Geology ❖ Computer Visualization of Three-Dimensional Deformation and Application to Upper-Crustal Settings ❖ Applications of Environmental Isotopes to Solving Hydrologic and Geochemical Problems ❖ Buck Rogers, Field Geologist: 21st Century Electronic Wizardry for Mapping and Field Data Collection ❖ Dynamical Systems Modeling for Undergraduate Education: From Coleman Coolers to Computers ❖ Environmental Issues at Modern and Historic Mining Sites ❖ Geology of Coal Bed Methane: The Perspective From Basin and Thermal History Studies ❖ Geomorphic Applications of In Situ-Produced Cosmogenic Isotopes ❖ Visualization in the Geosciences ❖ Paleosols for Sedimentologists ❖ Practical Remote Sensing for Geology ❖ (and more than 30 field trips!)

GLOBAL CONNECTIONS

**The Geological Society of America
Annual Meeting & Exposition
Salt Lake City, Utah · October 20-23, 1997**

Registration information and course and field trip descriptions were published in June *GSA Today*. For additional information, contact Edna Collis, Continuing Education and Field Trip Coordinator, GSA Meetings Department, P.O. Box 9140, Boulder, CO 80301, (303) 447-2020, ext. 134, fax 303-447-0648, E-mail: ecollis@geosociety.org or see GSA's Web site: www.geosociety.org.

CALENDAR

Only new or changed information is 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 below, to Editor, *GSA Today*, P.O. Box 9140, Boulder, CO 80301, E-mail: editing@geosociety.org.

1997 Penrose Conferences

September

September 10–15, **Faults and Subsurface Fluid Flow: Fundamentals and Applications to Hydrogeology and Petroleum Geology,** Albuquerque and Taos, 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, haneberg@nmt.edu. For more information, see http://www.nmt.edu/~haneberg/Fluids.html.

September 23–28, **Tectonics of Continental Interiors,** Cedar City, Utah. Information: Michael Hamburger, Dept. of Geological Sciences, Indiana University, Bloomington, IN 47405, (812) 855-2934, fax 812-855-7899, hamburg@indiana.edu.

1997 Meetings

November

November 3–7, **Scientific Inquiry for Planning & Managing the Grand Staircase-Escalante National Monument** symposium, Cedar City, Utah. Information: Suzanne Winters, (801) 538-1038, fax 801-538-1547, suz.winters@state.ut.us, or Marietta Eaton, (801) 865-5114, meaton@ut.blm.gov.

1998 Meetings

January

January 11–16, **American Meteorological Society Annual Meeting,** Phoenix, Arizona. Information: AMS, 45 Beacon St., Boston, MA 02108-3693, (617) 227-2425, fax 617-742-8718.

February

February 11–13, **Mexican Paleontological Society VI National Convention,** Mexico D.F., Mexico. Information: Marisol Montellano, Dept. de Paleontología, Inst. de Geología, UNAM, Ciudad Universitaria, Coyocán, México, D.F. 04510, México, phone 52-5-622-4280 or 4281, fax 52-5-550-8432, marmont@servidor.unam.mx.

April

April 27–30, **Modern Preparation and Response Systems for Earthquake, Tsunami and Volcanic Hazards,** Santiago, Chile. Information: Bruce A. Bolt, Dept. of Geology and Geophysics, University of California, Berkeley, CA 94720, fax 510-845-4816, boltuc@socrates.berkeley.edu, or J. Gutierrez, Inst. Geografica Militar, Santiago, Chile, fax 56-2-698-8278, seisvolc@conf.dgf.uchile.cl.

CLASSIFIED ADVERTISING

Published on the 1st of the month of issue. Ads (or cancellations) must reach the GSA Advertising office one month prior. Contact Advertising Department (303) 447-2020, 1-800-472-1988, fax 303-447-1133, or E-mail:acrawfor@geosociety.org. Please include complete address, phone number, and E-mail address with all correspondence.

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Positions Open

HYDROLOGY/SURFICIAL PROCESSES
The College of Wooster

Applications are invited for a tenure-track assistant professor position in the Department of Geology at The College of Wooster beginning August 1998. The successful candidate is expected to develop an introductory level course in environmental geology and upper level courses in hydrogeology and surficial processes/geomorphology; he/she also will occasionally teach a second-level course on processes and concepts in geology and a First-Year Seminar course in critical inquiry. Wooster has a strong undergraduate senior independent study program in which the successful candidate will participate as an advisor. Candidates with an interest in the role of fluids in shallow Earth's crust and who are able to work with existing faculty and student research programs in structural geology, hydrothermal processes, and paleoenvironmental analysis are especially encouraged to apply. Applicants for this position should have a Ph.D.

The College of Wooster is a highly selective liberal arts institution with an enrollment of approximately 1700 men and women. The department consists of four faculty members and approximately 50 geology majors. The department is housed in a recently renovated building and possesses a variety of modern research equipment, including an XRD, SEM, fluid inclusion stage, cathodoluminescence microscope, paleomagnetic laboratory, and a seismometer.

Interested persons should send a letter of application, a curriculum vitae, and three letters of recommendation by October 15, 1997, to Dr. Lori Bettison-Varga, Chair of the Search Committee, Department of Geology, The College of Wooster, Wooster, Ohio 44691, in order to be considered for an interview at the GSA meeting in Salt Lake City. Closing date is November 15. The College of Wooster is an equal opportunity/affirmative action employer.

ASSISTANT PROFESSOR OF HYDROLOGY

New Mexico Institute of Mining and Technology invites applications for a new tenure-track position in the Hydrology Program. The position is a joint appointment between the Department of Earth and Environmental Science and the Geophysical Research Center, a state-funded research agency. Applicants should have a Ph.D. in the Earth Sciences or a related field at the time of appointment. We seek candidates with expertise in water/land surface interactions (e.g., watershed hydrology, hydrogeomorphology, or hydroclimatology) who have strong quantitative skills and an interest in field problems. Excellence in research and potential for future growth are the most important qualifications. Responsibilities will include developing an active program of extramurally funded research, supervising and supporting graduate students, and teaching two upper-division or graduate courses per year. The successful candidate will join a program of five full-time Hydrology faculty, eight adjunct faculty, and 30 graduate students. Hydrology is part of the Department of Earth and Environmental Science, consisting of 16 faculty and 150 undergraduate and graduate students. Additional geoscience professionals on campus include the 28 staff members of the Bureau of Mines, New Mexico's geological survey. For futher information on the position and on New Mexico Tech see http://griffy.nmt.edu/Hydro/position.html. Applicants should submit a letter of interest, resume, college transcripts, and the names of three references to New Mexico Institute of Mining and Technology, Human Resources, 801 Leroy Pl., Wells Hall Box C-048, Socorro, New Mexico 87801. To receive full consideration all materials must be received by 1 September 1997. New Mexico Tech is an equal opportunity/affirmative action employer.

MINERALOGY/PETROLOGY/STRUCTURAL GEOLOGY

The Department of Geology and Geophysics, University of Missouri-Rolla, announces a tenure-track position at the assistant professor level. The successful candidate must hold the Ph.D., will be expected to teach mineralogy, petrology, and/or structural geology at the undergraduate level, and will develop a graduate research program (M.S. and Ph.D.) in one of those areas. Additional information regarding the position and department can be obtained from our web page <http://www.umr.edu/~geo-geop/> or by writing to: Chairman, Department of Geology and Geophysics, University of Missouri-Rolla, Rolla, MO 65409-0410. The deadline for application is September 15, 1997. UMR is an Equal Opportunity Employer.

HYDROGEOLOGIST
COLLEGE OF WILLIAM AND MARY

The Department of Geology at the College of William and Mary invites applications for a tenure-track assistant professor beginning August 1998. The successful candidate will teach an undergraduate field-based Hydrogeology, Environmental Geology, and related courses, supervise senior research students, and conduct his/her research. Expertise in applied geophysics and/or GIS is desirable. Ph.D. required. Applicants should submit a statement of their undergraduate teaching and research experience and goals, a vitae, transcripts of all college work, and postal and e-mail addresses and telephone numbers of three references to Gerald H. Johnson, Chair, Department of Geology, College of William and Mary, Williamsburg, VA 23187. E-mail <ghjohn@facstaff.wm.edu>. Review begins September 15, 1997. W&M is an AA/EEO university.

Services & Supplies

ALBORAN SCIENCE PUBLISHING. Have you seen our posters on "Societal Benefits of Geoscience?" Thumbnails and order forms are printed in *GSA Today* (May '97, p. 36/37) and *AAPG Explorer* (April '97, p. 58). Order Now!

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EARTH RESISTIVITY METER/BISON 2350B. $1600 with cables, reels and probes. Phone: Ken Maloney 541-482-9151.

Opportunities for Students

Graduate Student Assistantships in Hydrogeology, University of Nebraska-Lincoln (UNL). The Conservation and Survey Division has 3 or 4 graduate research assistantships available for both Ph.D. and M.S. students to start in either the 1997 fall semester or the 1998 spring semester. The 2-year assistantships are part of two projects; (1) Groundwater-surface water interaction and the impact of irrigation wells on river levels, and (2) the hydrology and geochemistry of saline wetlands. Projects will involve well installation, aquifer analysis (pump-tests), yearly monitoring, chemical and isotopic sampling and numerical modeling. Applicants should have a strong background in geology with emphasis in hydrogeology and geochemistry. Strong mathematical and computer modeling skills are needed for one position. For information on the projects, and an application package, contact Drs. F. Edwin Harvey (feharvey@ unlinfo.unl.edu) or Xun Hong Chen (x-chen@unlinfo.unl.edu), Conservation and Survey Division, 113 NH, UNL, Lincoln, NE 68588-0517; (402) 472-8237. Complete project descriptions can be found on Dr. Harvey's homepage at http://nesen.unl.edu/csd/staff/harvey/feharvey.html.

Director of Curriculum Development

American Geological Institute

The American Geological Institute invites applications for the position of Director of Curriculum Development from geoscience educators with experience in K–12 Earth-science curriculum development and management of large educational projects. A doctoral degree in the geosciences or Earth science education is required, and classroom experience is preferred.

This position provides an unparalleled opportunity for an Earth science professional committed to advancing the status of science education in the nation's schools based on the National Science Education Standards and the educational goals of AGI and its Member Societies.

The successful candidate will manage AGI's K–12 curriculum development projects from AGI headquarters in Alexandria, Virginia. S/he will interact on a day-to-day basis with project investigators, directors of other state and national education programs, professional societies, and private sector supporters. S/he will provide intellectual oversight on the content, pedagogy, assessment, and publishing of project-related materials in cooperation with project investigators. S/he will also manage logistical and financial operations of funded projects. The successful candidate will also be expected to identify and develop support for new program-related activities.

Applicants should send a letter of interest, vita, and names/ addresses of three references to the AGI Education Search Committee, American Geological Institute, 4220 King Street, Alexandria, VA 22302-1502 (fax 703-379-7563). Appointment is anticipated no later than September 1997. Review of applications will begin immediately. Applications will be accepted until the position is filled. For more information about AGI, its programs and activities, visit our Web site at <http://www.agiweb.org/>. AA/EOE.

1997 Geological Society of America

Annual Meeting and Exposition

Salt Lake City, Utah
October 20–23

Preregistration Due
September 19

Program Schedule
September GSA Today and the Web

See June GSA Today for information on:
- Technical Program
- Continuing Education Courses
- Field Trips
- Exhibits
- Registration
- Lodging and Travel

For information:
GSA Meetings Dept.
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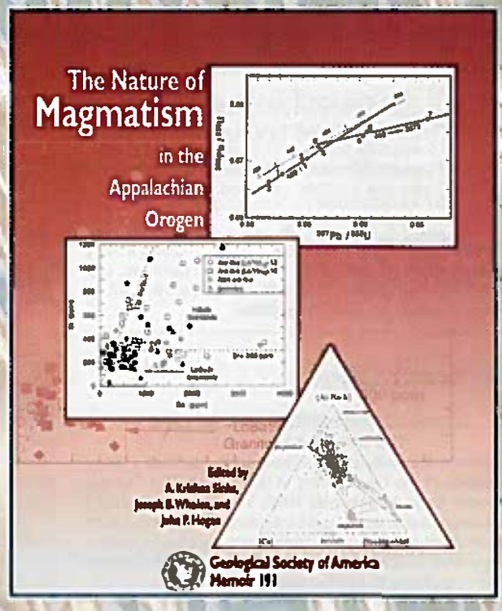
THE NATURE OF MAGMATISM IN THE APPALACHIAN OROGEN

edited by
A. Krishna Sinha,
Joseph B. Whalen and
John P. Hogan, 1997



The thermal evolution of mountain belts is commonly recorded in the distribution, origin, and ages of magmatism. In this volume, 20 contributors present the latest petrological, isotopic, and geochemical evidence to highlight the contribution of igneous rocks to the evolution of the Appalachian orogen in both Canada and the United States. These papers emphasize the use of modern geochemical and petrologic data to discriminate the sources yielding magmas, and thus the nature of the crust and mantle. The wealth of data available in this work provides a significant stepping-stone to more rigorous interpretation of the assembly and origin of the Appalachian orogen.

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