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INSIDE

Development of Geographic Information Systems–Oriented Databases for Integrated Geological and Geophysical Applications

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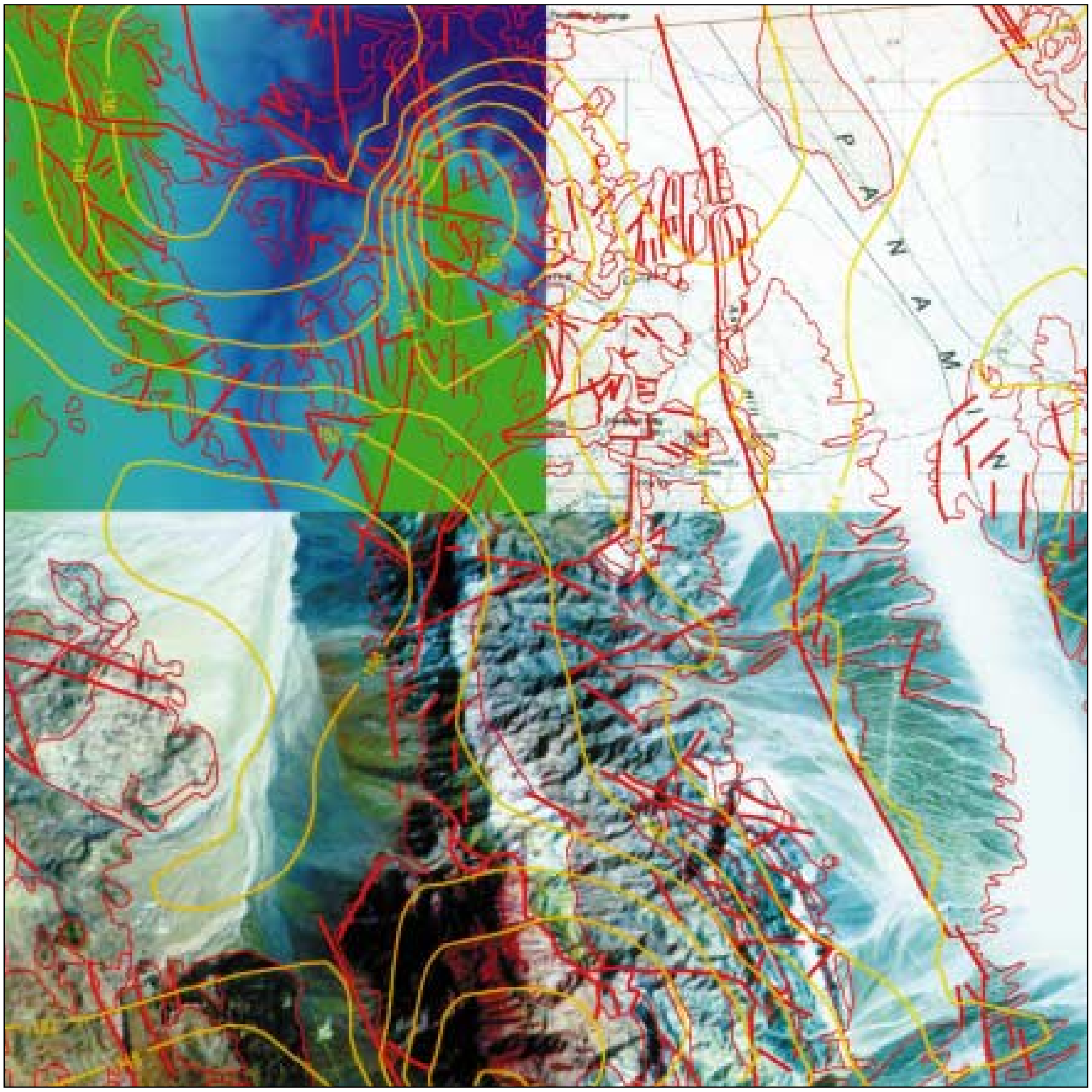

Figure 1. Composite satellite imagery, geologic contact, digital elevation model and gravity map of the Maturango Peak–Panamint Springs area, Argus Range and Panamint Valley, California. The map base is built from various contiguous image sources: lower half—16.5 m pixel thematic mapper image; upper left—15 m pixel digital elevation models (northwest corner); and upper right—part of the Darwin 1:100,000 sheet. Colors on the elevation model ramp from about 450 m for the darkest blue to about 1800 m for the brightest green. Overlain on this are geologic contacts (bold red lines representing faults, thin red lines showing depositional and intrusive contacts) from Moore (1976). The orange lines are Bouguer gravity contours in mgal from the National Geophysical Data Center data set. The area shown is approximately 30 km × 30 km.

ABSTRACT

The use of geographic information systems (GIS) is becoming increasingly common in geological and geophysical studies. These systems provide powerful tools for integrating and analyzing large data sets of various kinds and origins. One of the most complex and costly data sets to incorporate into these systems is surface geological information (geologic maps), which require intense and time-consuming effort to digitize, characterize, and check for quality. If entered thoroughly, that is with each geologic contact, rock unit, and structural measurement recorded and assigned explicit geologic attributes, the resulting data set is accessible to both casual and expert users. In addition, the attributes allow for detailed analysis of the geology. Other types of data—e.g., gravity measurements and earthquake foci—either are available free of charge or can be purchased at a small cost. These data sets are typically already in a form easy to integrate into a GIS database. When properly constructed, the final database contains a variety of types of information that are referenced to a common geographic base.

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INTRODUCTION

Geographic information systems (GIS) are being used by thousands of companies, government agencies, and other entities worldwide for the storage, retrieval, and manipulation of spatially referenced data. Several groups, such as the U.S. Geological Survey (USGS), work specifically with geological information (e.g., Wright and Stewart, 1990; Wentworth and Fitzgibbon, 1991; Fitzgibbon et al., 1991; Jacobson, 1993) and have put together techniques for handling such data sets. At the University of Kansas we have recently put together a GIS laboratory specifically for performing integrated geological and geophysical studies. We use the programs ARC/INFO™ (by Environmental Systems Research Institute, Inc.) for GIS generation and IMAGINE™ (by ERDAS, Inc.) for manipulating imagery data.

The usefulness of a GIS can be demonstrated in the following scenario. For a mapping project, a geologist usually starts out by examining a small-scale, regional geologic map (e.g., a state map) to pick a study area. Mapping is then done using 1:24,000 or larger scale topographic maps or air photos. The data are then compiled on topographic maps, possibly at another map scale, either by directly tracing on an overlay sheet or by visually transferring data by using topographic features. The geologist may also utilize a Landsat Thematic Mapper scene that shows important features that can be related to the compiled or regional geologic map. The scale of the Landsat scene is usually different from that of either of the maps. Finally, the geologist hopes to compare all the data mentioned above to an intermediate-scale map showing gravity values. To accomplish this goal, the scientist may photocopy the maps to get them at approximately the same scale in order to superpose them on a light table or flip back and forth between images much in the way a cartoonist checks frames for animation. In the end, the geologist compares data from the various sources (topography, geology, satellite images, aerial photography, geophysics) to solve a specific problem. This task would be much less cumbersome and time-consuming if all the data sets could be put to the same map scale, datum, and geographic projection (georeferenced).

All of the comparisons and overlays for this example project can be accomplished easily and efficiently using a computer-based GIS. Such systems allow for the manipulation of data in a manner that is scale independent (e.g., analysis and presentation can be manipulated to any scale). In addition, GIS software includes utilities for placing information into a common projection (i.e., universal transverse mercator [UTM]) and datum. This not only allows the data sets to be superposed, but also gives them geographic content (e.g., a map or image location contains information with regard to its actual location in real-world coordinates). Figure 1 shows an example of various types of data from numerous sources that were combined through the use of the ARC/INFO and IMAGINE software.

In this paper we provide some insight into the development of geological databases from the perspective of a small start-up academic laboratory. We cover many types of geological and geophysical data, but much of the discussion emphasizes incorporation of existing geologic maps. For more general discussions of GIS, see the suggested readings at the end of this article.

ACQUIRING GEOLOGICAL AND GEOPHYSICAL INFORMATION

Many different types of data are of potential use for integrated geological and geophysical studies. These include information about the surface geology and subsurface geology, geophysical survey measurements (usually referenced to individual sample points such as seismic shot points), and a variety of other spatially referenced data such as topography, remote sensing data, and cultural features (Fig. 1). The data sets can be represented spatially in a variety of ways, including points, lines, and areas for so-called "vector" data sets, and grids, images, and scans for "raster" data sets. The actual information associated with each spatial entity includes an identifying code or address, and one or more attribute values. An example of a linear spatial feature with an attribute value might be a fault (line feature) classified as either normal, reverse, thrust, or strike-slip (attribute).

Some of these data sets can be acquired without charge or for nominal charges through government channels. Examples include individual point information such as gravity data and earthquake hypocenter locations, grids of aeromagnetic data, grids of digital elevation information (known as digital elevation models [DEMs], or digital terrain models [DTMs], and vector data sets including digitized cultural features such as the USGS digital line graph (DLGs) product or the U.S. Census Bureau's topologically integrated geographic encoding and referencing (TIGER) system files on roads, waterways, pipelines, and telephone poles. A partial listing of access information is given at the end of this article for some of these public data sets.

Raster data sets, such as DEMs, and point data sets, such as gravity measurements, are usually already available in a digital form that is relatively simple to import into a commercial GIS package. Most GIS software packages will import a variety of grid or image formats, and will also handle tab- or space-delimited ASCII text data tables, which can be generated or customized in a spreadsheet or text editor.

Other types of data, such as air photos, satellite images, and geologic maps, must be purchased from a government entity, purchased from a commercial contractor, or input into the system in-house. Of all sources to be put into a GIS database, geologic maps are one of the most difficult and expensive to incorporate. Generating digital products from existing paper geologic maps is usually very expensive through commercial contractors; generating them in-house, however, takes a large amount of personnel time. If a large volume of data must be digitized from complicated published maps such as geologic maps or soils maps, the project quickly becomes extremely labor intensive and expensive.

NATURE OF GEOLOGIC MAP DATA

To properly incorporate geological mapping information into a GIS database we must look at how geological mapping is performed. Geologic maps are constructed by on-site inspection of the rocks cropping out at the surface. Although global positioning system (GPS) technology is available today for defining field location, virtually all currently available geologic maps relied upon location by inspection and triangulation using topographic maps or standard aerial photographs. The features that are actually marked on the base are mostly the contact lines between the rock units, and the point and line symbols bearing structural information.

Even if a geologist produces a map that follows topography perfectly, the map still has distortions inherent in all field mapping. Both the aerial photographs and standard topographic maps have some distortion. Topographic maps are imperfect representations, because of projection-based distortions and various errors that accumulate during the mapping process. Aerial photographs are usually even worse, because of in-flight pitch and yaw, camera distortions, and elevation (parallax) effects. They are not maps, and unless they have been through an orthorectification process to remove flight and elevation effects, their distortion is uncontrolled.

Another aspect of geological mapping which can cause problems in database development is the fact that geological field mapping involves a great deal of real-time interpretation. Two geologic maps of a given area produced by different mappers are never exactly the same, owing to the individual interpretations that occur in the field (e.g., of location, nature of contacts, etc.). The problem is exacerbated when multiple maps of differing scales exist for an area.

All of these considerations currently affect the overall accuracy of surficial geological information available for input into GIS databases. Most field geologists consider the field mapping to be the most trustworthy or most basic of all the data sets in the database—it is the "ground truth" that can actually be observed in nature but it is also one of the most complex data sets and one of the most difficult to accurately reproduce on the computer.

TYPICAL PRECISION AND ACCURACY OF DATA TYPES

As discussed above, surface geological information usually has some inherent uncertainty because of the manner in which the data are initially recorded and transcribed. Even so, the geological information may still be some of the more spatially accurate information in the database because of the relatively precise scale at which it was acquired. Geologists typically map with a pencil or pen that produces a line width of approximately 0.3 mm. The resolution of the geological information on the original map or photographic base is thus about 0.3 mm or about 85 dpi (dots per inch). A geologist mapping at a scale of 1:24,000 using a 0.3 mm pencil produces line widths that represent approximately 7 m of ground distance, or dot areas representing approximately 50 m^2 on the ground. (For a view from the USGS, see Ulrich et al., 1992.) Thus the precision with which the geologist attempts to record the data is probably much better than the final spatial accuracy of the map would indicate. Both field precision and final map accuracy will probably improve drastically in the future, because of GPS technology.

Geophysical data sets such as gravity measurements are difficult to examine in terms of their precision and accuracy. The location and elevation are surveyed to within, and are usually recorded in the database to a precision of, a few meters in location and perhaps tenths of meters in elevation. The original spatial precision and accuracy probably were even finer than what is recorded in the database. However, the data points are usually very widely spaced (hundreds or thousands of meters apart), and the data are often interpolated to allow the information to be displayed with other, more closely sampled data sets. Thus, the accuracy of the interpolated values can be called into question during later analysis and display, if the scale of the project is too small.

Data such as earthquake hypocenter, waveform, and source mechanism information can cause even more scale-related problems. Whereas microearthquake activity may be very closely monitored by a tight local array, regional information can have errors in location of several kilometers or more. Of course, this type of information is not suitable for interpolation, and its utility is thus very scale dependent.

DATA ENTRY

Geological and geophysical data sets are usually a mixture of both vector and raster data. To preserve the information recorded on a geologic map (with a nominal feature size of 0.3 mm) requires approximately 10 million points per square meter of map (following the discussion of Tufte, 1983, p. 162). All of these points are data. Geologic contacts (lines) are data. But the points contained within the unit boundaries are also data (e.g., a particular rock type generated by the enclosing contacts; see below). In this case, a vector-based GIS will be more efficient and generate a more easily used database (see also Bedell, 1994). Geophysical data are also easily and efficiently entered as point data. Image data, such as air photos, are recorded in raster layers.

Geological data are typically digitized into the computer system either from paper maps on a digitizing tablet (pulling

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TABLE 1. ATTRIBUTE FIELDS AND VALUES FOR GEOLOGIC CONTACTS

Contact type	Exposure type	Subtype	Additional characteristics	Significance	Fault slip	Notes
Fault	x	x	x	x	x	x
Intrusive	x	x	x			x
Depositional	x	x	x			x
Isograd	x	x		x		x
Shear Zone	x	x	x	x		x
Map Edge		x				x
	Known	Normal	Ductile	Internal	No. m	
	Approximate	Reverse	Brittle	Unit boundary		
	Approximate (?)	Thrust	Sharp			
	Inferred	Right-lateral	Gradational			
	Inferred (?)	Left-lateral	Chilled			
		Conformable	Unknown			
		Nonconformable				
		Unconformable				
		Alluvial				
		Scratch				
		Study area				
		Unknown				

Note: x indicates that an entry can be made for that attribute field. For example, a fault could be classified as contact type = fault, exposure type = known, subtype = normal, additional characteristic = unknown, significance = internal. Alternatively, a map edge would only contain the information: contact type = map edge, subtype = study area.

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data) or by using a mouse to trace lines or locate points from a scan that is displayed on a computer screen (heads-up digitizing). Both methods produce acceptable results, but our greatest success and ease has been with heads-up digitizing. Heads-up digitizing relies on registering a scan of the geologic map. As noted above, topographic features (peaks, stream intersection, etc.) are typically used for registration purposes because these features are those the geologist most likely used for reference when making the map. Most geologic maps can be scanned at a resolution of 0.17 mm (about 150 dpi). This preserves the feature size and data density of the map. Higher resolutions can be used if needed. We often scan at 200 to 400 dpi on maps with high information densities.

Most optical scanning software has built-in contrast and brightness controls. These are useful for color balancing geologic maps. It is also possible to use these controls to enhance greatly the quality of black and white scans. For example, many maps printed with geologic features as black contacts on a grayed topographic background can be scanned so that the topography is faded out while the geology is retained (of course, some topographic reference points must be identified and marked for registration). This makes heads-up digitizing much easier because the topographic line noise is removed. Similar procedures are possible for color scans of existing geologic maps.

Vector features can be extracted from scanned maps via the heads-up digitizing technique discussed above, but it seems logical to use the computer for digitizing as much information as possible. Autotracing algorithms are becoming more common in commercial packages on all systems (for example, Adobe Streamline™ and utilities in ARC/INFO). Some of these can be used in either a fully automatic batch mode or some form of interactive point-to-point mode. Our experience with these programs is that they still require enough correction and touch-up work that heads-up digitizing is faster. Once it has been digitized by autotracing, the vector information still must have attributes assigned to individual elements.

ASSIGNING ATTRIBUTES TO GEOLOGIC DATA

A very powerful feature inherent in vector-based GIS systems is the capacity to assign complex attributes for geologic information. For example, different line types are used for geologic contacts that are well exposed (solid lines) vs. those that are only approximately located (dashed lines) or inferred or concealed (dotted lines). This sort of information can be associated with any geologic contact or feature. The assignment of the geologic information is the key element to using GIS packages with geologic and geophysical data; typically no actual modification to the software is necessary.

A simple statement that preserves the fundamental idea of geologic maps is that "rock bodies are defined by their contacts." This is our basic working model for constructing the spatial relation, or topology, of geologic units. The first step in making a geologic map is digitizing the contacts. Once the contacts are entered into a "coverage" or data layer, the contact lines are joined to form polygons that define the rock units. This is the same as making a geologic map that can be colored without error; the contacts and map edges completely enclose the rock units. The rock-unit polygons are typically placed in a separate coverage, which is subsequently assigned attributes (see below). An important aspect of this is that the contact coverage is still retained: it still contains all of the information about the separate contacts, whereas the rock-unit coverage contains only information about rock types.

Most of the attributes we assign to geologic contacts (Table 1) fit normal geologic usage, except for entries on a fault. Faults are unusual geologic contacts in that they can separate different units or run through the same unit (the same is true for shear zones). For this reason, it is important to identify whether the fault represents a unit boundary or is internal to the rock unit. This, of course, can be deduced once all of the contact data are entered and the topology is constructed. Omitting internal faults simplifies the rock-unit coverage (Table 2) by decreasing substantially the number of separate rock-unit polygons that are constructed and need further classification.

Many structural data are associated with specific points. Items such as strike and dip of bedding or foliation are point features as represented on a geologic map. We treat here other orientation data assigned to faults and folds as point data as well. Specifically, the symbols for the dip and strike of a fault or the striations on a fault are usually represented on a geologic map as a set of arrows emanating from the fault. These data are best recorded as a point containing the orientation attributes. The point data (Table 3) can be subsequently tied or related to a specific contact or rock body. This extends to such features as the position of bar and balls marking normal faults. It is best to preserve positions of marks on faults and other sorts of contacts. In general, when working with published maps, it is difficult to know what the geologist meant by the position of these features, so it is best to assume that their placement is important. Of course, thrust barbs and other items that ornament the mapping of a fault do not have any real spatial importance in most cases, so they do not have to be entered separately. However, if a fault changes from low to high angle along strike or changes from a strike-slip fault (arrows) to a normal fault (ball and bar), then the attribution and symbols should change accordingly.

Some structural data are associated with other line features. Fold axes and lineaments fall into this category. These data are recorded as lines with attributes as to their structural character. Symbols on the lines, such as fold type or plunge information are entered as point data (see above) and can be tied to the structural feature.

Dikes are perhaps the most difficult geologic feature to enter, because many dikes are narrow rock bodies, and thus they are commonly shown as lines on geologic maps. Therefore, it seems appropriate to enter dikes as line features even though they are rock bodies. Wide dikes (those much wider than the map feature size) are treated as rock bodies. Developing a line coverage for dikes separate from the contact line coverage allows us to carry the necessary rock-unit information with the dikes.

In the example here of a geologic map that has been digitized and attributed (Fig. 2), note that the features associated with each geologic element are explicit and easy to understand. This makes the map accessible to both casual and in-depth users (see below).

BASIC QUALITY ASSURANCE AND QUALITY CONTROL

A basic aspect of any data entry is quality assurance and quality control, to make sure that the data are properly

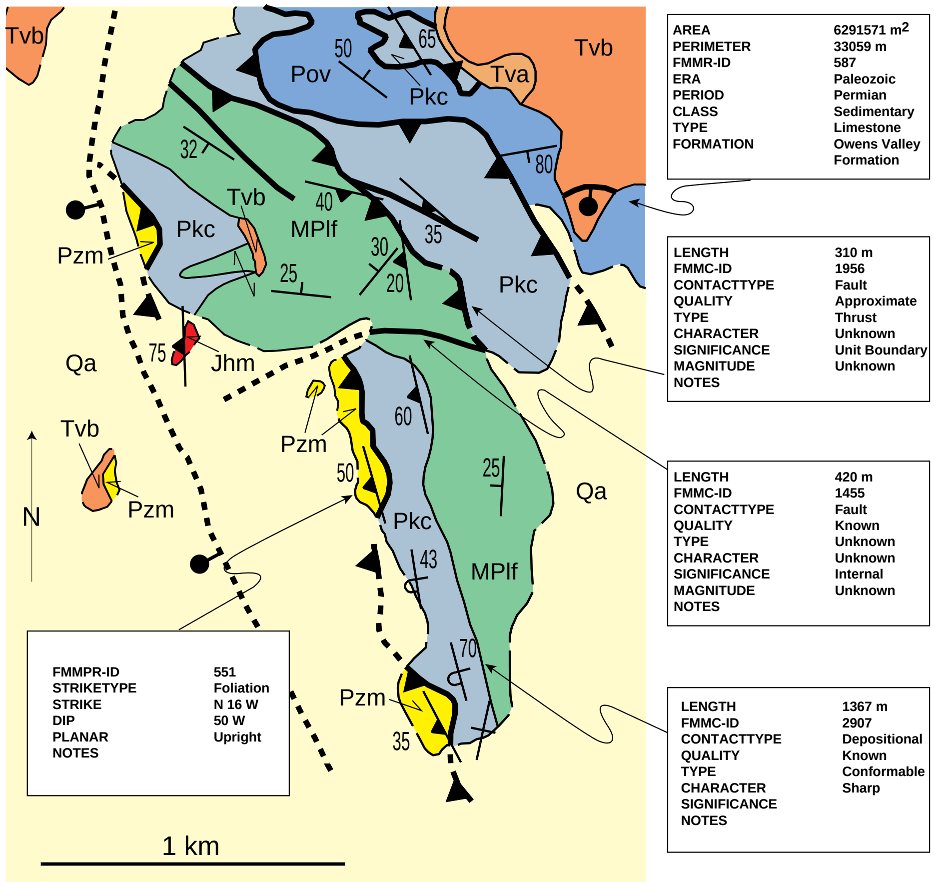

Figure 2. Part of the geological map of the northern Slate Range, California, from Moore (1976). The figure shows attributes given to various lines, points, and rock units. Rock units: Pzm, tectonite marble from Paleozoic rocks; MPlf, Lee Flat Limestone; Pkc, Keeler Canyon Formation; Pov, Owens Valley Formation; Jhm, Hunter Mountain quartz monzonite; Tva, andesite; Tvb, basalt; Qa, alluvium.

entered and attributed. This is done typically by plotting the data according to data type (e.g., a plot of faults alone) and then comparing the attributes associated with that data type with the original source map. In this way, the attributions can be checked for the proper classification of the contact, rock unit, or point feature as well as digitizing accuracy. We have found that a person other than the one who did the digitizing or attribution should do the checking in order to minimize errors. This process is very tedious but necessary to maintain the integrity of the data set.

The attribution of geologic data is usually unambiguous for well-prepared geologic maps. We have found, however, that even published maps sometimes have errors (open contacts or missing unit labels). In these cases, the error is noted, and open contacts are extended to close the rock unit. Missing unit labels can sometimes be easily interpreted—e.g., for laterally continuous sedimentary successions in areas of simple structure. Digitizing errors include digitized contacts or data points that do not overlap the

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TABLE 2. ATTRIBUTE FIELDS AND VALUES FOR GEOLOGIC ROCK UNITS

Type of information about rock units	Geologic age (Era, period, stage)	Absolute age (if available)	Rock class	Rock type	Formation name	Notes
Age	x	x				x
Rock type			x	x		x
Formal name					x	x
		X ± Y Ma	Sedimentary Igneous Metamorphic	Basalt Andesite		

Note: x indicates that an entry can be made for that attribute field. See Table 1 for examples of how fields are attributed. In addition, the Notes field can be used for reference to any sets of external data (e.g., chemical analyses, or isochron information) for a rock unit. Many additional entries are appropriate for rock type.

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same feature on the scanned image. For contacts, we strive for 100% overlap, but in practice we consider 95% overlap acceptable for areas with tortuous or complex data. All point data, however, are edited to ensure 100% overlap. This is judged qualitatively by those who digitize and check the map data.

ANALYSIS VS. DIGITAL MAPPING

The reason that so much emphasis is placed on proper attribution of surficial geological data is that each symbol on the map represents an important data point to the original field mapper. Most of the individual symbols were recorded because they were in critical locations and communicated a specific piece of information about the geological history of the area.

Some commercial GIS digital products do not assign attributes to the point and line features found on geological maps. They sometimes simply digitize the shape of the symbols as a series of vectors. This may be sufficient for the sole purpose of reproducing a paper copy on demand. In this case, some commercial drawing programs, such as Canvas™ from Deneba Software and Adobe Illustrator™, work very well and are easy to use. However, if the reason for digitizing the map is to integrate field data for later analysis, the approach of just digitizing a shape is not adequate.

This is an example of the difference in basic philosophy between a digital cartographic system used for geological applications and a true GIS applied to geological problems. The digital cartographic system may be capable of producing very spectacular hard-copy products on demand, with some analysis capabilities (for example, the SuperCard system discussed by Condit [1995] for data presentation), but the GIS allows the geologist to work with the data, compile and analyze it, and to model it within the system. In addition, data sets from different sources and of variable type can be easily integrated for analysis and modeling.

This flexibility is also why we prefer to take the approach of not only assigning attributes to each symbol on a geological map, but also retaining all the information associated with each gravity data point, each earthquake hypocenter location, and each geochemical measurement input into a database. After all, the GIS should facilitate data manipulation. Most GIS software has fairly extensive tools to clean, smooth, or rasterize data sets once they are in the system, in addition to the extensive analysis tools. Simplified maps or plots to perform a specific task can always be derived from the complete data sets.

In addition, we have chosen to make fairly extensive and explicit tables of the attributes (see Fig. 2). Another approach is to make short alpha-numeric codes for contacts and rock units that are translated through a look-up table (similar to DLG format; see Wright and Stewart [1990] and Ulrich et al. [1992]). This is more efficient for storage and display purposes. However, given current advances in both computer and storage technology (ever-increasing processor speed and ever-decreasing storage prices) we feel that the space and time penalties of explicit tables of attribute values are trivial compared to the enhanced ease of use and readability. In addition, collections of explicit values in a table make query functions easy for casual users (using readily available products such as ARCVIEW™ by Environmental Systems Research Institute, Inc.). Complex coding schemes make it somewhat more difficult to examine data sets directly.

DATA SOURCES CURRENTLY ON THE INTERNET

Digital Elevation Model Information (DEM)
United States at 1:250,000—data points at 3 arc-second spacing
World Wide Web—
http://edcwww.cr.usgs.gov
(EROS Data Center home page)
Anonymous FTP—edcftp.cr.usgs.gov

Digital Line Graph Information (DLG)
United States at 1:2,000,000 and 1:100,000
World Wide Web—
http://edcwww.cr.usgs.gov (EROS Data Center home page) or more specifically

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TABLE 3. ATTRIBUTE FIELDS AND VALUES FOR GEOLOGIC POINT DATA

Type of geologic point data	Orientation of planar feature	Planar feature characteristics	Orientation of linear features	Sense of motion	Type of linear feature	Type of fold	Notes
Bedding	x	x					x
Intrusive contact	x	x					x
Depositional contact	x	x					x
Joint	x			x			x
Flow layering	x	x					x
Foliation	x	x		x			x
Shear zone	x	x	x	x	x		x
Fault contact	x	x	x	x			x
Foliation and lineation	x	x	x	x	x		x
Lineation			x		x		x
Axial surface (mesoscopic)	x	x				x	x
Fold axis (mesoscopic)			x			x	x
Map–scale fold type		x	x			x	x
Map–scale fold plunge			x			x	x
Bar and ball			x				
	Strike and dip	Upright Overturned Vertical Unknown	Trend and plunge	Up-dip Down-dip Right-lateral Left-lateral None Unknown	Intersection Depositional Flow, igneous Stretching Mineral Crenulation Slickenside Mullion Unknown	Antiform Synform Anticline Syncline Antiformal syncline Synformal anticline S-fold Z-fold Monocline Other	

Note: x indicates that an entry can be made for that attribute field. See Table 1 for examples of how fields are attributed.

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Thematic Mapper—Landsat Information
Internet—xglis.cr.usgs.gov

Public-domain geophysics (potential fields, marine seismology)
Contact the National Geophysical Data Center: World Wide Web—http://www.ngdc.noaa.gov. Most of the NGDC data sets are not on-line, but can be ordered on CD-ROM from NGDC, Boulder, Colorado

Earthquake seismology
World Wide Web
General—http://geophys.washington.edu/seismosurfing.html
Specific networks—
http://quake.geo.berkeley.edu,
http://scec.gps.caltech.edu
World coverage—Passcal active experiments—http://www.iris.washington.edu

SUGGESTED READING

There are several good texts on geographic information systems. We have found the following books to give useful approaches or background:

Aronoff, Stan, 1989, Geographic information systems: A management perspective: Ottawa, Ontario, WDL Publications.

Bonham-Carter, G. F., 1994, Geographic information systems for geoscientists: Modelling with GIS (Computer Methods in the Geosciences, Volume 13): Kidlington, UK, Pergamon, 398 p.

Environmental Systems Research Institute, Inc., 1994, Understanding GIS: The ARC/INFO™ method: Redlands, California, Environmental Systems Research Institute, Inc.

HARDWARE AND SOFTWARE REQUIREMENTS

As computers in general become less expensive and more powerful, GIS products at all levels become more useful. How functional a GIS software product is, however, still depends somewhat disproportionately on the hardware on which the system is installed. For example, current versions of the most popular GIS packages are much more functional on UNIX work stations than on PCs and Macintoshes. The price reflects this fact: the differential is approximately 800% between the products, not simply because of speed differences of the machines, but because there are functions that you cannot buy in a PC version of the software. A full PC-based GIS package (at academic rates) would cost several hundred to a thousand dollars for the first license and one or two hundred dollars for each additional seat or machine. The equivalent UNIX-based package would cost several thousand dollars; additional seats would cost over a thousand dollars each.

ACKNOWLEDGMENTS

This work was supported by a contract from the Geothermal Program Office, China Lake Naval Air Warfare Center. We thank Frank Monastero for discussions on the nature of GIS and geological and geophysical data; Brian Macy, Dietrich Kastens, and Jerry Whistler for help with hardware and software problems; and Tim Byrne, Steve Davis, Randy Van Schmus, Rich Whitmarsh, and Suzanne Kay for beneficial reviews of the manuscript.

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Tufte, E. R., 1983, The visual display of quantitative information: Cheshire, Connecticut, Graphics Press, 197 p.

Ulrich, G. E., Reynolds, M. W., and Taylor, R. B., 1992, Toward digital geologic map standards: A progress report, *in* Johnson, A. I., et al., eds., Geographic information systems (GIS) and mapping—Practices and standards: American Society for Testing and Materials, ASTM STP 1126, p. 18–29.

Wentworth, C. M., and Fitzgibbon, T. T., 1991, ALACARTE user manual, version 1.0: U.S. Geological Survey Open-File Report 91-0587-C, 267 p.

Wright, B. E., and Stewart, D. B., 1990, Digitization of a geologic map for the Quebec–Maine–Gulf of Maine Global Geoscience Transect: U.S. Geological Survey Circular 1041, 16 p. ■

GSAF UPDATE

Robert L. Fuchs

Major Gifts Boost Second Century Fund

Several recent gifts from GSA members were instrumental in pushing the campaign total above $4 million. The contributions and pledges, ranging to more than $60,000, are important additions to the financial assets of the Society and its Foundation. These four gifts provide an interesting demonstration of the variety of methods and objectives that are available to contributors to the Foundation and the Second Century Fund—pledges, cash, dedicated funds, appreciated securities, planned or deferred gifts, and personal property. Each contribution was developed in a specific manner, to meet the personal desires and needs of the donor.

Farouk El-Baz Award Fund

A fund to encourage research in desert geomorphology has been set up as the result of a contribution and pledge to the Second Century Fund from Farouk El-Baz, director of the Center for Remote Sensing at Boston University. The fund will provide annual cash awards for outstanding work in this field by earth scientists.

Farouk El-Baz is a GSA Fellow, chair of the Committee on Honorary Fellows, and vice chair (international) of the Second Century Fund. Born in Egypt in 1938, El-Baz was educated at Ain Shams University in Cairo, Missouri School of Mines & Metallurgy, Massachusetts Institute of Technology, and University of Missouri. His distinguished career has been international in scope and varied in scientific study—from archaeology to space technology. He has received numerous honors and awards from governments and organizations. Farouk El-Baz was deeply involved in the Apollo space program and is a leading scientist in the study of desert geomorphology and the application of remote sensing techniques to ground-water exploration in arid lands.

He has been in the public eye on numerous occasions. Nondestructive investigations of the Pharoahs' tombs through remote sensing, under his direction, received enormous worldwide attention. Recently, El-Baz was prominent on TV network news programs on the occasion of the Million Man March in Washington D.C. The state-of-the-art crowd-counting techniques employed by his Center for Remote Sensing were favored by the media and the public over methods previously in use. He is the subject of a chapter in the book *Reinventing the Future: Conversations with the World's Leading Scientists*.

Melvin J. Hill

A gift to the Foundation's Pooled Income Fund was received in December from GSA Fellow and 41-year member Mel Hill. The gift was in the form of appreciated securities, a method of making a charitable contribution that has very beneficial tax results. In selecting the Pooled Income Fund, Mel Hill said that an important consideration was retirement income for him and his wife, Daphne, that would entail the least amount of attention on their part. The fund fits this requirement, along with its other tax and financial attributes.

Mel Hill retired from Gulf Oil Corporation in 1984 after a successful career in geology, research, and management. He began work for Western Gulf in Bakersfield, California, upon graduation from UC Berkeley. After holding jobs in California as district geologist and chief geologist, he was transferred to Pittsburgh, Pennsylvania, where he served in a variety of exploration, research, and management positions over a 12-year period. During the next 10 years, he was president of several Gulf subsidiaries in Houston, advancing to the position of executive vice president of Gulf Oil Corporation prior to retirement.

Over the years, Mel Hill has been active in scientific and academic organizations such as the Board on Earth Sciences of the National Research Council, university advisory committees and boards, and earth science professional societies. He wrote an important paper on wrench-fault tectonics with the late John Moody; it was published in the GSA *Bulletin* in 1956. Currently, Hill is a member of GSA's Committee on Investments and Audit Committee. An accomplished machinist, his workshop in southern California abounds with miniature steam engines and locomotives. He is also relearning the geology of California from the bottom up, although he readily admits to only a minimal amount of outcrop climbing.

Terry Huffington

Terry Huffington's two-year pledge to the Second Century Fund will benefit the Foundation's unrestricted endowment. She is chair of the board of Huffco Group, Inc. in Houston, an international oil and gas exploration and producing company, and she is an honorary chair of the Second Century Fund Committee.

After graduating from Stanford University in 1977 with a B.S. degree in geology, Huffington attended the University of Texas at Austin, earning an M.S. degree in geology. She worked for Chevron U.S.A. for four years, returning to school for an M.B.A. degree from Harvard. Her subsequent career was with Roy M. Huffington, Inc., a company founded by her father, Roy M. Huffington, one of the most successful independent oil explorers. Roy Huffington is a 43-year member of GSA, an Honorary Trustee of the Foundation, and former U.S. Ambassador to Austria. After Roy M. Huffington, Inc. was sold, Terry started Huffco Group Inc.

Terry Huffington is an active participant in and contributor to civic organizations and causes. Her list of activities outside of Huffco includes Stanford's School of Earth Sciences, the Bionomics Institute of San Francisco, The Madeira School in

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James E. Werner

Women in Science Fund
Helen M. Lang
Marilyn E. Quas

Virginia, and Houston's Asia Society, Museum of Fine Arts, River Oaks Baptist School, and Kid Care. Most important, she is married to Dr. Ralph Dittman and they are the parents of two young children.

David E. Dunn

As treasurer of GSA since 1993, Dave Dunn has been intimately involved with the Second Century Fund from its inception. More than most, he is fully cognizant of the long-term benefits that are accruing to the Society from this financial initiative. He was one of the first to make a multiyear pledge to the fund, and one of the first to complete his pledge, several years early.

Now Dunn has increased his participation by presenting to the Foundation a new and unique gift, one of personal property. Gifts of cash and securities are the most common forms of contribution to GSA. However, there are other types of gifts, such as life insurance, real estate, and personal property, that qualify as charitable contributions and can help individuals satisfy their particular philanthropic goals. Antiques, paintings, patents, and copyrights are examples of personal property gifts. Generally, the same favorable tax attributes apply to these gifts as apply to securities and cash, but each gift must be reviewed for feasibility and potential tax results.

The Dunn gift consists of three valuable oil paintings, currently on display at GSA's Boulder headquarters. The mechanics of such a gift can be cumbersome. Appraisals are required, and there are shipping and insurance considerations. Nevertheless, a gift of an asset of this sort can make perfectly good economic sense for both donor and donee. Clearly, GSA is not a repository for fine art, and at an appropriate future time the Foundation may decide to sell these paintings. Meanwhile, however, both Dave Dunn and the Foundation have benefited from this special charitable transaction.

HELP WANTED!

Section chairs for the Second Century Fund membership campaign need GSA members to help with fund-raising during 1996. If you feel the need to communicate a bit more with your fellow GSA members and also want to give GSA some personal time and assistance, please consider volunteering to be a campaign worker. The work is not overly time consuming, just calling and writing to 10 or 15 GSA members about their contributions to the Second Century Fund. You may just expand your own personal network in the process. ■

FORUM

Bruce F. Molnia

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

Politics and Economics: Geological Research Bridging the Gulf—The Near-Term Future—Part 1

This Forum, which is drawn from the IEE Forum at the 1995 GSA Annual Meeting (New Orleans), attempts to examine how geology fits into the larger fabric of society, especially in light of recent societal changes. The interconnections between the geosciences and current political, economic, and environmental movements are analyzed in light of anticipated changes in the business market and education. The second half of this Forum will be presented in the April 1996 issue of *GSA Today.*

PERSPECTIVE 1: Introduction to the Fourth Annual Institute for Environmental Education Forum

Douglas R. Gouzie, Atlanta, Georgia

The 1995 forum started as a theme session concept within the Hydrogeology Division of GSA. The idea was to ask award-winning and leading geoscientists to turn their research minds outside of our profession and make their best prediction of the near-term future. Our plan was to bring together a variety of speakers from all areas of our profession: academia, industry, and state and federal governments. In addition, we added a guest speaker from the Carter Presidential Center in Atlanta who brought us special expertise in global politics and economics.

We started with an overview of changes in the global marketplace and how political and economic factors influence the marketplace. We then shifted to an evaluation of recent changes in the U.S. political climate, particularly with respect to science programs and policies. The speakers then highlighted changes on the horizon in both federal and state governments, evolving issues in commercial practice, and changes brought on by advances in computing, modeling, and basic scientific understanding of the environment. The afternoon came to a close with an examination of changes likely in the academic arena over the next few years and an audience participation discussion.

The purpose of the forum was not to provide a guaranteed prediction of the future, but rather to start a public dialogue on issues of concern to our profession. Judging by the comments of many attendees throughout the rest of the GSA Annual Meeting, we succeeded in opening up a dialogue for GSA members to participate in over the next several months. I encourage you to be a part of this dialogue because I am certain that our profession will benefit if we all put our minds together to face the future.

After hearing the talks presented here and speaking with many of you personally in New Orleans, I do have a prediction of my own. I believe that our profession is moving from an arena where we primarily work with and for other scientists to one in which we are increasingly called upon to interact with business financiers, attorneys, politicians, and almost any other citizen. I believe this interaction is largely a societal change that has affected other professions far more deeply than ours. The most promising part of this trend of greater communication and interaction is, in my opinion, the tremendous societal contribution our profession can make using our traditional strengths and abilities in combining the other basic sciences, synthesizing the data, and communicating the story of Earth in both written and visual formats.

PERSPECTIVE 2: Global Dynamics

Gordon Streeb, Carter Presidential Center, Atlanta, Georgia

The dynamic of change in many of the developing countries entails transition from state-dominated to market-based economics and from one-party, imposed rule to democratically elected government. My observations are based on my service as U.S. ambassador to Zambia from 1990 to 1993 and, currently, as director of the Global Development Initiative at the Carter Center, with a focus on Guyana. These two countries are strikingly similar in the circumstances facing the newly elected governments when they took over in 1991:

- the economy is highly dependent on the export earnings from one or two commodities;
- price fluctuations for these commodities lead to alternating cycles of excessive government spending or borrowing;
- government control and/or subsidization of prices of basic goods and services lead to distortions in resource allocations and disincentives to farmers;
- as earnings from key commodities decline, losses of government-run enterprises are more glaring, debt increases, production declines, inflation accelerates, and infrastructure and social services deteriorate;
- technical capacities are weakened by emigration of large numbers of skilled and educated personnel;
- fed up, the people vote for change, voting out governments that have run the country virtually since independence from Great Britain.

In the postelection period, Zambia pursued a traditional pattern of reform, largely based on policy prescriptions imposed by the International Monetary Fund and World Bank, representing a donor community eager to help Zambia succeed and willing to designate it as a target for funding. Principal features of the stabilization program included: eliminating subsidies and removing price controls, putting government on a pay-as-you-go basis under a balanced budget, allowing the currency to float freely with no foreign exchange controls, reducing government employment, and getting the government out of the business world through a five- to ten-year privatization program.

The new government set out determined to implement these reforms, and by and large it succeeded, with some exceptions. Statistics indicated that inflation was brought down dramatically and government spending checked, but the consequence for the poorest sector was a dramatic jump in prices of basic goods and services and higher unemployment, in part created by a flood of cheaper imported goods, which evaded customs duties and forced cutbacks in domestic production. Corruption, uncertainties in government policy, and the slowed pace of privatization postponed the anticipated inflow of new investment and thus also postponed the creation of new jobs. Donors and the international financial institutions continued to follow traditional patterns of assistance to sectors of prime interest to them, albeit with determined efforts at coordination to promote complementarity and avoid duplication. Debt service, especially to the international financial institutions, continued to be a daily battle for the central bank.

In the immediate postelection period, Guyana too pursued the traditional path—like Zambia, it faced the most daunting per capita foreign debt burden in the hemisphere. But in early 1995, at the urging of former U.S. President Jimmy Carter, Guyana decided to initiate a new process, namely, a collaborative effort between the government of Guyana and the Carter Presidential Center in Atlanta, with financial support from major donors and private foundations. Its purpose was to prepare a comprehensive development strategy for the next 10 to 15 years. The strategy formulation process is designed to provide government (and the people of Guyana) the analytical base from which to set policies realigning the relative roles of government and the private sector; enact legislative and regulatory changes required to support this shift; establish priorities for government spending based on realistic projections of government revenues, including new revenue enhancements (fees, tax reforms, timber and mining concessions, improved tax collection); direct donor funding to priorities determined by government; seek debt restructuring and relief.

A strategy through which government clearly enunciates its policies and manifests its determination to adhere to these policies should stimulate donor and investor confidence, maximize the impact of available funds, and improve prospects for balanced and equitable growth. A unique feature of this undertaking is the methodology. The Guyana economy has been divided into 23 categories, with working groups composed of experts from the government, nongovernment organizations, the university, the private sector, and donors preparing a strategy for their respective sectors. Outside experts under contracts to the Carter Center, working with a technical committee chaired by the minister of finance, are overseeing the working groups and are responsible for pulling all this work together into a coherent package that can be presented to the cabinet for decision-making and to the general public for comment. Ownership is a centerpiece of the innovative methodology; all hope that it will contribute to longer-term commitment even through periods of political change.

The strategy formulation process also avoids exacerbating the ethnic differences reflected in the current structure of economic activity, and it incorporates policies targeted to alleviate poverty, empower women, and sustain the environment.

Will the Guyanese experience lead to greater, sustained growth than the more traditional path in Zambia? The evidence suggests that countries which have established a clear vision, made the tough policy choices, and brought the people into the picture so that they too appreciate the constraints, but at the same time see cause for hope, have a significantly higher probability of succeeding. The lack of a comprehensive context for both government spending and donor funding has undoubtedly contributed to Zambia's failure to capitalize on its new opportunities.

Free and fair elections are not enough. Multipartyism is not a guarantee of democracy. Market economics do not guarantee improvement in the general welfare. But an open system, in which there is equity and fairness, where people are engaged rather than told, and where government can demonstrate that its policies, programs, and priorities are clearly directed toward these aims surely offers the best hope for seizing the opportunity rather than slipping back to chaos. A wide variety of political and/or economic ideologies can be accommodated under this rubric. It is in your interest to lend your support and expertise to those willing to undertake such an effort.

PERSPECTIVE 3: The Changing U.S. Political Climate

John W. Hess, Desert Research Institute, University and Community College System of Nevada, Las Vegas

The pace of change in Washington this year has made looking at the future direction and funding of science and technology very difficult. We are at a critical time. Do we as a country have the discipline to control our spending and not to borrow from our descendants for short-term gains? Do we have the will to commit to investment in the future? These are some of the issues that defined the last presidential and congressional elections. How do the President and Congress balance funding for science and technology with other needs?

Fifty years ago, Vannevar Bush issued a document that marked the beginning of strong bipartisan support for science and technology. Today, Congress is talking about funding cuts that would eliminate a large amount of science and technology investment over the next seven years. Bush's model is being replaced with a new, but not yet defined model. To understand what is going on today, we must go back 50 years to 1945 and Vannevar Bush, who said in his report *Science, The Endless Frontier*, "The Government should accept new responsibilities for promoting the flow of new scientific knowledge and the development of scientific talent in our youth. These responsibilities are the proper concern of the Government, for they vitally affect our health, our jobs and our national security."

For the past 50 years federal science policy was rooted in Cold War perceptions of a world in which the United States had one military rival and virtually no scientific and technological equals. At the close of World War II, two factors conspired to promote Bush's vision deal and to drastically alter federal support of research and development. First, the United States was the only major industrialized nation that did not need to rebuild its industrial base. Second, during the war the nation had seen the power of technology harnessed for the national good. In the context of these two powerful factors, Vannevar Bush proposed a "contract" with science that, fueled by the Cold War, led to four decades of unprecedented investment by the federal government in research and development. Over these past 50 years, there has been a great return from our public investment in fundamental science, both through knowledge generated and through the education of an unmatched scientific and technical workforce.

The spendthrift budgets of the 1980s and early 1990s were unsustainable and mortgaged much of our national future. Resources are scarce, the country cannot afford the "free ride" for scientific research. All of this has set the stage for a new paradigm. The administration stated, in February 1993, its overarching goal for fundamental research: world leadership in basic science, mathematics, and engineering.

In August 1994 the Clinton administration issued a policy statement on science, *Science in the National Interest*. The document is the result of several high-level scientific forums, and it reaffirms the central role of science and technology in our society. But it changes the view of science from that of the "endless frontier" to that of "a critical investment in our nation's future." In the report, there is a demand for some control over the investment strategy and for the creation of the National Science and Technology Council.

The policy environment for science and technology in the United States changed radically following the election in November 1994 and the Contract with America. The Republican-controlled Congress began to implement an agenda calling for a balanced budget within seven years, drastic cuts in federal spending, and a reduction in the scope of federal programs and regulatory authority impacting programs such as the Safe Drinking Water Act, Clean Water Act, Resource Conservation and Recovery Act, and endangered and threatened species.

President Clinton's budget proposal for FY 1996, released in February 1995, also indicated a tight budget. Despite the Administration's stated commitment to science and technology as a cornerstone of

Forum *continued on p. 12*

Forum *continued from p. 11*

economic policy, it was the first presidential budget in more than 20 years to show a decrease in total federal research and development from the previous fiscal year.

Early on, the Republicans called for, among other things that impact the earth sciences, the abolishment of the U.S. Geological Survey (USGS), reduced funding for energy technology development, reduced overhead on federally sponsored university research, abolishment of the U.S. Bureau of Mines, a freeze on the funding for the National Oceanic and Atmospheric Administration (NOAA), reduced funding for resource conservation and development, downsizing the Minerals Management Service, restructuring the U.S. Bureau of Reclamation, limiting the growth of the National Science Foundation (NSF), and not forming the proposed National Biological Service.

The Republican majority pledged to protect those federal R&D investments they felt were proper for the government to support, while cutting or eliminating R&D programs they believed were best left to industry. The House supported the federal government's role in basic research by slightly increasing funding. However, because many in the House view industrial and applied R&D as corporate welfare, they believe that the federal government should not support these programs.

Other action in Congress that impacts science policy includes a proposal to create a Department of Science and HR2405, the Omnibus Civilian Science Authorization Act of 1995. HR2405 was introduced by House Science Committee Chairman Robert Walker (R—PA) on September 27, 1995. It is a combination of seven authorization bills setting funding limits and program direction for NSF, the National Aeronautics and Space Administration, the Department of Energy (DOE), NOAA, the Environmental Protection Agency, the National Institute for Standards and Technology, and the U.S. Fire Administration. The bill attempts to set science policy. Various appropriation bills eclipse HR2405, but this bill gives added weight to Congressional efforts to shape federal science policy and funding.

The President's Committee of Advisors on Science and Technology produced a statement of principles for guiding federal science and technology policy and future budgets in early autumn 1995, as follows.

1. Science and technology have been major determinants of the American quality of life and will be of even greater importance in the years ahead.

2. Public support of science and technology should be considered as an investment for the future.

3. Education and training in science, mathematics, and engineering are crucial to America's future.

4. The federal government should continue to support strong universities, research institutions, and national laboratories as part of the nation's science and technology infrastructure.

5. The federal investment portfolio in science and technology must support both basic and applied research, including the development of precompetitive technologies with and for the private sector as well as national needs.

6. Stability of funding, based on long-range planning, is essential for effective and efficient use of the federal investment in research and its associated educational function and for enhancing international collaboration.

Other questions and issues being struggled with include: (1) "Big" science vs. "small" science, (2) who controls the research agenda, (3) who sets the science policy, (4) is there a societal benefit to science, and (5) who speaks for science in this country?

We are at a point of change. The vision of Vannevar Bush is fading, and a new vision has not yet been formed and set in the minds of the American people. ■

GEOLOGICAL SOCIETY OF AMERICA

MEDALS AND AWARDS FOR 1995

PENROSE MEDAL
presented to
JOHN C. CROWELL

Citation by LEIGH H. ROYDEN

It is with very great pleasure that I present John C. Crowell as the 1995 Penrose Medalist. With this award, we honor John for a variety of outstanding contributions to geological science, any one of which would be worthy of the Penrose Medal. On the basis of five decades of careful mapping and field observations, John has produced pioneering works in sedimentology, stratigraphy, basin architecture, regional tectonics, and global paleoclimatology.

John's major contributions are too numerous to list here, but I would like to highlight a few of his most influential works. In the late 1950s (before the advent of plate tectonic theory) John documented that the displacement on the southern San Andreas fault system was approximately 300 km, providing a crucial element in the later recognition of transform faults. John's work on turbidite deposits in California and Switzerland led to a fuller understanding of their transport and deposition and eventually to new insights into the relationship between tectonics and sedimentation. His now classic studies of the Ridge Basin revealed the basin to be a pull-apart structure that grew tectonically during sedimentation, and provided a new concept in structural and sedimentary geology. John's original and imaginative field work on glacial deposits of all the continents of Gondwana (including Antarctica) provided a comprehensive picture of ice build-up, ice flow, and ice wasting in the context of global paleogeography and paleoclimatology. This monumental work is of special importance to the study of global change because it highlights the essential features of ocean-continent configurations and oceanic circulation that produce glacial periods.

Over the years I have attended many GSA awards ceremonies where Penrose Medalists have been presented by peers and contemporaries, by former students, or by colleagues with whom they have worked closely. This presentation is a little different, and it is a particular honor for me to have been asked to present John Crowell as the Penrose Medalist, because for a long time John's primary relationship to me was as "geo-hero," and I was influenced by John's work from afar long before I met him in person.

I remember that when I was in graduate school, I read a paper by someone named John Crowell called "The Origin of Late Cenozoic Basins in California." Despite the fact that my thesis area was in a distant part of the world, this paper contributed more to my understanding of the tectonics of that region than any other I can think of. I am certainly not alone in having been so influenced and inspired by John's work from afar, and this is but one example of how his work has reached so many generations of geologists.

It is also certain that I am not alone in having been greatly influenced by John's approach to solving problems in earth science. John's work is the epitome of how to combine and synthesize data across traditional disciplinary boundaries, and remains a humbling example for those of us who would aspire to follow in his footsteps.

As I have come to know John as a friend and colleague, I have discovered that, in addition to possessing a keen scientific intellect, John is a kind, thoughtful, and considerate person, attentive to the large and the small in life. On one end of the spectrum, he is the only person I know who sends out "thank you" notes after he receives reprints in the mail. On the other end of the spectrum, he has always found the time to combine his illustrious scientific career with the equally demanding role of husband and father. John has not allowed his work to separate him from his family for long periods of time (particularly difficult for a field geologist), and he has been accompanied on his extended jaunts to exotic places by his wife Betty and, in former times, by his daughter Martha. I hope that some day soon he may also be accompanied by his grandchildren Alisha and John.

I would like to end simply by saying that, on top of his illustrious scientific achievements, I consider John Crowell to be a "geologist's geologist" in every sense of the word, and it is my very great honor to present him to you as the 1995 Penrose Medalist.

Response by JOHN C. CROWELL

When I read the letter from President Stephenson informing me that the Society was awarding me the Penrose Medal, I was stunned and overwhelmed, and then I reflected: Why me? Why should I be picked out from so many more deserving geologists?

I concluded that if I had done anything significant it was because I was a product of the academic system: a product of universities where there is an emphasis on combined teaching and research. Here I wish to pay homage to that heritage and plead that all of us strive to make such a system continue and thrive. The system must flourish with appreciation from society and with adequate funding. More is involved than teaching formal classes and undertaking research and publication, however. The informal and casual teaching and camaraderie between experienced geologists and enthusiastic students are especially rewarding. Throughout my career I have gone on many field trips, both within easy reach of my universities and over the world. Although many trips have been parts of credited courses, especially memorable are those organized by student geology clubs or informal groups where the purpose was to have weekend fun and look at some interesting rocks or geologic features. For example, reconnaissance trips to the desert with students revealed rocks suggesting great displacement on splays of the San Andreas fault. I would not have known the right areas for further study if it had not been for these trips of discovery. Students often bring new insights by pushing for answers to perplexing questions.

As the turbidity-current concept evolved, students and I crawled over muddy outcrops looking for telltale sedimentary structures to reveal how basins filled. What tectonic settings were responsible for the basin shapes and styles? Conglomerates could be laid down in deep water, and mud mixed with pebbles and cobbles at depth could imitate deposits laid down by glaciers. And so with many students and colleagues, we looked at reported "tillites" to see whether they might indeed have had a nonglacial origin. Some did, but many sedimentary deposits document the past existence of glaciers on nearby land.

We geologists are social animals. Field trips organized by local geological societies have allowed me to discuss most profitably the observations and interpretations of industrial geologists. Everywhere over the world I have enjoyed and learned from interchanges with unselfish colleagues as we leaned over outcrops or chatted around happy evening campfires. Almost everything that I have found out about Mother Earth and her history has grown from such group discussions, with students and with professionals. Although we geologists commonly work alone or in small groups in both the field and lab, we relish sharing our discoveries with colleagues.

Many previous Penrosers have thanked persons influential in their careers by name. Reluctantly I have decided not to do this. So many geologists and friends have guided me that I cannot acknowledge them all! I sincerely thank each of them, but here I also wish to thank the academic and scientific system prevalent during my time, a time when students—undergrads and grads alike—are encouraged to mingle with faculty and staff and make discoveries together. I appreciate the wisdom of the Regents of the University of California in setting policies to encourage geology departments to set their own policies. And for their wisdom in allowing sabbatical leaves. I owe much to many organizations for travel and research support, both near at home and at distance, funded by a citizenry recognizing that what we professors do is valuable. We all must strive to see that such policies continue for the benefit of society at large and our human understanding of our remarkable Earth. I fear that such policies are threatened as we face fiscal restraints, along with accounting efforts to document the things that professors do.

I have lived at the right time and place. At a time when jet aircraft have allowed me to dash off to far parts of the globe where rocks significant to understanding Earth history are exposed. With other geologists I have puzzled and worked on significant geological relationships on all continents and have shared observations and concepts with those colleagues. My life has coincided with a time when funding for justified science and distant travel has been generous. I have happily lived during the plate tectonic evolution that has so successfully revealed how Earth's crust wrinkles and breaks and pieces move about, when we have learned that most of crustal history is recorded in blocks and slices caught up in continental terranes, and only parsimoniously preserved. I have witnessed a second revolution coincident with the growth of plate tectonics: a huge increase in understanding of what we know about Earth history during more than a half century of mapping, dating, geochemistry, geophysics, and other approaches, as geologists have scurried over our planet. I have also lived at a place near mountains and deserts where rocks revealing crustal history are magnificently exposed. How fortunate I have been!

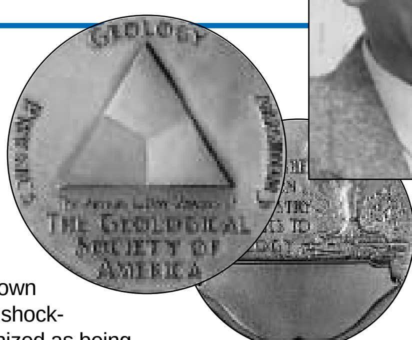
And so I plead: Let us all strive vigorously to assure that universities emphasizing combined teaching and research continue to thrive. Even though public funding is now strained, humankind's understanding and knowledge of our earthly habitat requires this. Geologists, such as us, are those most knowledgeable of the way the earth system works and the way it changes through time. We hold the key to the past record, and this history is the best guide we have of the future. May geologists and students long continue to wander and ponder as we document the history of our planet throughout geologic time!

Thank you very much indeed for this high honor. To receive the cherished Penrose Medal is the culmination of my career.

DAY MEDAL

presented to

THOMAS J. AHRENS



Citation by RAYMOND JEANLOZ

Impact and cratering have played a central role in the formation and growth of terrestrial planets, in the modification of their surfaces, and even in that most unique characteristic of our own planet, the evolution of life. Thus, shock-wave phenomena are now recognized as being among the most significant geologic processes on a planetary scale.

Few realized this 30 years ago, when Tom Ahrens began applying shock compression to research in the geological and planetary sciences. It took real vision to establish what is now the premier university shock-wave laboratory in the world. Since both high pressures and high temperatures are achieved on impact, this facility has provided key information on the interiors of Earth and the planets, as well as on cratering phenomena. Some of the first experimental constraints on the temperature and iron-alloy composition of Earth's core have come from this laboratory. It was also here that the first measurements were obtained showing that magmatic differentiation as we know it, with melts percolating buoyantly upward, is largely restricted to the near-surface environment. As if this were not enough, Tom Ahrens and his associates have made pioneering contributions to such diverse topics as the growth and early evolution of the atmosphere, the volatile budget of our planet, the mechanism by which meteorites from Mars and the Moon have ended up on Earth, and the most plausible way in which the Chicxulub impact may have caused the Cretaceous-Tertiary extinction.

It is for his visionary applications of shock-wave research in the geological sciences that we recognize Thomas J. Ahrens with the 1995 Day Medal.

Response by THOMAS J. AHRENS

It thrills and honors me to receive the Arthur L. Day Medal. I would like to say a few words about the many persons who have provided support, inspiration, and scientific collaboration.

My introduction to the questions of the evolution of Earth and the mysteries of how Earth works first came from MIT's Professor Patrick Hurley during my undergraduate years (1953–1957). I went into earth science because I love Earth, its many moods on the surface—the land and the sea. (However, its problems, unfortunately, led me into blowing up rocks in the basement.) Further inspiration came from Frank Press and Harrison Brown at Caltech, where I was a graduate student from 1957 to 1958.

During the following year, while I was fulfilling my Reserve Officer Training Corps commitment as a U.S. Army second lieutenant stationed at Aberdeen Proving Ground, Maryland, I had the good fortune to be assigned to work on the problem of the ground-shock vulnerability of the Army's NIKE Air Defense system. The Army was starting to put these NIKE missiles underground in bunkers. I learned that you could describe the dynamic properties of rocks by measuring the kinematics of shock-wave propagation.

At the close of my Army tour, I was fortunate to be taken on as a graduate research assistant by Professor Samuel Katz at Rensselaer Polytechnic Institute. Professor Katz had a contract with the Army's Aberdeen Proving Ground to study ground shock. Dr. Katz was a student of Maurice Ewing. After Lamont, he went to work for a geophysicist, Dr. Thomas Poulter, an Antarctic explorer, and expert on the geophysical applications of high explosives at his laboratories at Stanford Research Institute. Dr. Katz had just left Poulter Laboratory at Stanford Research Institute, where this group was pioneering the application of explosion-induced shock waves to measure the dynamic compression of metals. In 1962, after receiving a Ph.D. from Rennselaer, I went to work at Poulter Laboratory and began to use high explosives to study the properties of rocks and minerals. My first paper on shock compression of crustal rocks, co-authored with Victor Gregson, Jr., appeared in the *Journal of Geophysical Research* in 1964. This was exciting, hands-on research. I came home at night with my ears still ringing from the day's explosions and with TNT under my fingernails.

I began to realize that the high-pressure dynamic properties of earth materials could be applied to understanding both the physics of planetary interiors and impact processes. At that time, primary interest was on impact cratering on the Moon. President Kennedy had just announced the U.S.'s intention to race the Soviet Union to the Moon.

However, in July 1965, the Mariner 4 spacecraft sent to Earth the first images of Mars' surface, and to my (and many others') surprise, that surface was also heavily impact cratered. Thus, planetary surfaces other than the Moon were cratered. Since then, impact craters have, of course, been found to be ubiquitous features of all the solid planets and nearly all satellite surfaces in the solar system imaged in the past 30 years.

I decided to pursue the study of shock effects in minerals. As Stanford Research Institute was a total soft-money, not-for-profit operation, I applied to NASA for support and began research on shock compression and adiabatic release from high pressure of rock-forming silicate minerals.

The high-pressure, rutile-structured polymorph of quartz had just been synthesized in Moscow at the High Pressure Institute by a graduate student, Sergei Stishov. A few months later, Ed Chao and co-workers discovered this phase at Meteor Crater, Arizona, and in the Ries Crater in Germany, and named it stishovite. This was the first silicate mineral in which oxygen was in octahedral coordination with silicon—a precursor to the high-pressure mineralogy of the lower mantle now being studied so intensively. I realized that the properties of high-pressure phases of minerals could be studied using shock-wave data.

At this point in 1967 Caltech's Division of Geological and Planetary Sciences was seeking a junior faculty member who was interested in relating seismic velocity versus depth profiles, like those Don Anderson and his students were measuring, to determine their relation to high-pressure mineralogy and temperature. Several months after a tongue-in-cheek discussion I had with Frank Press, who was then chairman of the Department of Geology and Geophysics at MIT, as to whether one could mount a big gun vertically onto the tall, skinny MIT Green Building, Caltech appointed me an associate professor of geophysics. It appeared that I would have a superb opportunity to conduct research and teaching in a highly supportive environment.

In 1967, the Caltech geophysics group was mainly located in the Seismological Laboratory. This laboratory's offices were housed in a spacious mansion in the San Rafael Hills, five miles west of campus in an exclusive neighborhood adjacent to the Annandale Country Club. This appeared to *not* be a good place to conduct high-explosive experiments!

With the help of Hal Swift of the Naval Research Laboratory, I developed a 40 mm gun system that eventually was able to launch 90 gram projectiles to speeds of 2.5 km/s and thus achieve, upon impact, pressures of 400 to 600 kilobars, equivalent to Earth depths of 1200 to 1800 km. To many people's surprise, the adjacent seismographs never detected these high-frequency shots.

Just when the 40 mm gun and a small, converted, Sears and Roebuck shotgun, used for mineral shock recovery experiments, were operating, I had the good fortune of having the 3000 sq. ft. Lindhurst Laboratory of Experimental Geophysics assigned to me in the new S. Mudd Geophysics Building under construction on the main Caltech campus. We moved—lock, stock, and, especially, barrel—in 1974.

Again, I had the good fortune to be joined by my citationist, Raymond Jeanloz, my fourth graduate student. He is an extraordinarily imaginative and productive scientist.

At the time we moved the shock wave lab into the campus geophysics building, I had managed to obtain a surplus, heavily worn 108-ft.-long, 20-ton light-gas gun developed by Alex Charters, a former Caltech student (of Von Karman), from NASA/Ames. At Ames Research Center, this gun was used to launch models of reentry vehicles into planetary atmospheres. After some 16 failed shots, Raymond and I managed to launch projectiles in the 4 to 6 km/s range to study the equation of state of pyroxene at lower-mantle pressures. Now we know that we were studying pyroxene transformed to the perovskite structure.

In the early 1970s we also started conducting experiments to measure the equation of state of lunar samples. This research would not have had much, pardon the pun, impact, were it not for the collaboration of Dugan O'Keefe, then a graduate student at UCLA and a full-time employee of TRW. Dugan and I used the lunar-rock shock data set to determine the partitioning of energy and the amount of melt and vapor produced in planetary impact as a function of impact velocity. We did this work with what was then the most powerful computer available—the Lawrence Berkeley CDC 7600.

With Manfred Lange (a University of Kiel graduate student and later a Caltech postdoctoral fellow) and graduate students Mark Boslough and Raymond Weldon, we began a program to study impact devolatilization of water and CO_2 from minerals containing these species and began to investigate the formation of planetary atmospheres.

With NSF support, Gregory Lyzenga, Arthur Mitchell, and I conducted the first shock temperature and melting point measurements of minerals to lower-mantle pressures. With colleague Professor Edward Stolper and graduate students Sally Rigden, Gregory Miller, and Linda Rowan, we conducted shock compression studies of molten silicates. We demonstrated "Stolper's hypothesis": at pressures greater than 60 kbar (180 km depth) basalt becomes denser than the mantle, and this depth was also established to be the maximum depth from which basalt could erupt on Earth. Stolper's hypothesis also predicts the neutral buoyancy of olivine in a magma ocean at 60 kbar, a result also obtained by last year's Day Medalist, David Walker.

I will stop at this point to thank the dedicated technical and administrative staff and leaders of Caltech over the years, as well as the 24 graduate students, and some 26 postdoctoral fellows and visiting associates with whom I have so far collaborated at Caltech.

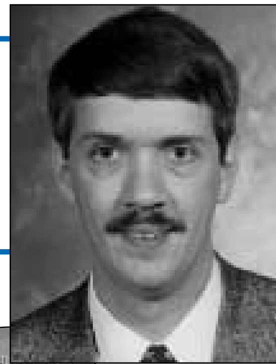
Arthur L. Day indicated that this prize was to inspire further work from its recipients. As my family and my present students and colleagues will report, I am still very much hard at work.

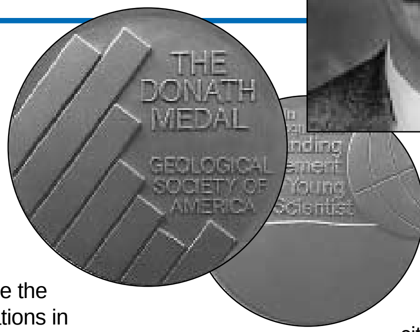
It gives me great pleasure to receive the Arthur L. Day Medal. Thank you very much.

YOUNG SCIENTIST AWARD (Donath Medal)

presented to

WARD EARL SANFORD





Citation by LEONARD F. KONIKOW

Many geologists now recognize the important influence of ground water on geologic processes. Similarly, ground-water hydrologists increasingly recognize the value of sound geologic interpretations in developing models of ground-water flow and transport. Ward Sanford is the rare person who can comfortably “bridge the gulf” between the geologic and hydrologic disciplines, and do so creatively and quantitatively.

As a prelude to his Ph.D. thesis research at Penn State University on dissolution of calcite in saltwater mixing zones in coastal carbonate aquifers, Ward first had to develop a viable numerical model of variable-density ground-water flow and multicomponent solute transport. I knew Ward had something special going for him when he completed this so-called preliminary “task” in just one summer, yielding a model that is now widely used by hydrogeologists in analyzing saltwater intrusion problems. His subsequent coupling of that model with aqueous geochemistry models revealed and explained patterns of porosity and permeability development in carbonate systems that had not been anticipated by scientists previously studying this problem.

Ward’s work shifted from sea level to a mountain top to participate in a study of the acid crater-lake system of an active volcano in Costa Rica. As we breathed the sulfurous fumes, were drenched by acid rain, and hiked precariously on the steep slopes above the hot crater lake (which, incidentally, had a pH of about 0), we pondered the age-old question: *“What the heck are we doing here?”* Fortunately, Ward knew, and the outcome led to a better understanding of how ground-water flow affects the fluid, chemical, and energy budgets of such crater-lake systems.

In a drier part of the world, Ward’s recent work on playa lakes on the High Plains of Texas showed how ground-water flow can control the thickness and mineralogy of evaporite deposits.

Overall, Ward’s scientific contributions have application in hydrogeology, civil engineering, aqueous geochemistry, ore deposits, volcanology, and ground-water contamination. As our political leaders are demanding “relevance” in science, we can cite Ward as an example of a young scientist whose contributions provide both theoretical understanding and practical tools.

In this year [1995] when a hydrogeologist [Dave Stephenson] is the president of GSA, I find it particularly fitting that Ward Sanford becomes the first hydrogeologist to receive the prestigious Young Scientist Award.

Response by WARD EARL SANFORD

It is truly an honor for me to be named the recipient of this year’s [1995] Young Scientist Award. It’s humbling to look over the names and contributions to geology of the previous recipients. I know that my contributions to geology have come only after many individuals have made significant contributions to my career. Therefore, I hope you will take these few moments to allow me to recognize and thank some of these people.

My first and greatest thanks must go to my parents, Richard and Eloise Sanford, for though they never had the opportunity to attend college themselves, they always held higher education in the highest regard, and so they strongly encouraged me to attend college and follow my interests in science. As an undergraduate at Purdue University I can remember catching the excitement of geology from the late Henry Meyer, an expert on diamonds and kimberlites, by seeing his gem and mineral collection and hearing his stories of travels to Africa. My real career guidance at Purdue, however, was soon provided by Darrell Leap. His lectures on hydrogeology allowed me to see the many practical applications of the field, and how a hydrogeologist could help meet the needs of society.

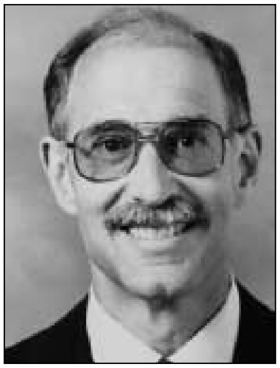
It was with the recommendation of both Darrell Leap and Henry Meyer that I applied for and accepted enrollment in graduate school at Penn State. After arriving at Penn State I soon discovered that my advisor, Dick Parizek, was a professor keenly devoted to his students. It was because of Dick’s selfless devotion that he encouraged me to take up an opportunity I had to do cooperative research with the U.S. Geological Survey, rather than tack on to one of his own projects. There is another faculty member at Penn State who affected my career—Turgay Ertekin, a petroleum engineer and an outstanding teacher. His incredibly detailed lectures on solving the equations of flow through porous media gave me a confidence in quantitative methods that has since allowed me to tackle more complex problems.

I must say, however, that the biggest break in my career came when Lenny Konikow asked me to start doing research with him at the USGS during the summers while I was enrolled at Penn State. Lenny introduced me to solute-transport models, and guided me into a project coupling ground-water flow with the geochemistry of saltwater mixing zones in coastal carbonate aquifers. In my early days at the Survey I met Mark Person, another student fortunate enough to work with Lenny. Mark and I had similar interests, and through many personal conversations we both became excited about studying the role of ground water in geologic processes. My career has also benefited tremendously by the other world-class hydrogeologists at the Survey that I get to interact with nearly every day. Some of these include Cliff Voss, Chris Neuzil, Allen Shapiro, Bill Back, Niel Plummer, Blair Jones, and especially Warren Wood. Warren and I have worked together for years now at a saline lake site in West Texas, and it was through this collaboration that we came up with an evaporite model for hydrologically open basins.

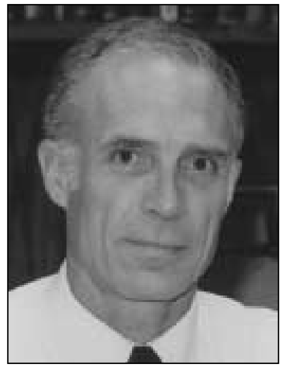
I cannot end, however, without giving a sincere thank you to my wife Chris, who worked for four years while I played in graduate school, and since then she has spent endless hours raising our two boys while I’ve been off gallivanting around the world. Finally, I love studying the earth. I love seeing how all the processes within it operate and interact by such elegant laws. I believe we are studying the masterpiece of a truly great artist. I am privileged to be able to study the earth and get paid for it. I am also privileged to work for the U.S. Geological Survey, but I am especially privileged to accept this prestigious Young Scientist Award from the Geological Society of America. Thank you.

DISTINGUISHED SERVICE AWARD
presented to

JOHN E. COSTA, HENRY T. MULLINS, ARTHUR G. SYLVESTER


Costa


Mullins


Sylvester

Citation by DAVID A. STEPHENSON

The GSA Distinguished Service Award was established by Council on the centennial anniversary of the Society in 1988 to recognize individuals for their exceptional service to the Society. Tonight, on behalf of the Society, it is my honor to recognize John E. Costa and Arthur G. Sylvester for serving as Editors of the *Bulletin* from 1989 through 1994, and also to honor Henry T. Mullins who has served as Editor of *Geology* from 1990 through 1995. Hank, John, and Art could not be here [in New Orleans].

The Society owes much to these individuals for their intensive efforts. During their service as editors, 3736 manuscripts passed through their offices, and 15,609 pages of science were published in 144 issues of *Bulletin* and *Geology.* Many hours were unselfishly devoted by them. This went beyond their professional commitment. It is my privilege and pleasure, Hank, and John, and Art, to present to you the GSA Distinguished Service Award.

RIP RAPP GEOLOGICAL ARCHAEOLOGY AWARD
presented to

JOHN P. ALBANESE

Citation by GEORGE C. FRISON

Although most archaeological data are recovered from geologic deposits, few geologists have regarded these kinds of deposits worthy of serious study. In North America in particular, culture-bearing deposits are relatively recent and contain little if anything of economic value. However, archaeologists are well aware that geologic processes have operated continually, and accurate evaluations of archaeological site formation processes and site integrity are necessary in order to formulate better interpretations of past human activities as they are revealed in the geologic record. Although Old World archaeologists are strongly oriented toward the earth sciences, New World archaeologists emerge from anthropology departments with strong ties to the social sciences. Consequently, the need for trained geologists is critical for archaeology but, unfortunately, most academic departments of anthropology are rarely able to retain a geoarchaeologist on their staff, and most geology departments express relatively little interest in the geologic aspects of archaeology.

The need for the trained geologist is especially true in Paleoindian sites where the evidence is often contained in deeply buried stream terraces and covered by alluvial, colluvial, eolian, or other deposits. The archaeologist needs to know, for example, what landform was utilized for bison procurement in any given site in order to make a reliable estimate of the strategy utilized by the human predators involved. Trapping bison in an arroyo headcut requires a different strategy and manpower requirements than driving them into an artificial corral, although in both cases the only remaining evidence may be a badly decomposed bone bed.

Nearly three decades ago, Wyoming archaeologists in particular and Plains archaeologists in general were to receive badly needed help from an unexpected source. John Albanese came to study geology at the University of Wyoming after World War II and, after acquiring a master's degree in geology, became a very successful petroleum geologist. However, along the way he developed also a growing interest in Wyoming archaeology, enough so that he became an active member of the Wyoming Archaeological Society. With an added impetus on Wyoming and Plains archaeology in the late 1960s, John Albanese began to contribute his geological expertise to the investigation of archaeological sites. Of particular significance—and an impressive demonstration of the value of geology to archaeology—was John's help in determining that the 10,000 year-old Casper Bison kill, discovered in 1971, of over 100 extinct bison was accomplished by driving the animals into the trough of a parabolic sand dune that served as a natural trap. All but the trough of the parabolic sand dune had been removed by industrial activity, and the determination of the landform involved would most likely not have been resolved without John's geological expertise.

Although John was always ready and willing to interpret the geology in archaeological sites of all ages, his greatest interest has been directed toward Paleoindian sites. Following the Casper site was the discovery of two major Paleoindian sites in the Big Horn Basin, the Hanson Folsom site, and the Colby Mammoth kill site in 1973. In addition, during 1977 a reinvestigation began at the Homer site, also in the

Big Horn Basin and the type site of the 9000-year-old Cody cultural complex, that had been excavated earlier by Princeton University and the Smithsonian Institution. John Albanese agreed to do the geology of both the Hanson and Colby sites and was able also to clarify, expand, and change outright many of the geological observations made during the 1950s at the Homer site by Glen Jepsen, a paleontologist from Princeton University. This was important to Paleoindian bison studies because Jepsen's interpretations would have required a different procurement strategy than the one based on John Albanese's reconstruction of paleolandforms at the time of the site occupation. John's geological observations were published as book chapters in the final reports on the four Paleoindian sites mentioned above.

Another major geological work was done by John Albanese at the reinvestigation of the deeply stratified, multicomponent, Paleoindian Agate Basin site in eastern Wyoming during the 1970s. Site investigations had been initiated by the Smithsonian Institution in 1942 and continued in 1962, but no formal report had been made. The site formation processes in this case were extremely complex and needed to be clarified if meaningful site interpretations were to be realized. Once again, the results were published as a book chapter in 1982. John was retained to do the geology of the Mill Iron site in southeast Montana, a site that is a manifestation of the Goshen cultural complex first recognized during 1966 at the stratified, multicomponent Hell Gap Paleoindian site in southeast Wyoming. The geology of the Mill Iron site will appear as a book chapter in 1996.

John Albanese's expertise in geoarchaeology was recognized by the Smithsonian Institution in the 1970s. He expanded that expertise to several states, including Colorado, Montana, South Dakota, and Texas, and to South and Middle America. John considered going back to finish his Ph.D. and seek an academic position, but his independent nature led him in a different direction. This is unfortunate in some ways: John is a natural born teacher, both perceptive and articulate, and would have performed well in the classroom to train students in geoarchaeology.

However, despite raised eyebrows and, in many cases, outright disbelief and consternation among many of his former colleagues in the petroleum geology business, John chose to establish himself in a new and different career, as a full-time consulting geoarchaeologist. He has done very well in this venture and is sought out continually by the academic, contracting, and cultural resource management branches of archaeology. It is a sign of progress in the geology profession and the Geological Society of America that geoarchaeology is now recognized and accepted as a legitimate area of research. It is fitting and proper that John Albanese be presented the Rip Rapp Archaeological Geology Award. No one is more deserving through both his scholarly contributions and for major progress in bridging the gap between archaeology and geology during the past three decades.

Response by JOHN P. ALBANESE

I thank the Archaeological Geology Division of the GSA for choosing me as the recipient of the Rip Rapp Award for 1995. I feel honored and am sincerely grateful.

I entered the profession of archaeological geology in middle age, at a time when many people are beginning to think about retirement. This career change would be difficult, to say the least, if one did not have the support and encouragement of one's spouse. My wife, Evelyn, has lent her support, worked as my field assistant for many years, and accompanied me on most of the major projects that I have worked on. Needless to say, we do get along; we have been married for 49 years. A second person I wish to acknowledge is George Frison, retired head of the Department of Anthropology at the University of Wyoming. It is through George's direct support and encouragement that I entered the field of archaeological geology. I had developed an interest in archaeology as a hobby, and it was through this avocational interest that I became acquainted with George. He had been attempting to recruit someone from the Department of Geology at the University of Wyoming who would carry out the geological investigation at the Ruby Site, a Late Archaic Besant bison kill located in the Powder River Basin of Wyoming. He had not been successful. At that time, 1968, I had nearly 20 years experience as a professional geologist, but it was all in the exploration segment of the oil and gas business. I think that out of desperation, or exasperation, or perhaps both, George asked me if I would carry out the geological investigation at the site. I did so, apparently with some success, as I later found myself working with George on other projects. I soon discovered that there was as much similarity between petroleum geology and archaeological geology as there is between Godzilla and St. John the Baptist. However, things worked out, and due to George Frison's recommendation, I later found myself working with another man who had a great influence on my professional career. This person is Dennis Stanford, head of the Department of Anthropology at the Smithsonian Institution. I worked for Dennis on a number of Paleoindian sites in Colorado, and as a research associate at the Smithsonian, I had the opportunity to work on old sites in Central and South America. For the whole time that I was carrying out these geoarchaeological projects, I was still working in the oil business. Three other men and I owned a small oil company engaged in formulating, leasing, and drilling oil and gas prospects, an endeavor that did result in the discovery of some oil and gas fields. I was a partner in the firm until 1978, when we terminated the venture on a very amiable basis, and I became a full-time consulting geoarchaeologist, an endeavor that I have continued to the present.

My experience as a petroleum geologist has influenced how I view the field of geoarchaeology. One great difference that I first noticed between the two specialties was the methods of testing hypotheses. In the oil business, after spending large amounts of time and money on a particular project, one tested the prospect by spending more money and drilling a well. At the time I was in the oil business, the success ratio, within the United States, for drilling a wildcat well was 1 in 8. However, the rate of success in finding an economically viable oil field was only 1 in 40. Currently in domestic-oil–producing areas with high well densities and for which there are abundant subsurface geologic data, the use of 3-D seismic, a sophisticated and very expensive tool, results in a wildcat success rate of approximately 50%. What the preceding says about the ability of geologists to predict, I leave to the audience to decide.

In 1968, the testing of archaeological geological hypotheses within the northwestern Plains area, by either core-hole drilling or backhoe trenching, was nonexistent and essentially still is, for that matter. Fortunately, the situation is much better in the mid-continent portion of the United States where the core-hole rig is not an uncommon tool and the detailed geological examination of local drainage basins is not an uncommon endeavor. Here, geoarchaeologists have developed models, based on detailed surface and subsurface data, that concern the Holocene evolution of local and regional drainage basins. These efforts have been accompanied by the formulation of predictive models that concern the geographic distribution of buried archaeological sites.

I personally feel that the most important task facing the field of archaeological geology is the development of local and regional detailed databases that encompass all facets and types of information necessary to develop predictive models concerning site distribution, an effort similar to the aforementioned one currently taking place in the midcontinent. I might be accused of plagiarism in saying this, as it is similar to statements that have appeared frequently in the recent literature, but they are still worth repeating. I am acutely aware of the need for a regional synthesis, because of my work in the northwestern Plains where the effort of developing detailed syntheses has not yet been initiated. To my knowledge, an analysis of individual drainage basins, similar to that being made by current investigations in the midcontinent, does not exist in the states of Wyoming or Montana. Of course this type of detailed study should not be restricted to drainage basins alone, but should also be applied to other large geologic features such as eolian dune fields. In southwestern Wyoming, an area of high archaeological site density, most of the sites are in sand dunes. If one is looking for an archaeological site, one heads for the sand dunes, a fact well known to amateur artifact collectors. Some geological work has been done on the major dune fields, but very little is known about the detailed Holocene history of small dune fields, where many of the sites are located.

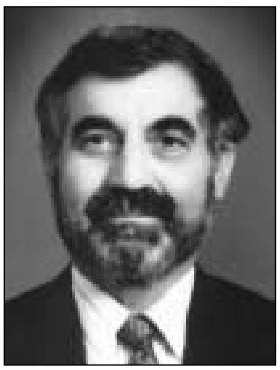
There is another endeavor of geoarchaeologists that I consider nearly as important as that previously discussed, and that is the dissemination of the results of geoarchaeological investigations to the archaeological profession. I know some archaeologists who can barely spell the word geology, let alone know what new developments are occurring in the field of archaeological geology. Many archaeologists are unaware of the geologic factors that affect site preservation or visibility. How many archeologists are aware of the argument recently presented by Rolfe Mandel in "Geomorphic Controls of the Archaic Record in the Central Plains of the United States," Geological Society of America Special Paper 297, published in 1995, in which he presented evidence that the paucity of recorded Archaic sites in the Central Plains, especially those dating from about 8000 to 4000 B.P., is a result of geomorphic processes instead of prehistoric settlement patterns. I would urge more geoarchaeologists to spread the gospel and present papers at meetings in general as well as geoarchaeological sessions. The main thing that distinguishes the Archaeological Geology Division of the GSA from the Quaternary Geology and Geomorphology Division is the word archaeological. Our main function is to facilitate the study of archaeology by pointing out the effect of natural processes upon the archaeological record and by distinguishing between effects resulting from the actions of man and the processes of nature.

GILBERT H. CADY AWARD

presented to

LOUIS G. (LOU) BENEDICT and RICHARD R. THOMPSON

Citation by JOHN C. CRELLING



Benedict

Thompson

The Gilbert H. Cady Award for 1995 is presented to Louis G. Benedict and Richard R. Thompson in recognition of their outstanding work in advancing the science of coal petrology and for applying it to practical problems in the steel industry. The research contributions of this team have been exceptional, both in their significance and in their scope. They were pioneers in the application of coal petrography to coal quality control, and they developed coal selection and quality-control procedures that are still in force after 30 years of use. They developed a unique and broadly applicable system of coke-quality prediction based on petrographic analysis. They were the first to differentiate the maceral vitrinite on the basis of its physical and chemical properties, and they defined the maceral pseudovitrinite. They conducted some of the earliest work on the effects of petrographic properties on coke reactivity and developed the Bethlehem Steel Reactivity Test, which foreshadowed present tests. They researched the effects of coal weathering on coke quality and devised systems to detect weathered coal in both the field and the laboratory. They also contributed considerably to the study of coalification and the effects of coal rank on coke quality. They published some of the early work on rank-related carbon forms, and they did significant research on the discontinuous nature of vitrinite coalification paths. Their research results have been widely accepted and well published.

Louis G. Benedict and Richard R. Thompson have served the profession well as strong and persistent advocates of applying coal geology and coal petrology to practical industrial problems. Their greatest service has been in freely inviting colleagues into their laboratories for demonstrations, consultations, and encouragement, especially in the 1970s and early 1980s, when they were one apex on the great "coal science triangle run," which included stops at their laboratory at Bethlehem Steel in Bethlehem, Pennsylvania, and at the labs of two other Cady Award winners, Bill Spackman at Penn State and Ralph Gray at U.S. Steel in Pittsburgh. This run was made by both domestic and overseas colleagues, from universities, government agencies, and even other industrial laboratories, wanting to know anything from the basics of setting up a coal lab to the latest cutting-edge research.

Louis G. Benedict and Richard R. Thompson have set a high standard for professionalism, collaboration, and publication, while making landmark contributions to the sciences of coal geology and coal petrology.

Response by LOUIS G. (LOU) BENEDICT

My entire life has been directly linked with coal and the coal mining industry: son of a 40 year underground coal miner, raised and educated in a coal company town, nurtured and influenced in a coal mining environment.

Although I did not fully appreciate it at the time, a number of important life standards existed in the mining community family unit that have had a strong bearing on my personal development. Foremost among them were a strong work ethic, honesty, reliability, compassion, patience, and an understanding of one's capabilities. These standards were not learned, just practiced and passed on in everyday life.

Subsequent academic and professional associations served to expand on these earlier influences. I had the good fortune to know and associate with many of the individuals previously honored by the Cady Award, including Dr. Cady himself. Although not exclusive, this group played a major role in the development of the concepts and technology that elevated coal petrography to the science that it is today. As I look back on this group of individuals, it is clear that they all possessed standards similar to those associates of my early years, with particular emphasis on work ethic and honesty. Additionally, the individuals in this group were all teachers and sharers of information and techniques that were extremely important to my professional development as a coal technologist.

Dr. Cady, for whom this award is named, was a standard of reference for all entering the field. Dr. Spackman, one of the early recipients of the award, was an inspiration and a role model nonpareil. Dick Thompson, my colleague and co-recipient of the Cady Award, was a mentor and friend. These individuals, as well as others too numerous to cite, were largely responsible for any success that I have achieved over the past 35 years, and I am eternally thankful to each and every one of them. Their example as teachers and sharers and their motivating spirit has been an example for most of my working career. Efforts to emulate them by giving back to others in a similar fashion has always been a personal goal, albeit a very difficult one to obtain.

I had the good luck of entering the coal petrography field at a most opportune time, the 1960s. Coal petrography was undergoing rapid development as a science, and the transition to applications was beginning. Many of the recognized experts in the field were at their professional peak, and there was a phenomenal accumulation and dissemination of knowledge world-wide. Business and economic conditions were good, thus supporting and facilitating high volumes of research and published information from universities, industries, government agencies, and the private sector. Numerous venues were in place to dispense this information and to provide opportunities for researchers from all over the world to meet and share information and ideas first-hand. Finally, there was a serious need to focus coal petrography and demonstrate its applicability, efficiency, and utility in the coal and coke industries. The literature provides a living record of the success this group had in reaching those goals. It was always an honor for me to just be associated with this surge of activity.

I view the period 1960–1980 as the boom period of coal petrographic development, and it was a wonderful time to be introduced to the science. It was a period that probably will never again be duplicated in terms of people involvement and research production. There was a pervasive spirit of the period that provided a motivation that made work days productive but also fun. That same spirit remains with me to this day, and I credit all of those earlier associates for imparting it to me.

The past was great for coal petrographic accomplishments and involvement, but what can be said about future activities and opportunities? In my opinion, there is still a lot to be done in the area of coal petrographic research to support current coal-based operations, as well as those that will be developed and implemented in the near- and long-term.

Coal will continue to be the primary fuel source for some time into the future, especially in developing countries. China, for example, has vast coal reserves that will need to be evaluated, developed, and utilized. Petrography will be needed to bring this about on economic and efficient scales.

With the present focus on expanding electric furnace steelmaking, at the expense of steel made via the conventional blast furnace method, scrap will become a scarce and expensive commodity that could strongly limit this activity in the near future. Direct reduce iron (DRI) will be looked at more strongly as a supplemental scrap source. Coal-based DRI methods will be revisited and will require coal characterization, to effectively control costs and operation efficiency.

Pulverized coal injection technology is being applied rapidly on blast furnaces throughout the world. Coal is favored for this use because of its lower delivered cost relative to natural gas and because it allows for higher injection rates. Current coal selection philosophies are based on nothing more than lowest delivered cost of coal to the blast furnace tuyeres. Little has been done to develop criteria for characterizing coals for this use. Coal petrographic means will need to be employed to formalize the coal selection process to ensure optimized coal costs and maximized operating efficiencies.

A new type of ironmaking facility is being developed that will totally eliminate the use of coke and will rely on coal as *the* reductant agent. Corex, the best known of these systems, is currently in operation on a pilot scale in South Africa, and on a 600,000-tons-per-year scale in Korea. Similar developments are underway in Japan, and the technology is being studied in the U.S. Since these operations are entirely coal based, requiring large volumes of coal, good coal characterization techniques will be crucial to efficient operation and to the production of quality iron. Coal petrography must play a role in this development.

There are a number of other coal-based technologies that await the right economic conditions to be revitalized and that will also require petrographic assistance to make them viable. Coal liquefaction, gasification, briquetting, and pelletizing come immediately to mind. Other applications are still to be identified, and could involve efforts to develop methods to upgrade in some way the vast reserves of low-rank coals in the Midwest, to expand their marketability and use.

Coal petrography has demonstrated its utility over a long period and will continue to be the analytical technique of choice for all applications requiring coal as a feedstock. We will rely on the current generation to maintain the spirit of the petrographic community and to provide the personnel needed to support these activities.

In closing, I would like to say that my 35 year association with the coal and coke community has been a joy. Due to the people involved and the nature of business, every day has been a good day, and the people that I have met along the way have been great.

Receiving the Gilbert H. Cady Award and being forever recognized with my peers is the highlight of my career. I cannot begin to thank all of those who helped me along the way, but I would like them to know that I will be forever thankful. I especially thank the selection personnel of the Coal Geology Division of the Geological Society of America for considering me for the award and allowing me to share it with my long-time friend and colleague Dick Thompson. Finally, I thank Bethlehem Steel Corporation for strongly supporting our coal- and coke-related efforts.

Response by RICHARD R. THOMPSON

It is a very special honor to be a recipient of the Gilbert H. Cady Award and especially to share it with Lou Benedict, my longtime colleague and personal friend. It also is an unexpected and humbling honor when one considers the list of distinguished past recipients and the longer list of active contributors to coal geology who have not received this award and who probably merit it as much as I do. I gratefully thank the Coal Geology Division for this significant recognition.

Doc Cady was well known as both a scholar and a gentleman, as so aptly described by many past recipients of this award. I knew him mainly as a gentleman, from his visits to Penn State as a consultant on a project concerning the petrologic study of anthracite coal. I remember his vigor and enthusiasm, his quick mind, and the friendliness and empathy he had for graduate students and their families. To me, Doc Cady was simply a special human being. His scientific contributions are known by all of us.

I was born and raised in Midland, Pennsylvania, then a town of about 5000 people and the home of the major plant of Crucible Steel Company. I mention this seemingly irrelevant fact because I am now the second recipient of the Cady Award from that small town, the first being John Ferm in 1991.

John and I didn't know each other well in Midland because we are separated by a few years (John is older). But we have become reacquainted over the years through his visits to Penn State and Bethlehem Steel, my visits to Kentucky, and other professional affairs.

My father was superintendent of the coke plant at the Crucible Steel plant and, after listening to his many trials and tribulations, I assured him that I would never work in the steel industry, as I headed for college to pursue a career in geology. After graduating from Antioch College and marrying immediately prior to that, I entered graduate school at Penn State, where I eventually earned a Ph.D. in carbonate stratigraphy and petrology. My goal then was university teaching, but when no appropriate position appeared at the time, I decided to stay in wait at Penn State, and I accepted the position of research associate at the Anthracological Laboratories, a job offered to me by Bill Spackman. That began my career in coal. I worked initially with Bill Berry and Lou Benedict on a U.S. Steel project and found myself among many friends, including Russ Dutcher, Jim Bayer, Alex Cameron, John Shigo, Dick Moses, and Phil and Jane Dolsen.

Bill Spackman clearly was the man most responsible for my career in coal. He made me feel at home in his laboratories, gave me responsibility and freedom to pursue ideas, and provided me worldwide exposure through the International Committee for Coal Petrology, the Gordon Conferences, the Geological Society of America, and other significant professional involvements. Bill also was on my doctoral committee and had the privilege to pose the first question on my comprehensives—a question I will never forget. Because I was in a descriptive science, he asked me to define a chair, a disarming start, to say the least. Next came the request that I define growth; this led to a lively committee discussion that, thankfully, gave me time to regain some composure.

Through Dr. Spackman's recommendation, I was employed at the Homer Research Laboratories of Bethlehem Steel Corporation in late 1962, thus negating my proclamation of many years before to my father. I was now in the steel industry. My initial job was to establish a coal petrographic laboratory and to develop the coal petrographic analysis as the primary tool for coal selection for the 30 coke oven batteries existing at that time.

A key person in my career at Bethlehem Steel was Robert P. Aikman, who managed the Coal and Coke Section until late 1976, and who was the person most directly involved in my employment. Bob was a strong supporter of coal petrographic research and was very knowledgeable about carbonization, having been one of the inventors of the Bethlehem 18-inch test oven. Bob promoted me to supervisor in 1965, at which time I essentially became his assistant. Together we planned all activities of the section until 1976, when Bob transferred to Steel Operations and I became manager of the Coal and Coke Section. My training under Bob served me well in the years ahead.

Finally, of course, there is Lou Benedict, my co-recipient. After joining Bethlehem Steel, I continued to communicate with Lou because of our mutual interest in the unusual behavior of certain vitrinitic macerals in the carbonization process. Lou had followed Bill Berry to Bituminous Coal Research, Inc., but I finally managed to lure him away in 1965. From that time forward we worked together to develop the Bethlehem system of coal petrology, and this relationship is evidenced by our many jointly authored publications. Lou then supervised the coal evaluation group from 1972 until 1983 and, in that capacity, had more direct input to the research program than I did. I am happy to report that Lou and I remain good friends today, and I am grateful that he continues to work to help support my retirement.

While I always tried to remain closely involved in the details of research, most of my personal time was devoted to the management of the Coal and Coke Section and later the Basic Studies and Raw Materials Evaluation Section. Perhaps my most important contributions related to the formulation and justification of research programs and the integration of the talents of personnel into those programs. Most helpful throughout my research career was the outstanding support provided by Bethlehem Steel. We were funded well for programs and equipment and had strong philosophical support, including a liberal publications policy. This support enabled us to attract and keep the outstanding people that we had in those days.

In 1982, raw materials research was reduced greatly at Bethlehem Steel in response to strong competitive pressures. I then was transferred to the Mining Department, which later became BethEnergy, the coal business unit. The BethEnergy part of my career not only utilized my research background, but called forth new or latent talents especially when addressing coal and coke marketing and sales. Someone once asked how I was able to make the transition from research to sales without sales experience. My reply was that I had excellent sales training in the Research Department, because I found it much easier to sell coal and coke to people who needed it than to sell a research program to a tough operator who didn't necessarily want it. Furthermore, I knew most of the technical people in the industry, and they are the folks who really make the basic purchasing decisions.

The other major aspect of my job with BethEnergy was to establish a Total Quality Management System for the coal mines and the Lackawanna coke plant. My challenge was to spearhead a new system for doing business which, in turn, required major cultural change in the organization. The success of this work was the development of a Total Quality Plan that was accepted by all of the facilities after four years of effort. The plan concentrated on continuous improvement of all processes by using statistical process control and other measurement tools.

Bethlehem Steel underwent great change over the life of my career. When I arrived, Bethlehem had more than 90,000 employees; now it has less than 20,000. It operated 30 coke oven batteries and 27 coal mines, and one steel plant alone used 40 or 50 individual coals annually to make coke. Now only two coal mines remain, and one of those is devoted totally to trade sales. Seven coke oven batteries are now operating, but two of those make coke for outside sales. All coke is now produced from only 10 or 12 coals, so one can see why the need for internal coal petrology and raw materials research has diminished.

During the peak years of the 1960s and 1970s, the coal and coke research program at Bethlehem Steel was wide ranging, covering coal evaluation and geology, carbonization and coke oven operation, coal mining and preparation, the behavior of coke in blast furnaces, new cokemaking processes, and environmental control. The Coal and Coke Section employed about 60 people at its high point, about one-half of whom were professionals. Basic research had a prominent position in the program, so that new information was continuously forthcoming. The technological information generated by that group not only contributed to the solution of the problems of those days, but still forms a basis for many of today's decisions.

Coal petrographic analysis remains vital to the steel industry for the selection of coals and coal blends, the monitoring of coal supplies, and the evaluation of mines supplying the coals. However, the research aspect of coal petrology is now a thing of the past in the American steel industry. Most companies have reduced or eliminated their internal petrologic capabilities and rely largely on the services of commercial laboratories to provide the information to meet immediate needs.

In spite of these changes, however, one cannot forget the major contributions that the industrial coal petrologists made to the steel industry and to the scientific community in general. Not only were coal blends and coke products improved, but much was discovered about the fundamental nature of coal and about its geologic setting. The techniques developed by these coal petrologists also continue to serve the petroleum industry and the characterization of the nation's coal reserves, and new applications are being developed in such areas as coal combustion and conversion in carbon-carbon composites.

Of all the aspects of my career, I will remember most the wonderful people of the coal and steel industries. The coal and coke researchers, in particular, were a small fraternity, a size that allowed us to know each other both personally and professionally. I am also grateful that early in my coal career I was able to know many of the true pioneers in the field, which provided a personalized historical perspective. But at the top of the list, I remember the people who worked for me and with me throughout my career as those who are really sharing this moment with me.

The professional coal petrographers who were employed at Bethlehem Steel at various times include Dr. Jack Crelling, Gary Mitchell, John Shigo, Harvey Zeiss, and Jack Rentschler. Of those people, only Jack Crelling and Gary Mitchell remain active in the field. Both were involved with basic petrographic studies at Bethlehem Steel, and both remain proponents of the Bethlehem coal petrographic system. At Southern Illinois University at Carbondale, Jack Crelling continues to promote the science of coal petrology in general and has made considerable personal effort to preserve the past coal petrographic data that were generated at Bethlehem Steel. Unfortunately, all of the polished specimens of coal, coke, and other carbon materials were discarded before they could be rescued.

Also deserving of recognition are the many outstanding carbonization people who generated the data so vital to our petrographic prediction systems. Particular mention should be made of the three supervisors of carbonization, namely Dick Wenger, Tom Conarty, and Jim Bayer. Dick and Tom remain in responsible positions at Bethlehem Steel, whereas Jim Bayer retired early in 1994 from his position as director of Coal Preparation and Quality Control for BethEnergy. Jim also has a strong background in coal petrology and, in fact, provided the incentive that led to our real-time study of the mesophase development in coking coals.

Finally, I am most grateful to my wife, Froy, who has shared the ups and downs of my career and who always has supported me when most needed. We now have been married more than 41 years, and I am glad that she is here today to share in this honor.

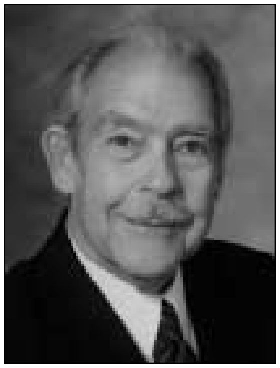
Throughout my career, I have tried to operate by certain principles, among the most important of which are integrity, the pursuit of excellence, high personal standards, and a concern for people. I firmly believe that Doctor Cady represented those same values throughout his lifetime. In that light, I am most happy to accept this award and I gratefully thank the selection committee and the Coal Geology Division of the Geological Society of America for this meaningful honor.

E. B. BURWELL, JR., AWARD

presented to

DONALD R. COATES and CHARLES G. HIGGINS

Citation by HELEN L. DELANO



Coates

Higgins

"The E. B. Burwell, Jr., Memorial Award will be made to the authors of a published paper of distinction which advances knowledge concerning principles or practice of engineering geology, or of related fields of applied soil or rock mechanics where the role of geology is emphasized." So goes the first sentence of the award criteria approved by the GSA Council in 1968.

The 27th Burwell Award goes to two eminent geomorphologists, Professors Charles G. Higgins of the University of California, Davis, and Donald R. Coates of Binghamton University (of the State University of New York system). The paper for which they are so honored is Special Paper 252 of the Geological Society of America, *Groundwater Geomorphology—The Role of Subsurface Water in Earth-Surface Processes and Landforms.*

Why did the Burwell Award Committee feel it appropriate for the editors of a geomorphology book to receive an Engineering Geology Division award? Engineering geology involves (or should involve) the application of the full range of available geological information to engineering projects. Geomorphology is particularly relevant to engineering geology because the two subdisciplines approach many of the same materials and settings from slightly different philosophical bases. This is not an original idea—Don Coates is one of a number of earlier proponents of similar thoughts—but it is an idea that deserves to be repeated every so often. Geology is a generalist science, drawing on other disciplines and applying them to the study of the earth. Similarly, engineering geology is a generalist field, drawing on various specialties within and outside of geology. It is useful for practitioners of engineering geology to be occasionally reminded of the merits of looking outside our own specialized literature of case histories, new mechanical testing procedures, and applications, to see the new developments of the rest of our science.

Groundwater Geomorphology is an outstanding compilation of information about the ways in which groundwater affects materials and processes at and near the surface of the earth. Some of the topics addressed include: hydrology, mechanics, and geomorphic implications of erosion by subsurface flow; the relation of subsurface water to downslope movement; piping (in both dry and humid lands); karst processes and landforms; spring sapping and seepage-induced cliff recession. Engineering geologists deal with these issues regularly and should be aware of developments in our understanding of them.

Some of the information in this book is available elsewhere, but it is not summarized for easy reference and is typically scattered in conference proceedings, specialty journals, and unpublished technical reports. This volume provides an easily accessible, concise reference and suggests a new way of looking at an important part of engineering geology. I found the discussions of seepage, sapping, and piping to be invaluable in helping me understand things I see on the Lake Erie bluffs in Pennsylvania. I think most engineering geologists can find similarly useful material here relating to their own work.

The Burwell Award is given *for* a publication, but it is also given *to* a person, or as in this case, to two people. Both Professors Higgins and Coates emphasized that all of the many contributors to the volume deserve to be included in the award. This may be true, as all have contributed to making the final product. But special recognition is due to the two editors, who saw the need for such a compilation, organized the other writers, and wrote or co-wrote 40% of the chapters.

Groundwater Geomorphology has a long history. I will leave the interesting details to its editors to tell, but will note that the book could not have come into its present form without the combined experience of its editors. In this sense, it is the product of two careers spent (among other things) developing ideas and expertise in the effects of groundwater on the surface of the earth.

Charles Graham Higgins is a native of Oak Park, Illinois. He received his geological education at Carleton College, the University of Chicago, and the University of California, Berkeley. He was a student of notable geologists, including Laurence McKinley Gould and J Harlan Bretz. He studied a limestone cavern for his master's thesis and the geologic development of part of the Russian River for his Ph.D. Most of Professor Higgins's teaching career was spent at UC Davis, where he continued research in geomorphology, including several facets of groundwater geomorphology—dissolution and deposition of carbonate rocks by groundwater, and spring sapping, piping, and seepage erosion—in settings ranging from California beaches to Mars.

Donald Robert Coates was born in Grand Island, Nebraska. He received his bachelor's degree from the College of Wooster, and his master's and doctorate from Columbia University, where he was a student of Arthur Strahler. Although he is probably best known for his many years of teaching glacial geomorphology at Binghamton and for his role as co-founder of the Binghamton Geomorphology Symposium Series, Dr. Coates has worn a number of other hats in his career. He was a project chief for the USGS Groundwater branch in Arizona for several years and has had an extensive consulting practice in glacial, groundwater, and engineering geology. He also has considerable editing experience, including the 1977 GSA Reviews in Engineering Geology series volume, *Landslides,* and several of the Binghamton Geomorphology Symposia volumes.

The Foreword of *Groundwater Geomorphology* tells of the various stages in the development of this project. A very abbreviated version is as follows.

His studies of sapping and piping led to Prof. Higgins's participation in the 1982 Binghamton Geomorphology Symposium "Groundwater as a Geomorphic Agent." This in turn led to collaboration with Don Coates and other authors on a chapter on landform development by subsurface water in the GSA DNAG volume on hydrogeology. The book for which we are presenting the Burwell Award is an outgrowth of that chapter, and of a symposium of the same title at the 1984 GSA Annual Meeting (11 years ago).

Our two award winners not only organized and edited the book, they wrote substantial parts of it. Professor Higgins contributed chapters on gully development and seepage-induced cliff recession and is a co-author of the chapters on piping and pseudokarst in drylands, and permafrost and thermokarst. Dr. Coates is author of the chapter on downslope movement and the concluding chapter on how geomorphology controls groundwater, and a collaborator on the permafrost chapter. I hope it is not an indication of the arduousness of the tasks that both of our authors retired from active teaching the same year the book was published. It may be an indication of their energy that it was prepared while they were teaching full time.

I congratulate Professors Higgins and Coates on a remarkable contribution to geological knowledge, *Groundwater Geomorphology*, and thank them for a profoundly useful book.

Response by DONALD R. COATES

A list of past recipients of the Burwell Award reads like a Who's Who in engineering geology. Unlike these predecessors, my part of the geologic landscape has tended toward geomorphology and hydrogeology. However, as a missionary of these fields I have always preached that these geoscientists must master a host of science specialties—physics, chemistry, mathematics, mineralogy, petrology, structural geology, and sedimentation, to name a few. Such subjects provide a proper springboard to launch into interdisciplinary studies. This broad spectrum of subjects has provided the flexibility to move where problems and opportunities are in the geosciences. In addition, I had the good fortune to become involved with environmental affairs starting in the 1960s. This background and fortuitous events helped pave the way for the preparation of our book.

There are two themes which for me are necessary in explanation of the book. The first and most immediate of these started in 1970, the year we at Binghamton established the Binghamton Geomorphology Symposium series. It was our goal to show that geomorphology was alive and well. The assembling of a distinguished cast of speakers allowed for a forum and in-depth discussions on a single topic of interest. I am happy to report that the 26th of these annual events was recently held at the University of Virginia.

The second theme that paved the way is of a personal nature. My work in hydrology at Columbia University under the guidance of Professor Arthur Strahler was very influential in setting the stage for my career. Also, three years spent in Arizona as party chief in groundwater with the USGS provided an indispensable background for knowledge of the many ramifications of underground waters. This was followed by 36 years at SUNY Binghamton, where I wore two hats, one as professor in the Department of Geology and the other as head of my geoscience consulting firm, Coates & Associates Inc. In the former capacity I taught courses related to hydrology and groundwater. My consulting firm engaged in more than 250 cases and 125 litigations with many projects that involved groundwater. These covered a broad range of assignments as with the U.S. Army Corps of Engineers on siting of the Cowanesque Dam in Pennsylvania to cases where artificial channelization caused accelerated erosion of river banks and losses to riparian properties.

I view much of this work as belonging in the field of geomorphic engineering or environmental geomorphology. In my 1976 book *Geomorphology and Engineering* I discussed the interrelationships of geology, geomorphology, and engineering. Speaking at the Second International Geomorphology Conference held in 1989 at Frankfurt, Germany, I stated, "Environmental geomorphologists are specialists who actively apply scientific principles to the solution of societal problems. Their projects take two basic forms: (1) those where natural surface processes affect installations and property, and (2) those where natural surface processes are being changed by human activity."

The discipline lines among the geoscience specialties have now become blurred. I view the projects that my firm has produced as often cutting across several areas of specialization. For example, our work on numerous gasoline spills and landfill sites required an eclectic knowledge that integrated many otherwise seemingly diverse disciplines. Several typical case histories are included in the two chapters I wrote for the book. They illustrate, for example, how the practical use of geomorphology can aid in the solution of societal problems. This type of documentation demonstrates the importance of geoscientist involvement with "real" world problems, and that society suffers when such expertise has not been sought or used.

I am sure that most of you could cite horror stories of what can happen when inadequate attention is given to geologic conditions at project sites. In my chapters in the book I present some personal case histories such as the following.

To aid in protection of the Binghamton region from flooding, 21 dams were constructed under the Watershed Management Protection Act of 1954. Construction of one of the dams was undertaken by Old Forge Construction Company, a firm located in the Adirondack Mountains, New York. Work began in April 1974, but unfortunately did not proceed on the planned time schedule. Numerous delays and equipment breakdowns occurred because the character of the soils and terrain was more formidable than had been predicted by their engineers. This resulted in large cost overruns to the company. I must parenthetically point out that civil engineers, not engineering geologists, were the design personnel for the project. By late May, the company was so aggrieved they brought a lawsuit to obtain additional funds from Broome County and the U.S. Department of Agriculture. They had not predicted discharge of springs into the wetland environment, or the character of the substrate, which consisted of nearly impervious till and muck soils. As an expert witness for the government, I showed that Old Forge had not made a geomorphic or hydrogeologic study of the site. Instead, the company had anticipated conditions similar to those in the Adirondacks, and believed the locale would be dry and underlain by sandy soils. As consultant to the governmental bodies I demonstrated in court testimony that the Broome County Soils Survey map had correctly identified the soil properties and, furthermore, that on-site soil borings had properly described the soil characteristics. It became abundantly clear that company engineers had not done their homework, nor utilized the available data. I emphasized to the jury that a competent earth scientist would have properly predicted the hydrogeologic conditions at the site. The jury dismissed the case with no compensation and said it was without merit.

The message is clear: geoscientists must be willing to "become involved," and they should not hesitate or shrink from the public eye in announcing how their capabilities can be used in societal matters. Such talents should not be hidden, and it is incumbent on the entire profession to mount a more aggressive and effective public relations program that documents the importance of these associations.

My relationship with the Engineering Geology Division began more than two decades ago and in 1975 led to my appointment as editor to produce a volume on landslides in the GSA Engineering Geology Review series. This resulted in the 1977 publication by GSA of the *Landslides* volume and the subsequent awarding of the Certificate of Merit from the Engineering Geology Division. I am extremely happy to be the 1995 co-recipient of the prestigious E. J. Burwell, Jr., Award. It is a delightful and much valued valedictory to my nearly five decades in the geology profession. Furthermore it is with great pleasure that I share this honor with my personal friend and colleague, Charles Higgins. It is with heartfelt gratitude that I now accept this award. Thank you all so very much.

Response by CHARLES G. HIGGINS

This award for our book is for us an honor that is as much deeply appreciated as it was unexpected, and we wish to share it with the 23 other authors. They are, alphabetically: William Back, Victor R. Baker, Thomas Dunne, D. J. Haggerty, Barry R. Hill, Alan D. Howard, J. A. A. Jones, Edward A. Keller, R. Craig Kochel, G. Mathias Kondolf, Julie E. Laity, André K. Lehre, Robert M. Norris, Waite R. Osterkamp, Arthur N. Palmer, Garald G. Parker, Jr., Troy L. Péwé, James M. Robb, Ruth A. M. Schmidt, Charles E. Sloan, C. Rowland Twidale, William B. White, and Warren W. Wood.

We also want to acknowledge five additional contributors to our earlier presentations of the groundwater geomorphology story, at our symposium for the 1984 GSA Annual Meeting in Reno and/or in Chapters 41 and 42 of the *Hydrogeology* volume in GSA's Geology of North America set: William E. Dietrich, Derek C. Ford, Helaine Markewich, Milan Pavich, and J. David Rogers (who received this award last year).

We are also indebted to an international team of 35 persons who reviewed chapters of the book as well as to the 15 who reviewed the abstracts for the Reno symposium. They are named in the Foreword to the book.

Further, because the idea for our series of presentations was, in effect, inspired by the 13th Annual Binghamton Geomorphology Symposium, "Groundwater as a Geomorphic Agent," presented at Rensselaer Polytechnic Institute in 1982, we wish to express our appreciation for the contribution of its organizer, Robert G. LaFleur, particularly because he asked me to cover both sapping and piping in my talk for the symposium and thereby made me learn more about piping.

We're also pleased to acknowledge the vision of William Back, who attended that symposium and planted another of the first seeds of our book at that time by asking me to organize and edit a section on groundwater in landscape development for the *Hydrogeology* volume that he and Paul Seaber were creating as part of GSA's Geology of North America project.

Finally, I am especially indebted to Don Coates. Early on, I asked him to help when it became apparent that the *Hydrogeology* volume would not provide the scope we needed to tell the full story of groundwater geomorphology and its significance in the development of the Earth's surface. Don unhesitatingly accepted, and his enthusiasm for the project, his long experience as an editor, his broad knowledge of groundwater processes, and his common sense and patience were essential to the completion of our project. When we commenced this odyssey, I was at the University of California, Davis, and Don was at the State University of New York, Binghamton. Ours was a long-distance collaboration.

Without the contributions of these individuals, you would not be honoring our book.

Subsurface water affects near-surface processes in a wide variety of ways in virtually all parts of the Earth, including drylands, tropical regions, the frozen Arctic, and even parts of the submerged continental borders. "Groundwater geomorphology" is the name we coined for a diverse group of studies of the effects of these waters, both above and below the water table, on the Earth's landforms.

Our book was at least eight years in the making, from my talk at the 1982 Binghamton Symposium to the book's publication in 1990. However, our understanding of the geologic processes involved has been much longer in the making, beginning in the 19th century, when visionary pioneers began to recognize the influences of groundwater in aspects of weathering, soil development, and slope failure, and in cold regions. Despite such early insights, though, the work of subsurface water has long been overshadowed in the literature by that of surface runoff. Indeed, from the outset, geological thought has been largely dominated by fluvialism, a doctrine which holds that subaerial erosion by rain and running water is the preeminent cause of regional denudation and landform development. This view became well established by the late 19th century and has hampered appreciation of the effects and importance of any agents and processes other than running water.

To be sure, most introductory texts in geology, geomorphology, and physical geography have long noted the importance of water in weathering, and most include discussions of groundwater corrosion and the formation of limestone caverns and karst, but their chief emphasis on groundwater is generally its utilization and hydrology. Some texts also discuss the role of water in slope failures or in subsidence caused by fluid withdrawal. Generally, though, there is much about running water, little about subsurface water. This failure reflects a continuing dominance of fluvialism in geological thought, but I suspect that it also owes much to the hidden or invisible nature of underground water. It is out of sight, out of mind.

My own awareness of this hidden water began when I was a child, spending summers on Lake Michigan and digging holes in the beach. There I discovered the cool, moist sand—in what I would now call the capillary fringe—that lies just above the surface of the underground water, and I learned that when I tried to dig below that water-table surface, sand would be carried in from the sides, refilling the hole and undermining its sides by a process that I much later learned to call "sapping."

When I was nine I visited and was impressed by Wind Cave in the Black Hills of South Dakota. Later, at the University of Chicago in the 1940s, I studied a cave in Missouri for an M.S. thesis under the direction of J H. Bretz, who had just published his monograph "Vadose and Phreatic Features of Limestone Caverns." Still later, I wrote about the caves of the Acropolis of Athens, and in 1963 attended the First International Speleological Conference in Greece, where I presented a field study of the "Cave of Nestor" near Pilos. At the time, I was in Greece to study coastal beachrock and try to discover where and how it becomes cemented by interstitial waters underground. While there I gained first-hand acquaintance with the Ghyben-Herzberg lens of fresh groundwater that underlies many coastal areas, and I observed some of groundwater's corrosive effects: nips and notches along protected calcareous coasts and the etching of mysterious solution pipes in some coastal eolianites.

Meanwhile, during field mapping in California, I had found an area where the modern drainage was developing by headwall retreat at springs controlled by buried Pliocene topography. That was my first experience of spring sapping. Then in the early 1970s, on some southern California beaches, I witnessed the development of miniature drainage systems created wholly by groundwater outflow during low tide. These observations led to my suggestion, at the 1974 GSA Annual Meeting in Miami Beach, that some much larger drainageways of Mars may have formed in a similar manner. I expanded these observations in a 1982 *Geology* paper, and that led to my presentation on the development of landforms by groundwater outflow for the 13th Annual Binghamton Symposium, which in turn led to the book honored with this award.

These experiences were my introduction to some aspects of the work of underground water, and the more I learned about it, the more I realized how important it can be. The 1982 Binghamton Symposium was a milestone in the recognition of the geomorphic importance of groundwater. Since then, Don and I have tried in our book and earlier presentations to provide a synoptic view of the many ways in which both near-surface and deeper subsurface waters can affect Earth-surface processes and the development of landforms—and vice versa. We have hoped, too, that in stressing the significance of water underground we have helped restore a balance in geomorphic and geological thought, which for too long has been dominated by fluvialism.

Another landscape-shaping process that was long ignored is downslope movement. The late C. F. S. Sharpe's book *Landslides and Related Phenomena,* published in 1938, awakened geologists' awareness of the importance of the gravity-driven processes involved. We developed our own book with the hope that it would do for subsurface water what Sharpe's book did for downslope movement, and we urge all who are involved in Earth study to realize that the unseen waters below may in various ways be affecting the Earth's surface and playing a significant part in its development. Recognition of these varied and hidden underground processes can provide fresh insights for interpreting and remediating the Earth and its surface.

Thank you all for honoring our efforts with the Burwell Award!

GEORGE P. WOOLLARD AWARD

presented to

WALTER D. MOONEY

Citation by Robert P. MEYER

It is with great pleasure and honor that, on behalf of the Geological Society of America, I present Walter D. Mooney, researcher and leader with the U.S. Geological Survey and consulting professor at Stanford University, as the 1995 recipient of the George P. Woollard Award. This award, presented yearly by the Geophysical Division, is given to a person who "contributes in an outstanding manner to the solution of a fundamental problem of geology through the application of principles and techniques of geophysics." Thus, today we honor two leaders, Walter D. Mooney and George P. Woollard. I have known each well. Walter came to Wisconsin from Cornell as my graduate student and I was a graduate student of George Woollard. I can, therefore, make some meaningful and relevant comparisons that shed light on the origin and significance of this award as well as on the latest awardee.

George Woollard considered life to be a gift with which to do something special. Without question, Walter Mooney thinks likewise. Walter has many more Woollard characteristics, e.g., he is a Renaissance man, having wide interests in several quite separate areas. He is gregarious, and able to gather and effectively work with large numbers of colleagues on a one-to-one basis, sharing fairly credit for achievement. More than 83 different individuals appear as coauthors in Walter's 85 publications. He is catalytic, causing things to happen and advances to be made.

Like George, Walter believes that if global geophysical data are thoughtfully collected in large quantities, it will assure a significant geological reward. Walter, against my advice, joined the Survey after his graduation rather than going into academia because, and I quote, "That's where the data are."

For George Woollard, an example of a large data-collection undertaking is his obtaining, with his Wisconsin students, gravity values on a 7-mile grid covering most of North America. This effort had many scientific rewards, including the discovery of the Precambrian North American Midcontinent Rift, a feature without surface exposure. For Walter and his colleagues, the data-gathering effort has been the collection and interpretation of thousands of kilometers of seismic profiles in the U.S., including Alaska, often at 100- to 500-meter seismometer spacing. Scientific results from these profiles include the identification of distinct crustal types correlating with tectonic provinces (e.g., arcs, extended crust, orogens) and the imaging of the crust in the San Andreas transform region and in the subduction regime of the Pacific Northwest, both regions of high seismic risk. These studies have also led to a better understanding of the physical properties of the Mohorovičić discontinuity.

Walter is an enthusiastic participant in numerous international geophysical projects. These undertakings caused him to enter the fray in the modern debate concerning the composition and origin of continental crust and the evolution of the lithosphere from the Archean to the present. This work has involved a global synthesis of crustal seismic measurements. To this end, his recent activities include negotiating for the release of thousands of kilometers of unique Russian "peaceful nuclear explosion" (PNE) refraction profiles and organizing their cooperative reanalysis. In China, he has undertaken the joint inversion of wide-angle seismic data from the Yunnan and Dabie Shan regions, the latter being the site of surface diamonds at the end of a major transform fault.

His successes include interpretation of: offshore-onshore seismic profiles crossing the region of subduction beneath Colombia, South America, and off the western USA that add to our understanding of subduction and transform plate boundaries; a long seismic refraction profile that reveals the deep structure of the Arabian shield and the remarkable thinning of the shield crust as the Red Sea is approached; and, with U.S., European, and Kenyan colleagues, refraction profiles of the Kenya Rift, providing insight into processes of rifting and uplift. These studies have increased our understanding of the evolution of continental crust from assembly to rifting, the latter stimulating and reviving interest in the driving force of plate motion. Both mentally and physically, Walter's science is an adventure sometimes worthy of a documentary! One that might be titled "A Night in Lake Turkana" would recount his unplanned swimming experience in this lake following a very close encounter with a 400-kg underwater seismic charge.

The speed and efficiency with which Walter carries out his scientific work is matched only by his enthusiasm for high-speed British sports cars. He is endeavoring to assure that the most stylish and the best of the British purebred cars, particularly the Jaguar, will be appreciated, used, and preserved. A future award might be a knighthood for services to the British motor industry.

If George Woollard were here today, he would remark, "Ah'm proud o' you, son." Let us echo his sentiments! It gives me special pleasure to present Walter Mooney to receive the 1995 George P. Woollard Award!

Response by WALTER D. MOONEY

Thank you, Bob, for those kind, if overly generous, words and for providing me with a greater appreciation of George Woollard. I got to know George in late 1973 when he returned to the University of Wisconsin for a period of several weeks. I can recall two talks he gave at that time—22 years ago this month—in which he gave a marvelous synthesis of the structure of the Pacific Ocean basin based on seismic and gravity data. I had just finished my Ph.D. thesis with Bob Meyer and I went through it carefully with Woollard, who showed great interest and patience with the work of a then young scientist 43 years his junior. Our next meeting was at the San Francisco AGU, where George came up to Bob Meyer and me just as we were engaged in a spirited (you could even say "heated") discussion of whether he (Bob) should sign my thesis as final, or whether substantial additions were warranted. As you can imagine, I was advocating the former, whereas Bob was enamored with the latter. George Woollard understood the nature of the discussion immediately, including the fact that I was already employed, by then, at the USGS and working on new projects. He turned to Bob and growled, "Sign the damn thesis, Bob." So you see, it is hard for me to separate George Woollard the distinguished scientist from George Woollard my patron saint. It seems to me that everyone I've ever met that had any significant contact with Woollard has a similar anecdote concerning his magnificent intervention on their behalf.

Bob has emphasized Woollard's belief that scientific data must be collected with sufficient areal distribution—ideally globally—for its true significance to be appreciated and correctly interpreted. Woollard set out in the early 1950s to make gravity measurements throughout the world, and time has certainly shown the wisdom of his approach. Woollard's global approach to science has been further impressed upon me by several other individuals. As an undergraduate at Cornell from 1969 to 1973, I was influenced by Jack Oliver, who, with Bryan Isacks and Lynn Sykes had published a paper entitled "Seismology and the New Global Plate Tectonics." This paper demonstrated simply and elegantly that the global distribution of earthquake hypocenters was consistent with what was called "the plate tectonics hypothesis." In the mid-1970s, Jack, together with Bob Meyer, Bob Phinney, and Milton Dobrin, went on to propose a global network of seismic reflection profiles, and together initiated the Consortium for Continental Reflection Profiling. Here again, these men advocated continent-wide surveys, with long transect lines. George Woollard would have approved. With the success of COCORP, more than a dozen countries followed suit, and today a semi-global distribution of seismic reflection profiles has been recorded, with great scientific benefit.

When I arrived at the University of Wisconsin in 1973, the global perception was still alive and well, with Bob Meyer leading field programs in Mexico, Colombia, and Peru, and Charlie Bentley leading the highly successful Antarctic program. Indeed, I can recall a period of 16 months when I only spent one week in Madison, Wisconsin, the remaining 68 weeks being spent in South America and Europe where I continued my scientific work and pursued my future wife, Jodi, who was studying music in Cologne, Germany. I should note that I was unconsciously emulating George Woollard by combining science with strong family interests.

I arrived at the U.S. Geological Survey in 1978 and was a little disappointed to discover that they expected me to be present in Menlo Park for more than one week per year, but I was very pleased to discover that collecting data in diverse geologic settings, including internationally, was encouraged. In fact, the first crustal seismic data that I had the opportunity to analyze were data collected by Jack Healy and others across the Arabian shield. My interest in the Precambrian Earth has continued to this day. Since then, I have had the privilege to pursue crustal seismology—both in data acquisition and data compilation—in such diverse settings as Kenya, China, Alaska, Mexico, Russia, and India. George Woollard would have been very pleased and impressed by the progress made in crustal seismology in the past two decades.

The theme that I emphasize here is the benefit that our science achieves from data acquired on a continent-wide and global scale. Geophysical work on such a grand scale requires a spirit of cooperation, both nationally and internationally, and here again I've been inspired by Woollard, who recognized that scientific collaboration, while occasionally requiring compromises, results in better scientific results. Furthermore, few of us flourish intellectually in isolation, and modern collaboration in geophysical investigations ensures that no one will begin to take his or her own ideas too seriously. There is always a colleague willing to point out the limitations of one's latest ideas. This, in turn, leads to the next round of conceptualizing and field experimentation.

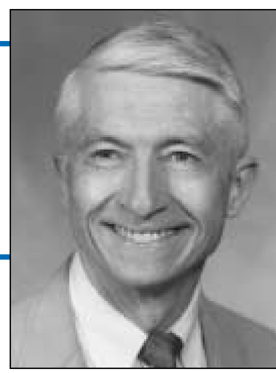
It is commonly observed that one has too many colleagues and associates to mention them all at an award ceremony. However, I think it is appropriate to reveal the names of at least a few of the guilty parties. The first, of course, are my parents, Martha and Vincent Mooney, who provided a rich and loving home. My wife of 18 years, Jodi, has always been a source of inspiration and continuing support. I can't imagine a more rich and diverse institution at which to work than the U.S. Geological Survey. At the Survey, I was encouraged and given my start by such fine scientists as Jack Healy, David Hill, and Lou Pakiser. My present colleagues, Harley Benz, Tom Brocher, Rufus Catchings, Jim Luetgert, Gary Fuis, Jill McCarthy, and Tom Parsons (to mention only those in crustal geophysics) have corrected my errors and encouraged my better instincts. Many distinguished colleagues at universities have provided stimulation, including Larry Brown, Bob Meyer, Nik Christensen, Randy Keller, Larry Braile, Dallas Abbott, Claus Prodehl, Karl Fuchs, and Aftab Khan. At Stanford, I have greatly benefited from my association with both faculty and students, and for this, and much more, I am grateful to George Thompson, Simon Klemperer, and Mark Zoback. In view of the time [allotted for this response], regrettably I am unable to mention many others, including especially my international collaborators.

Mr. Chairman, Bob Meyer, my dear friends, thank you for giving me this opportunity to honor George Woollard on this happy occasion.

HISTORY OF GEOLOGY DIVISION AWARD

presented to

ROBERT H. DOTT, JR.



Citation by JOANNE BOURGEOIS

Bob Dott has a long and distinguished career both in the geological sciences and in history of the geological sciences, and has earned respect and admiration in both geology and history of science communities. A short summary of his contributions in history of geology includes:

- Significant scholarly research in history of geology, including two edited books, some 20 journal articles, and numerous book reviews and editorials;
- Outstanding contributions to teaching history of geology, both as a separate subject and within geology courses, particularly through his pioneering and influential text, *Evolution of the Earth;*
- Thoughtful perspectives on the history of science, and on its place in geological and general science education;
- Important service to various history of geology organizations.

Bob Dott is the son of an eminent geologist (Robert H. Dott, Sr.), and academic offspring of a renowned stratigrapher, Marshall Kay (Columbia University). Raised in Oklahoma, Bob graduated from the University of Michigan, where he met and married Nancy Robertson, beginning a strong partnership and a large, scholarly family. The Dotts have also become extended family to many geology graduate students, including a number who are active in history of geology.

Receiving his Ph.D. in 1955, and after a brief stint in the petroleum industry, Bob began his academic career in 1958 at the University of Wisconsin as a sedimentary geologist. In the mid-1960s he revived the "History of Geological Thought" course taught before him by Stanley A. Tyler and also began research in the history of geology, publishing his first paper in the field, on James Hutton, in 1969. He has maintained strong ties with history of science faculty at Wisconsin, in particular with Robert Siegfried, with whom he has published work on Humphry Davy.

Bob's research in history of geology has focused on mountain building and on late-19th-century American geology. He has called attention to unique contributions from the American geological community, and to the influence of these ideas in Europe. Several of his papers treat the history of geosynclinal theory in America, as well as other aspects of the history of tectonics, of cratonic studies, and of eustasy. This latter interest led him to organize the highly successful 1990 GSA History of Geology symposium, "The Ups and Downs of Eustasy," the papers from which have been collected in a GSA Special Paper. Throughout this work, Bob has exemplified a non-Whiggish internal historian, bringing critical insight to bear on histories of geological investigations.

Probably Bob's most far-reaching contribution to history of geology is through his undergraduate Earth history text, *Evolution of the Earth,* published in five editions since 1971 (coauthored with Roger Batten, and most recently with Donald Prothero). Having myself experienced the prior generation of historical geology texts, I'm not sure those of you who didn't can understand what a breath of fresh air this text was. It replaced the "roll call of the ages" approach (a Larry Sloss term) with a conceptual approach, addressing the question, "How do we know?" rather than "What do we know?" The text is replete with examples from the history of geology, including original quotes, illustrations, poems, and cartoons—rather than just portraits of the "giants of geology."

Bob's philosophy of education, also reflected in articles and editorials over the years, is well expressed in the preface to the first edition:

> Our experience indicates that students are stimulated greatly by … exposure to scientific controversies, occasional spicy personal feuds or an amusing faux pas. The student also needs to become a partner in the endless process of hypothesis testing.…
>
> The historic elaboration of the development of basic principles for interpreting earth history … provides a proxy for the reader's actually recapitulating discoveries and interpretations accomplished by past generations that make up the fabric of geologic principles. Secondly, it helps to make clear that … science is a human activity, and that the quest for the understanding of nature is an on-going … process in which the reader … could participate. Finally, the historical approach reveals the cultural relationships of the science, which are unusually rich in the case of geology.

As a scientist, historian, scholar, and educator, Bob Dott is a worthy recipient of the 1995 GSA History of Geology Division Award. As one of the many students he has mentored, I take great personal pleasure in participating in the presentation of this award to Robert H. Dott, Jr.

Response by ROBERT H. DOTT, JR.

In anticipation of this honor, I asked myself, How did I get here? Not surprisingly, my parents had a lot to do with it, for both were very interested in history. One of my father's off-handed remarks when I was about to graduate from college made a lasting impression. He doubted that a person could fully understand his/her chosen profession unless they knew its history. A decade later, I left industry for academia largely because of a thirst for greater intellectual diversity, a trait also inherited from parents and my childhood in the university setting of Norman, Oklahoma. When I settled at Wisconsin, I had among many books from my father's library Von Zittel's *History,* Geikie's *Founders,* Merrill's encyclopedia of early American geologists, Fairchild's first 40 years of the GSA, and Clarke's biography of James Hall. To this list I had added, while a graduate student, Lyell's *Principles,* the Fentons' *Giants of Geology* and DuToit's delightful *Our Wandering Continents.* So when science historian Robert Siegfried came to my office on a proselytizing mission a few years later, I was ripe for his suggestion that I revive an old course on the history of geology. My subsequent associations with the faculty and students of the Wisconsin History of Science Department have been very rewarding and have helped me avoid that introversion by hyperspecialization which is in danger of overwhelming academia today and which I have fought against throughout my career. What a pleasure it has been to have a few geology students like Jody Bourgeois and Bill Jordan, as well as outside students, who share my interest in the history of geology. The outsiders have included Dennis Dean, Julie Newell, Beau Van Riper, and Susan Schultz, among others. I thank them all for their stimulation, as I thank the Division for the honor it has given me. It is particularly nice to receive this award from my longtime friend and colleague, Bob Ginsburg.

Five years ago, I had the pleasure of presenting the same award to Gordon Craig, James Hutton Professor of Geology of the University of Edinburgh. In his witty response, Gordon presented ME with a copy of handwritten notes by Charles Lyell for a "Lecture No. 9 for Philadelphia, March, 1842." My curiosity was piqued because Lyell's published New York lectures numbered only 8. What did this "extra" lecture mean? When a blizzard closed my university unexpectedly a few months later, I decided to transcribe the notes just for fun. With help from other cryptographers, I soon had a fair copy containing such interesting items as quotations from John Milton's *Paradise Lost.* And so I convinced myself that this "unknown" lecture might deserve publication. But I faced the problem of schizia shared by many members of the Division—it is very difficult to fit an historical hobby into a full geology teaching program. And so the project languished.

Then in 1994, I retired from teaching in order both to have more time for history and to create an opening for a young, aspiring scholar in the present, dreadfully restricted academic market. I decided to take as my first retirement project the completion of the Lyell study. During his first visit to America in 1841–42, Lyell had lectured three times—at Boston, Philadelphia, and New York. The New York lectures had been published immediately, so I decided I should find out something about the Boston and Philadelphia offerings. At the 1994 San Diego Penrose Conference on the history of geology, I had met Earle Spamer of the Academy of Natural Sciences in Philadelphia, and I asked if he might give me some leads. He soon E-mailed that there was both good news and bad news. The good news was that he had found two newspaper accounts, but the bad news was that there had been 12 rather than 9 lectures! Meanwhile, my own search of 1841 Boston papers soon confirmed that there had also been 12 lectures in Bean Town. The supposed importance of the notes for Lecture No. 9 suddenly seemed to evaporate!

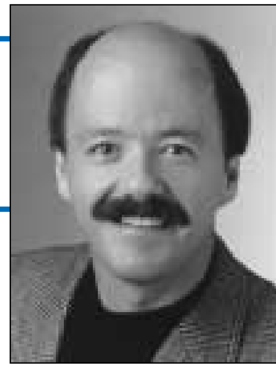
I tell this story on myself in order to draw two morals. Number 1 is do your homework thoroughly before rushing to speak or write. As Michelle Aldrich admonished when she received the Division's award 3 years ago, we internalists must do our historical scholarship as thoroughly as we would our scientific research.

I was on the verge of abandoning my Lyell project with the satisfaction that, at least, it had provided fun and further experience in reading poor microfilms, an art to which I had been introduced in the 1970s by my historian friend Robert Siegfried, when we collaborated in the editing of Humphry Davy's geology lectures. Moreover, I had vowed 30 years ago never to get involved in either the Lyell or Darwin industries because I felt that, relatively speaking, those two were over-studied in contrast to many other important geologists—the foot soldiers, so to speak. During a winter visit to Minneapolis, however, historian Leonard Wilson, a leading Lyell scholar, urged me to expand my investigation to encompass all of Lyell's three American lecture series given between 1841 and 1852. Accordingly, I took advantage of Leonard's generosity in making available his extensive Lyell archive, and I resumed reading microfilms. Historian Robert Silliman of Emory University, who has been working on Lyell's interactions with American geologists, also provided encouragement and valuable feedback. Consequently, thanks to such fine cooperation from historians, I expect to have a much different manuscript covering all of the lectures and travels in America in time for the Hutton-Lyell Bicentenary in 1997.

And now for moral number 2. I present this confession in order to reemphasize a point I made in an editorial a few years ago about the problem of "two separate cultures" in the study of the history of geology. The second moral is that internalist geologists and externalist historians need each other. The trained historian brings a perspective richer than most scientists possess of the broader historical contexts of science as well as a keener sense of historical research techniques and standards of historical scholarship. The historian can help us avoid the common fallacies of hero glorification and the writing of Whig or presentist history in which ideas seem to have evolved smoothly and inevitably to a present, revealed "truth." Conversely, the practicing scientist should possess a deeper insight into nuances between the past and present practices of a science, which are like land mines for the unwary. For example, old terminology still in use generally takes on subtly different meanings as a science matures, and one who is naive about those differences can make serious errors. Obvious examples include the nineteenth century versus present meaning of "Silurian," application of the term "facies" to metamorphic as well as sedimentary rocks, the modern versus earlier meanings of "grauwacken," and the difference between Ampferer's meaning when he coined the term "zone de subduction" and our present usage of that term. Perhaps less obvious are the potential pitfalls of comparing geologic maps of the same area but of different vintages without a full appreciation of subtle changes that had occurred in the interim both of cartographic conventions and the even more subtle fashions of geologic mapping of structure and stratigraphy. Much more serious, however, is a trend in the history of science profession to leave out the science and to focus entirely upon the social, political, and philosophical relationships of the scientists. Does this mean that only we internalists will be doing the science history in another decade or so?

It is regrettable—if inescapable—that our two clans are centered in such different academic settings with widely differing customs for publication and professional meetings. All of this creates formidable barriers to communication, which I admonish everyone to try to surmount. The healthy mix that we have in our History of Geology Division as well as in the recent Penrose Conference and the INHIGEO symposia every few years certainly helps to ameliorate the separation of cultures, but each of us could do more. You may not be so fortunate as I am to have access to a department of the "other type," populated by congenial colleagues, but at least you could start by taking your "cousins" to lunch more than once a year at the GSA meeting.

O. E. MEINZER AWARD
presented to
GRANT GARVEN



Citation by CHRISTOPHER E. NEUZIL

I am quite pleased to be the citationist for Grant Garven, the winner of the O. E. Meinzer Award for 1995. The Meinzer Award recognizes scientists whose papers have significantly advanced hydrogeology. Grant has had a profound influence on hydrogeology both directly and as a mentor of several talented students, making him particularly deserving of this year's award.

Grant grew up near Regina, Saskatchewan, a pleasant little city on the plains of western Canada. For those of you not familiar with Canadian geography, Regina is about 40 miles east of Moose Jaw. Now, I must emphasize that this is actually an amazing coincidence, because Grant is *the second* Meinzer Award winner with connections to the Regina area. The first is John Cherry who, I understand, moved to Regina as a teenager. As many of you know, John received the Meinzer Award in 1985. One wonders whether there is something in the water up there.

Grant received a bachelor's degree in geology from the University of Regina. While an undergraduate, he did field work in the Williston Basin and the Canadian Shield. During this work, Grant spent a lot of time in the field, looked at lots of outcrops, and really got to know the rocks. Thus, even though Grant doesn't have that much time to look at actual rocks any more, we can surmise that he still remembers what they look like.

In pursuing a master's degree in hydrogeology, Grant sought to work under Stan Davis at the University of Arizona, and later did research under Joe Tóth, who was then at the Alberta Research Council. As many of you know, Stan was the Meinzer winner in 1989, and Joe won the very first Meinzer Award in 1965. Then Grant met Al Freeze, and ended up pursuing a Ph.D. under Al at the University of British Columbia. Al Freeze is, of course, the 1974 Meinzer Award winner. It almost appears that Grant winning the Meinzer Award was foreordained.

Since 1982 Grant has taught hydrogeology at Johns Hopkins. In that capacity he has mentored a select group of highly successful students. Among them are Mark Person, who teaches at the University of Minnesota; Shemin Ge, who teaches at the University of Colorado; and a more recent graduate, Jeff Raffensperger, who teaches at the University of Virginia.

I believe that a very important part of my task is to briefly mention Grant's work and why his papers are being recognized today. There is growing awareness that fluids in the subsurface, particularly groundwater, play a very significant role in geologic processes and the evolution of the crust and that the reverse is also true; that is, geologic processes often profoundly influence groundwater regimes. This idea is not new. However, I believe that the variety and profound significance of such interrelationships is only now entering the thinking of many earth scientists.

It is in this realm that Grant has worked. Specifically, he is being recognized today for his work on groundwater flow regimes that are thought to have emplaced certain types of ore bodies. Hydrogeologically speaking, these problems entail a particular difficulty: they involve flow at regional scales occurring in the geologic past. Hydrogeologists in the audience know how difficult it is to characterize modern flow systems. The problem that Grant and others tackled, which requires attempting to reconstruct paleohydrology, is much harder. (On the other hand, some argue that analyzing paleoflow systems is relatively easy because there are fewer data to mess up one's conceptual model.) In any event, there is a lot of uncertainty about the geologic framework, boundary conditions, and hydraulic properties. Despite the uncertainties, I believe that efforts exemplified by Grant's work are beginning to shine some light on this aspect of Earth's history.

Grant is being honored here for three papers:

The first paper, "Genesis of Stratabound Ore Deposits in the Midcontinent Basins of North America" was published in the *American Journal of Science* in 1993. It was authored by Grant, Shemin Ge, Mark Person, and Grant's colleague at Johns Hopkins, Dimitri Sverjensky. This paper examines the genesis of Mississippi Valley–type (or MVT) lead-zinc ore deposits in the U.S. midcontinent; it shows that topographically driven groundwater flow could have delivered the chemical mass and heat required to create these deposits. The contribution of this paper, as I see it, is its comprehensive examination of the paleohydrology of a very extensive region through a long and rather complex geologic history.

The second paper, "Hydromechanical Modelling of Tectonically Driven Groundwater Flow with Application to the Arkoma Foreland Basin," was published by Shemin Ge and Grant in the *Journal of Geophysical Research* in 1992. This paper represents a further step in exploring the coupling between geologic and hydrogeologic processes. It analyzes the effect on fluid flow of tectonic squeezing and mechanical loading by thrusting. Using an extreme case of instantaneously applied tectonic stress and load, Shemin and Grant showed that while such effects could strongly alter the flow regime, they were unlikely to deliver the chemical mass and heat needed to generate ore deposits. They concluded that the so-called "squeegee" effect, which had been proposed some time earlier, was an unlikely mechanism for creating ore deposits.

The third paper, "A Sensitivity Study of the Driving Forces on Fluid Flow During Continental Rift Basin Evolution," was published by Mark Person and Grant in the *Geological Society of America Bulletin* in 1994. In this paper, a geodynamic model of rift-basin evolution was used as the basis for examining the groundwater flow over time in a rift basin. Mark and Grant concluded that ore deposits associated with rift basins probably result from topography-driven flow, rather than density- or compaction-driven flow. This paper is notable for its integration of geodynamic and hydrodynamic models to explore processes in these poorly understood hydrogeologic regimes.

Our understanding of the role of groundwater flow systems in geologic processes has taken a step forward with these papers, making Grant Garven certainly deserving of the 1995 O. E. Meinzer Award.

Response by GRANT GARVEN

Thank you, Chris, for the kind citation and introduction. This is at least the second time you've performed the citationist role—maybe you ought to start charging a fee for your service!

I am indeed honored to receive the 1995 O. E. Meinzer Award. Thank all of you very much for this great recognition of the work we have done at Johns Hopkins University. I was thrilled to receive the news, as were my co-authors on the cited papers.

It is traditional to use this time at the podium to acknowledge one's family, research mentors, former students, colleagues, and institution for paving the way for success. I do this with great enthusiasm.

I was particularly rewarded when my mother Jean surprised me with the announcement that she bought an airline ticket and GSA luncheon ticket for New Orleans so she could attend this ceremony. Mom came all the way from Regina, Saskatchewan, to watch me receive the Meinzer Award. My mother has always been there for me in times of triumph and trouble throughout my life—I am delighted she is here today.

One of the first questions my mother asked when she learned I was receiving an award this year for my work in groundwater geology was: who was O. E. Meinzer? I responded with the usual reply that he was considered by many to be the founding father of hydrogeology in North America and was best known for his pioneering studies on the elastic response of confined aquifers. But I'll have to confess that I really didn't know much more about Meinzer, other than the fact that Chris Neuzil's office in Reston, Virginia, housed Dr. O. E. Meinzer's original drafting table/desk. For those of you who have not visited Chris's office, it is not a Smithsonian-type shrine. Nevertheless, I've always been impressed by the fact that O. E. Meinzer's table is still in active use (piled with research papers and materials, of course, as Meinzer probably would have wanted it). By the way, Meinzer retired as the USGS Geologist in Charge of Ground Water in 1947, so his office furniture has been in use for at least 80 years—an amazing record!

My second confession to my mother was that I really didn't know a lot about the origin of the O. E. Meinzer Award except that it was given annually, and that it had been given to dozens of hydrogeologists over the years, including a few Canadians like myself. Somewhat embarrassed by my poorly informed answer, I felt compelled to do some research on the subject before today's meeting.

It was 30 years ago that the newly founded Meinzer Award was presented to a young hydrogeologist from Canada, Dr. József Tóth, at the Annual Meeting of the Geological Society, November 4–6, 1965 in Kansas City, Missouri. Phil LaMoreaux, the 1963 Division Chair, is credited for spearheading the drive to honor O. E. Meinzer and appointed S. W. Lohman the task of formulating the ground rules and drafting the award—a suitably inscribed certificate. Kudos to LaMoreaux and Lohman. Their unselfish effort is the reason why I'm privileged to stand here today.

The 1960s were exciting times for hydrogeology. Our GSA President David Stephenson received his Ph.D. degree in 1965 at the University of Illinois. The fascinating work of Hubbert and Rubey on the role of pore pressure in geologic faulting was still being strongly debated in the GSA *Bulletin.* Joe Tóth had completed his benchmark articles on the theory of groundwater flow in drainage basins. Allan Freeze had recently completed most of his theoretical and field work with Paul Witherspoon on regional groundwater flow. Much of their thinking is intertwined with my own contributions related to continental-scale groundwater flow in geologic basins. I also owe much to the pioneering efforts by John Bredehoeft, Bill Back, Pat Domenico, Bruce Hanshaw, and Jack Sharp, who first demonstrated and quantified the important role of groundwater in geologic processes. All of them are Meinzer scholars, and I feel privileged to join them on this honor roll.

So that's the history lesson for today. I might add that a number of Canadian hydrogeologists have won this award before—in fact the Meinzer Award Committee has recognized Canadian authors on a regular basis in 1965, 1974–75, 1984–85, 1995. Perhaps it's some sort of Milanković cycle thing associated with North American hydrology.

My interests in hydrogeology date back almost two decades now, as noted by Chris, and if you can bear with me a little longer I'd like to say a few words of acknowledgment on behalf of the people who have helped me fulfill the research goals for which I am being honored today.

I probably would not be standing here had it not been for academic serendipity. Although my primary interests in geology were born out of curiosity about underground water from the family farm in Saskatchewan (my mother always feared her sons would fall down one of the many abandoned wells on the farm), the idea for pursuing graduate studies in hydrogeology came from my undergraduate geology advisor at the University of Regina. Laurence Vigrass introduced me to his fascinating work on the hydrodynamics in the Williston Basin in the mid-1970s and encouraged me to seek out an American hydrologist that he knew at Stanford University . At the time I spent most of my summer days working as a field geologist in the Canadian Shield under the tutelage of Bill Coombe. Bill cultivated my early interests in hydrothermal ore deposits. More importantly, I met another geologist in the Canadian north, Audrey Curry. We were married in 1977 and now live in Towson, Maryland, with our three young children, Elaine, Glenn, and Ellen. The hard work of Audrey and the tolerance of my family has enabled me to roam the world and pursue the research for which the Meinzer Award is being made today. I'm so grateful for their continual support.

Eventually I tracked down Laurence Vigrass's colleague, Stanley Davis, who had recently taken up the position of professor of hydrogeology at the University of Arizona. I went to Arizona and completed a master's degree in hydrology in 1980. Although Stan had encouraged me to pursue research related to groundwater production and subsidence issues in the alluvial basins of southern Arizona, I set my sights north to cooler climates! In 1978 Joe Tóth invited me to join his groundwater division at the Alberta Research Council as a summer intern and research assistant. How fortunate. Thus began my multiyear study of the Pine Lake watershed in central Alberta, near the original field area cited in the first 1965 Meinzer Award to Joe Tóth.

Another great event happened at the University of Arizona. I met Allan Freeze during one of his sabbatical visits to Tucson. Al persuaded me to follow him back to Vancouver and initiate a Ph.D. research project with him that would build a bridge between workers like himself in groundwater hydrology and geologists interested in processes such as hydrothermal ore formation, oil migration, and basin faulting, to name a few examples. Chris has detailed my recent contributions to the hydrogeology of sedimentary basins. Suffice it to say the past 15 years have been wonderful, and with the help of my students I continue to explore the role of groundwater in geologic processes. My research today spans the hydrogeology of carbonate-hosted ore formation in Missouri and Ireland, the nature of overpressuring and sandstone diagenesis in central California, and the hydrodynamics of submarine fluid flow in archipelagic aprons near Hawaii.

Besides having the opportunity to study with an olympic "dream team" of research mentors—Tóth-Davis-Freeze—who have helped open doors for me all along my career path, I've been blessed with many close colleagues at Johns Hopkins University, my employer since leaving graduate school at the University of British Columbia. Professor Reds Wolman persuaded me to join his Department of Geography and Environmental Engineering (a.k.a. "DOG-EE") in 1982. Hopkins is a great university for hydrology and geology, much of this reputation being attributed to special scholars like Reds Wolman. Thank you, Reds, for being such a wonderful colleague and for not pressing me too hard to jump onto the bandwagon of environmental hydrology. Two other Hopkins colleagues, Dimitri Sverjensky and Hugh Ellis, have provided the intellectual support for my work over many years. I'm grateful for their friendship and guidance.

Last but not least, I owe a debt of gratitude to my graduate students. The cited papers for this year's Meinzer Award include the names Shemin Ge and Mark Person. Shemin Ge now teaches at the University of Colorado and Mark Person at the University of Minnesota. Both studied with me during 1985–90 and have since gone on to distinguish themselves in hydrogeology careers of their own. Another more recent graduate student, Jeff Raffensperger, is here today, and I am equally proud of his academic achievements at the University of Virginia. Probably no greater reward can be made to a teacher than to see his students prosper in science. I have indeed been rewarded by their success.

Thank you all again for honoring me with the 1995 O. E. Meinzer Award.

G. K. GILBERT AWARD
presented to
BAERBEL KOESTERS LUCCHITTA

Citation by EUGENE M. SHOEMAKER

It is a special pleasure to present Baerbel Koesters Lucchitta for the Gilbert Award. The great breadth of her interests and scientific contributions mirrors the breadth of Gilbert himself; her scientific career has unfolded in the same organization for which Gilbert served as the first Chief Geologist—the Geologic Division of the U.S. Geological Survey. She can fairly claim to be a direct intellectual descendant of Gilbert.

Little Baerbel Koesters lived in Weimar in eastern Germany during the waning days of World War II, not far from infamous Buchenwald. She had some hair-raising experiences as the area was occupied first by American and then by Soviet forces. Ultimately, her family fled to the West, where she remembers a happy childhood playing in the bombed-out ruins of Muenster. A bright student with a very strong classical training in languages, she entered the University of Muenster, where she studied both "old English" and geography. A Fulbright scholarship enabled her to come to Kent State, Ohio, by which time she had switched her focus from geography to geology. Fortunately, she graduated at Kent State before the student upheavals of the mid-1960s. She was attracted to Penn State for graduate work by the presence there of P. D. Krynine, famous for his claims (only moderately exaggerated) that you could read the geologic history of a terrane from the petrology of a sandstone.

After she arrived at Penn State, Baerbel switched to structure and tectonics, because a grant was available to support a thesis. This led to her first brush, all unaware, with astrogeology. She mapped a part of the overthrust belt near the southwestern border of Montana. There she saw and described peculiar conical fracture surfaces decorated with horse-tailing lineations. Alas, neither her advisor nor anyone on her committee told her what they were. Mind you, this was at Penn State, one of the few academic institutions, at that time, where there was a strong interest in impact craters. Two decades later, the shatter cones of the Beaverhead structure, the largest known impact structure in the United States, were rediscovered by Rob Hargraves while searching for gold prospects in the heart of Baerbel's thesis area.

An event that ultimately brought Baerbel into planetary geology was her marriage in 1964 to fellow Penn State student Ivo Lucchitta. After Ivo was offered a job in the Surface Planetary Exploration Branch of the USGS, Baerbel and their daughter, Maya, came to Flagstaff to be with him in 1967. Baerbel, with her newly acquired Ph.D., was offered the princely position of a GS-7 Physical Science Technician by the Branch of Astrogeology. (This, as you will have noted, was before the days of Affirmative Action and Equal Employment Opportunity.) She quickly rose, however, from photoclinometric studies of potential Apollo landing sites to geological investigations of the North Polar region of the Moon and the Apollo 17 landing site, as a full-fledged geologist (GS-11).

It was Baerbel's involvement with Apollo 17 and her characteristically thorough study of the geology of the site that led to some of her most enduring contributions to lunar geology. She very early recognized the genetic relationship between the dark mantle deposit in the floor of the Taurus-Littrow Valley and the more extensive dark mantle deposits of the Sulpicius Gallus Formation on the other side of the Serenitatis Basin. After the mission, she published her famous paper with Jack Schmitt that identified orange and red, as well as black, pyroclastic material in the Sulpicius Gallus Formation, thus linking the origin of these vast deposits (and others like them elsewhere on the Moon) to the laboratory results obtained from the Apollo 17 samples of the orange soil. Moreover, the geologic relationships of the Sulpicius Gallus unit showed unequivocally that the deposits were pyroclastics and not produced, as some people thought, by impact splash in a puddle of molten mare basalt.

Another major contribution was Baerbel's identification and proof of the occurrence of Tycho secondary craters and secondary deposits in a swath across the Apollo 17 landing site. This enabled a firm date to be established for Tycho from the Apollo 17 samples, which, in turn, provides a key datum for the cratering history of the Moon. I use the age of Tycho and the density of superposed craters on the Tycho ejecta blanket as one of the linchpins in the argument that the cratering rate in the Earth-Moon system has increased, perhaps by a factor of two, late in geologic history, a result that carries implications for the rate of comet impact and the history of the z-oscillation of the Sun in its travels around the galaxy.

From her careful study of the mare ridge and related scarp in the floor of the Taurus-Littrow Valley, Baerbel showed that this feature and related ridges and scarps can be produced by offset on nearly vertical faults, a result still not fully appreciated by students of mare ridges. She also thoroughly examined the ages of graben around Serenitatis and other basins and showed that they formed after the emplacement of the older mare lava but before the youngest lavas of the basins. This ties the circumferential graben to the episode of lithospheric bending on basin margins during loading of the basins by the mare fill.

The next major extension of Baerbel's scientific horizons occurred when she was assigned as an observer during the Mariner 9 mission in 1972. This inaugurated her long and continuing involvement in the land forms and surface processes of Mars. Unlike some of the rest of us, Baerbel's favorite holes in the ground are not craters but the various valleys of the Valles Marineris. With the aid of the Viking images, she has probably spent more time "peering" into the Valles Marineris than anyone else. She was early intrigued by the giant landslides originating on the valley walls, and she has argued, I think convincingly, that they were lubricated by ground water. She has also been responsible for identifying various volcanic deposits on the valley floors, including diverse light-colored flows as well as young dark patches, very likely formed by pyroclastic outbursts, that are aligned along faults. She has shown that the great Marineris rift valley developed in multiple stages and had a prolonged history of evolution.

Elsewhere on Mars, Baerbel has focused on the abundant evidence for ground ice and on the role of ice or ice-lubricated flow in the sculpting of the terrain. She showed how ice-facilitated flow probably shaped the fretted terrain and may have formed rock glaciers on the Martian volcanoes. Always willing to challenge accepted wisdom, she has championed the flow of ice as a primary agent of erosion of the huge outflow channels on Mars. By careful attention to scale and to the detailed features of the channels—longitudinal grooves, hanging valleys, the forms of the islands—she has made a strong case. Before you jump to the conclusion that the channels were all formed by giant floods, you had better read her papers. Perhaps the truth lies somewhere in the middle—a combination of both floods and ice shoving (which is what she really suspects).

When the Voyagers flew past Jupiter, they opened another chapter in Lucchitta's career, as they did for so many of the rest of us. She became the guru of Europa and the mother superior of Ganymede geologic mapping. Her description, with Larry Soderblom, of the geology of Europa remains the standard reference. She published the first detailed description of the grooved terrain on Ganymede and recognized that it was formed by replacement of the old cratered terrain. She also documented evidence for lateral displacement in the grooved terrain. She later did an outstanding job of managing the program of systematic geologic mapping of Ganymede.

In 1982, Baerbel planted one foot firmly back on Earth—in Antarctica. She does not regard her work on the Antarctic ice sheet as planetary geology, but I do. Earth is a planet, and the areas of blue ice she defined as a part of her mapping project of Antarctica from Landsat multispectral images are the key collecting areas for meteorites. Undoubtedly, there was synergy between her study of Antarctic glaciers and her continuing work on the role of ice in the evolution of the Martian landscape.

Lucchitta was chief of a project that produced very popular multispectral images of Victoria Land, Marie Byrd Land, the Antarctic Peninsula, and special maps of selected quadrangles and ice streams. By analyzing crevasse patterns, she realized that the velocities of outlet glaciers could be measured, and she successfully promoted an international campaign to reacquire Landsat images over Antarctica. She measured the velocities of numerous glaciers from the displacement of the crevasse patterns and, in some cases, documented accelerations. She found that the tongues of glaciers draining the West Antarctic ice sheet are moving significantly faster than those in East Antarctica. These observations may be relevant to the possible breakup of the West Antarctic ice sheet.

After 28 years with the USGS, Baerbel elected to retire this year along with her husband, Ivo. In fact, she came to receive this award straight from Cancún, where they were exploring the ruins of Yucatán. But is she really going to abandon planetary geology? When the Galileo images of Europa come in, I'll bet that you know who is going to be there. Madam Chairperson, I proudly give you Baerbel Lucchitta for the G. K. Gilbert Award.

Response by BAERBEL KOESTERS LUCCHITTA

Thank you, Gene, for these gracious words, and thank you, Planetary Geology Division, for presenting me with the G. K. Gilbert Award. I am very honored. In fact, I was stunned when chairperson Odette James informed me that I was to be the recipient of the award. I could not comprehend why I should have been chosen, when there are so many more deserving candidates. Was it that I am one of the old-timers, who started out by researching the Moon? Was it that I just officially retired from the government, even though I have no intention to quit research? Was it that I am a woman, and no female has yet been so rewarded? Was it that I have been active in the Planetary Geology Division for several years? Or was it that somebody actually did appreciate my scientific contributions? I like to think that perhaps it is a combination of the above. Even though my papers may not have been of earth- or, rather, planet-shaking importance, when I look back, perhaps I did contribute something to the understanding of the Moon, Mars, the Jupiter satellites, and even the Earth. And I am proud to be a field geologist of sorts in the planetary program, where my contributions are mostly based on careful inspection of the images returned by the missions and on subsequent mapping of subtle relations that are otherwise readily overlooked. I am proud that I always strove to place observations first and interpretations and models second, even though we are all subject to bias governed by our experiences. And of course, as many of my predecessors in this award expressed, I was extremely lucky by falling into a part of history when the space program was in full swing and anything one noticed on another, newly encountered planet was bound to be a discovery.

As the first woman recipient of this award, I will take the liberty to look back in a personal way upon my path as a woman in science, and upon the obstacles and rewards and occasional humorous encounters I had to face as a woman. But first I want to acknowledge the many men and women who helped in my career. These include my parents, a geologist husband, university professors, colleagues, assistants, secretaries, and students. There are so many, I cannot mention them all by name.

As Gene mentioned, I grew up in war-torn Germany. My first encounter with Americans was terrifying. They came in the sky, silver with planes, dropping bombs. But then, 50 years ago on a beautiful spring day (Armistice Day), the future seemed suddenly bright and life secure. The American occupation soldiers became our friends and freely dispensed a sweet white substance from small gray cartons. It was called "soogaar" (sugar), my first English word. Eventually, I swore to myself I would go to America and partake in those riches. Adventure stories were my favorite literature as a child, and I suppose my appetite for travel, exploration, and finding-out stem from that time. I resented being a girl, partly because I sensed that exploring distant worlds would be more difficult for a girl than for a boy, but mostly because in those days of limited toilet facilities, boys had a distinct advantage. Schooling was in all-girl schools, which fostered individual development, unencumbered by male competition. From amongst many interesting sounding disciplines ending in "—ology," I eventually chose geology as having the prospect of actually making some money. After I finished high school, the cozy unisex atmosphere was quickly dispelled, and reality, including societal pressures, set in: at the university, males aggressively dominated the classes and totally intimidated me. My mother, Fridel Koesters, a very intelligent woman who only wished for the best, nevertheless strongly recommended that I become a grade school teacher, just to have a profession to fall back on in case my future husband died. She was certain I would get married to a wealthy man. My father, Bernhard Koesters, an architect, actively supported that I pursue a professional career; yet even his underlying bias showed in one instance, later, when I was already an established geologist. When asked what his children were doing, he cheerfully announced that his son was a civil engineer, and his daughters were married in America. The university teachers uniformly told me that geology was not for women. Should I have been bitter about those attitudes? No, because they also brought opportunities. Rather than being pushed into a money-making career to support a family, as happened to my brother and many young men of the times, I was free to pursue what I wanted, because a profession for women was considered just frills. I was free to pursue geology.

Then my dream came true and, at age nineteen, I obtained a Fulbright scholarship to study in the United States for one year. Again, being a woman may have been an advantage: I was the only female applicant, and in my final interview I was interrogated, in English, by a contingent of very serious men. One of them inquired why, on the application form, I had written the name of my hometown when asked for my citizenship. I explained that citizenship obviously pertains to "city." The men were so impressed by this unparalleled feat of logic that they gave me the scholarship. I was placed into Kent State University because it was considered a typical, middle American school. Contrary to my expectations, America was not the great land of freedom. As a woman, I was beset by 10 p.m. curfews and dress codes, and, much to my disgust, my sponsoring sorority forced on me pleated skirts, bobby socks, sneakers, and Bermuda shorts, all of which I considered rather ugly. I was the only woman in my geology classes and sometimes felt quite isolated.

Against the Fulbright agreement, I stayed in the United States for a second year, teaching German, and obtained my bachelor's degree in geology from Kent State. Then I went to Pennsylvania State University, where I met my husband, Ivo Lucchitta (to some now, Mr. Grand Canyon). I also met my thesis advisor, Robert Scholten, a former Dutchman ill-treated by the Germans during days of the Dutch resistance in his youth. I am grateful to Rob that he extended to me a hand of reconcilation with the past, and, not insignificantly, a grant to study the Rocky Mountain thrust belt in Idaho and Montana. It is to my husband's credit that he pushed me into accepting the grant, in spite of my fear of bears. I was the first female Ph.D. in the geology department at Penn State, and I was accepted as an equal by students and professors.

At that time, discrimination tended to be in my favor. "Patronizing women" is a curse or an asset, depending on the situation. I made the best of it. Young women of today would fault me for selling out, but at the time women were not hung up on modern principles. For instance, my then fellow graduate student, now colleague and good friend John M'Gonigle (recently retired from the USGS), gave me the better of two available ancient jeeps; ranchers, sheepherders, and cowboys fell all over themselves to help me, gave me horses to ride, let me have access on roads that were otherwise closed to the public, and rescued me from ditches when my jeep got stuck. However, all of this attention on occasion backfired. One evening an irate woman rolled into camp with the intent to beat me up because I had allegedly seduced her husband. I had never met her nor the man, and can only guess that he fabricated the story to arouse her jealousy. Also, an enamoured sheepherder threatened to shoot my then boyfriend Ivo, when he came to visit at the end of the summer. Ivo and I moved across the continental divide to the Idaho side of my field area, as a precaution.

As Gene mentioned, my field area was in the Beaverhead Range, which is riddled with thrust faults. The area is now acclaimed to include the largest impact structure in the United States, as deduced from shattercones. Of course in 1962, when only a handful of geologists had ever heard of shattercones, I had no idea what I was looking at. I assiduously described those peculiar hashed-up rock chips as having "conchoidal fracture surfaces with fan-shaped grooves on them." I thought I was looking at a breccia zone with strange fault striations. Of course, I never searched for and thus never saw the one outcrop that shows immense shattercones in their full glory. Too bad.

Marriage brings rewards and difficulties to a woman embarked on a career. Our landlady decided that living in sin was not to be condoned, so Ivo and I got married. Then the inevitable happened, and I became pregnant. My well-laid plans were to have my Ph.D. thesis defense first, then take two weeks to study up on babies, and then deliver. You guessed it, my plans were foiled. Much to the relief of my thesis committee, who envisioned me going into labor during the defense, the baby arrived the night before the scheduled exam. We took the baby home and had no idea what to do. It screamed, but a frantic phone call to a friend with kids quickly alleviated the situation: he suggested we change the diapers. Miraculously, the screaming stopped. In spite of all, my daughter survived.

The next obstacle we encountered is faced by many two-career couples: how to find employment for two professionals. In 1966, Ivo got hired to work on the Apollo Program at the USGS in Flagstaff, and I stayed home for a year as an illegal alien fighting for an immigration visa after my exchange student status had terminated. After I received the visa I did what many women did then and still do, I sneaked in through the back door. I first worked part-time as a technician and then worked my way up to become a geologist. My assignment was to make maps of the Moon. Contrary to many of my predecessors in this award, I was not entirely thrilled by the prospect. As a field geologist, sitting in an office with a bunch of pictures was not my idea of fun. Yet, adaptability, which I consider a virtue possessed by many females, soon paid off and I discovered that many treasures were hidden in those images; my interest was aroused. Don Wilhelms, the foremost lunar mapper, taught me the fine points of mapping other planets, and I am very grateful that he kept encouraging me even in some of my more outrageous ideas.

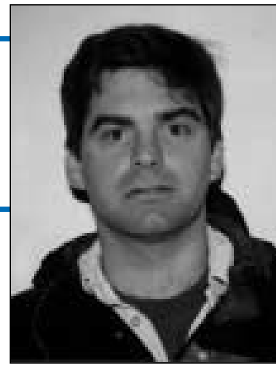
However, my career was slow in taking off. I succumbed to "the good-girl syndrome," an attitude that afflicts many women: you hope that doing a good job will bring rewards. It does not necessarily. My first attempts at being assertive were off to a false start. I took all my courage and walked into the branch chief's office, asking for a raise. I timidly pointed out that Odette James, then as now of the USGS and, of course, the current chairperson of this Division, had just received a raise and that maybe there was room for advancement for others. My ever so tactful branch chief rebuffed me with the remark: "But she is smart!" Eventually "Equal Employment Opportunity" came along and with it peer promotion panels that looked at the records. Within a few years I advanced through the ranks to pull even with male colleagues of similar achievements.

A more important part of one's career is, of course, the research one enjoys. My first break came with Apollo 17. My female intuition served me well. At a meeting where future Moon landing sites were debated, I sensed that Jack Schmitt, the Apollo 17 geologist astronaut, badly wanted to go to the geologically interesting Taurus Littrow Valley. I quickly changed my geologic mapping assignment to that site, and thus joined the ranks of only a few geologists who had their lunar maps field checked. Those were exciting days. Astronauts were "big-hero" stuff, and I was absolutely thrilled to be flown to the Cape, to have supper with the astronauts in their quarters, and to give informal after-dinner lectures. And when the big day of the Apollo 17 landing came, I was right there in Houston, near mission control, hanging on every word uttered by the astronauts on the Moon, hoping to influence the action, being elated to be part of such momentous history. And things did not slow down for many years. Mars turned out to be a most interesting planet with many Earth-like features. I went to JPL for every new mission and encounter, and I watched in fascination as the first images ever of other planetary surfaces slowly built up on the screen, sometimes line by line. Imagine, to be there when landscapes emerge that no human being has ever seen before! I tried, but never succeeded to become a formal mission team member. Perhaps I was too junior, a woman, or simply not considered good enough. But I always managed to get into the action, either as back-room researcher, as guest investigator, or as research assistant. I thank Larry Soderblom of the USGS, who repeatedly made such assignments possible. And I also thank my assistant Holly Ferguson, now retired, who steadfastly supported my work.

However, a woman's scientific career also brings frustrations. First there is the never-ending task of juggling career and family; even though it's better now, the major chores of child rearing still fall on the woman. The high visibility of women in male-dominated fields brings rewards and dangers. One cannot blend into mediocrity; one stands out and has to perform well, both for oneself and for one's gender. One is judged more harshly. One has to work a bit harder. One is frustrated when ideas expressed at workshops are politely ignored, only to be acclaimed loudly when expressed later by male colleagues. One used to be excluded from the "Boys' Clubs" that went out at night and discussed shop. One was not part of "the gang." Recently, things have changed much for the better, and women are included in activities once considered a man's domain. But let us not spoil these gains and let us be tolerant when men, sometimes inadvertently, transgress the fine line between friendly advances and what is now called sexual harassment.

To conclude, my childhood dreams of discovery were amply rewarded. I had new worlds to explore. There were secrets to be probed in craters, plains, and landslides on the Moon. There were cold-climate features on Mars, and mysterious channels, volcanoes, and huge tectonic structures. There was the Jupiter moon Europa displaying strange lineations, the moon Ganymede racked by ice tectonism, and there is Antarctica, whose environment is close to that on other planets and gives invaluable clues. I am grateful to John Behrendt, Jane Ferrigno, and Richard Williams of the USGS, Olav Orheim of the Norsk Polar Institutt, and my assistant Christine Rosanova for enabling the Antarctic connection. There is the excitement of learning new subjects such as remote sensing and image processing and glaciology. There is the challenge (and trepidation) of dealing with specialties in many scientific fields, often having only marginal knowledge. There is the hope that, as a woman with laterally well connected brains (as they say), one will be well equipped to make those intuitive leaps that are so important in advancing science. And above all, let us not forget, research and finding out, exploring and discovery, are a lot of fun.

KIRK BRYAN AWARD
presented to
JIM E. O'CONNOR



Citation by VICTOR R. BAKER

The 1995 Geological Society of America Kirk Bryan Award is presented to Dr. Jim O'Connor, U.S. Forest Service, for his monograph *Hydrology, Hydraulics, and Geomorphology of the Bonneville Flood,* published in 1993 as Geological Society of America Special Paper 274. This is the highest award of the GSA Quaternary Geology and Geomorphology Division, and it is presented to the author of a published scientific paper advancing our science.

The paper associated with this year's Kirk Bryan Award documents, in especially convincing fashion, the processes associated with an ancient fluvial event of exceptional intensity for energy expenditure. As geologists we explore the world of the past. This is the world that has been called "deep time." Let there be no mistake, however; this is not the time of which theoretical physicist Stephen Hawking writes in his very popular book *A Brief History of Time.* For us geologists time is not some parameter input by the analyst into his or her modeling equations. Time is nothing in geology if not the richness, detail, and complexity of all natural experience. I submit that the essence of geological experience lies not in some numerical formulation but rather in those rare conjunctions of intense processes that are sometimes accorded the label "catastrophic." The energy levels for these events are so high that process indicators are profoundly impressed upon landscapes, sediments, and the minds that interpret them. These impressions are signs read by geologists, and they constitute a language of nature expressed in the loudest of exclamations.

The paper that we recognize here is a reading of nature's language through the working hypotheses of its author. Nature's language is translated into the symbols, including words, diagrams, and mathematics, that most effectively convey the story to an audience of fellow scientists. Though the story is nature's, we can indeed celebrate its telling and its teller, much as we celebrate the poet, whose love of human language enriches another kind of telling.

Just as the poet must love her human language, so the geologist must love nature's language. The paper we celebrate here would not be possible without a profoundly creative and loving author, one whom I value immensely for association in that educational experience which we label as professor and graduate student.

Jim E. O'Connor is no stranger to honors by this division. He twice received the J. Hoover Mackin Award, first in 1984 for his M.S. work and then in 1987 for his Ph.D. proposal. Jim also received in 1988 the GSA's Robert K. Fahnestock Award for his Ph.D. project, the successful culmination of which resulted in GSA Special Paper 274. This latter award was highly appropriate, since Ken Fahnestock was an ardent proponent of the approaches so ably refined in Jim's Special Paper. It is also fitting that this Kirk Bryan Award is the second for a study of the Bonneville Flood, following Hal Malde's work of a quarter century ago. Hal, of course, followed hints from G. K. Gilbert, thereby tying to a continuum of heroic geological inquiry.

Jim O'Connor was destined to do this study. Born in the city where J Harlen Bretz taught high school, Jim graduated in 1982 from the University of Washington. He then moved to southern Arizona, where graduate fluvial geomorphology students were influenced, gently I hope, to listen and to communicate nature's shoutings, that is, to let ancient floods tell their own stories.

There is something about great cataclysms that makes one feel very small. Perhaps there is a kind of primordial memory, embedded in the human psyche, that collectively recalls migrations across landscapes that were suddenly and spectacularly transformed by immense flows of water. Our awardee will now have to give us his own reflections, but mine are rather intense. One works as an educator and as a researcher in the profound hope that these are not two disparate activities, separately indulged, as accounted for in the short-term productivity mania sweeping our universities. Science, education, research, and service compose a continuum of activity. When a student/colleague receives the highest recognition by a scientific body, then one can feel that this continuum with nature, with colleagues, and with science has been maintained. Jim's advisor was mentored by Bill Bradley, last year's Distinguished Career Award recipient. Bill studied with Arthur D. Howard and J. Hoover Mackin, both of whom were students of Douglas Johnson. Johnson, of course, was mentored by William Morris Davis, whose advisor was Nathaniel Southgate Shaler. Shaler, in turn, was the student of Louis Agassiz, who studied with Baron Georges Cuvier, perhaps geology's most eminent catastrophist. We are, all of us, a part of this continuum with the world. We are all seeking to be the poets for nature's great stories. It is in this spirit that I have the pleasure and the honor of participating in the presentation of the 1995 GSA Quaternary Geology and Geomorphology Division Kirk Bryan Award to Jim E. O'Connor.

Response by JIM E. O'CONNOR

I am truly honored and flattered to be receiving this award. As previous Kirk Bryan Award recipients have noted, there is a twinge of discomfort associated with being selected for such a prestigious award, knowing that many equally deserving papers have not been selected for such recognition.

You now know from Vic's comments that *Hydrology, Hydraulics, and Geomorphology of the Bonneville Flood* is basically an unadulterated version of my dissertation. Although I am now five years and several postdocs removed, I still find it relevant to share with you my perspectives on being a student.

As an undergraduate at the University of Washington, my first geomorphology class was cotaught by Tom Dunne and Steve Porter. What a combination! Taking several classes with Tom Dunne, some of them more than once, led to my continuing interest in how hydrologic and geologic processes shape the landscape. I also gained an appreciation as to how the disciplines of physics, chemistry, and mathematics can be used in conjunction with careful field observations to arrive at satisfying insights into understanding earth-surface processes. Steve Porter's classes emphasized that the landscape is more than a matter of physics, chemistry, and mathematics but also a product of a long and complex history of processes at a variety of temporal and spatial scales. Moreover, Dr. Porter encouraged my interest in large floods—primarily by his own interest, but also by threatening to not write letters of recommendation for me for graduate school unless I applied to the University of Arizona, where Vic had just been hired. I'm exaggerating, but just a little.

The people at the University of Washington who most influenced the direction of my career, however, were not the tenured faculty. I became a geology major because of the direct influence of a couple of graduate students. My interest in Pleistocene flooding was sparked by field trips and discussions led by graduate students and instructors. Interaction with grads and undergrads in many fields led to my first tastes of actually doing science—these were the tidbits and experiences that led me on.

At Arizona, faculty such as Vic Baker, Bill Bull, Clem Chase, Owen Davis, and Simon Ince, among many others, were important guides and role models. These were the people that, for me, tuned the instrument of learning at the University of Arizona. The music was really made, however, by the other graduate students. At Arizona I was fortunate enough to be part of an ensemble of students with a wide variety of backgrounds, abilities, and interests working under faculty members who encouraged reaching out across disciplines. The result was a concert of enthusiasm, inquisitiveness, and creativity. The names of all my fellow students should really be on the award certificate. I'm pleased that many of them are here tonight—you know who you are and I hope that you feel you are sharing in this with me.

This leads to a message I want to state clearly: I feel that Vic Baker's and Bill Bull's success as scientists and teachers, and the success of their students, isn't necessarily a direct consequence of Vic's and Bill's powerful intellects, keen field skills, or the quality of their prose, nor can it be measured by the number of papers published and awards won. In my mind, their biggest, most far-reaching, and longest lasting success will stem from their ability to bring together people who are excited about learning, and foremost, fostering an environment where young scientists are allowed and encouraged to explore in directions that are satisfying to themselves. Guidance and judgement are offered, but not forced. In my opinion, this is the type of environment that promotes the creativity that leads to steps forward in our science.

The other part of the message is for current students. Savor the moment. I also encourage you to explore beyond the bounds of narrow disciplines that are increasingly becoming the graduate student path. Your fellow students are your primary and best resource for learning and doing science. Take advantage of them—you won't be in school forever. And graduate students, you have unique opportunities to bring on the next generation of scientists, including geomorphologists and Quaternary geologists.

Since graduating, I have worked as a government scientist, first with the U.S. Geological Survey, and now with the Forest Service. I have been fortunate to have these opportunities and the chance to work with dedicated scientists on a variety of research and policy issues. Government science, however, is undergoing a transition—a painful, hard, and not necessarily fair process. The recent downsizing of the USGS is just one example.

Government science, for better or worse, is in the process of adjusting to new realities. In this day and age, there just is not the money or, frankly, the justification for esoteric research aimed at publishing papers destined for the countless journals that fill ivory-towered libraries. Congress, if not the American public, is fed up with perceived big government and perceived waste. And government science and scientists are now paying the price. I suspect that these same economic realities will soon begin having major impacts on scientific research in the academic world, if they have not already. At the same time, we all know that human activities all over the world are increasingly resulting in hydrologic and geologic consequences that are posing serious risks to the ecologic integrity of the planet. I hope these statements are not simply viewed as a doom-and-gloom view of our future. There are serious real-world issues out there, but they provide endless research and educational opportunities. I am truly optimistic about the positive role that science, especially geomorphology and surficial geology, will play in future policy. But we have to make it happen.

We must go beyond simply conducting research that is "relevant." We cannot be content to be disinterested scorekeepers blithely keeping tally while watching the home team lose. Most of us are lucky enough to be in positions, or will be in positions, to make positive changes, and we need to seize the opportunity to do so. We must launch wholeheartedly into issues that we know and care about, and attempt to make contributions, whether they be scientific, educational, or other, that are truly meaningful in terms of improving the state of our magical world.

I've finished standing on my soap box. I will now close with a few thank-yous. I truly appreciate being the recipient of the Kirk Bryan Award. But *Hydrology, Hydraulics, and Geomorphology of the Bonneville Flood* was, in the end, a concerted effort of many people.

I thank GSA and the division for initially funding the project through its research grants programs. More than the money, the motivation to produce well-thought-out proposals, and the encouragement that goes along with receiving research grants, helped propel the project from the very beginning. I also thank the National Science Foundation for its significant contribution.

I thank my dissertation committee members, Vic Baker, Bill Bull, Owen Davis, and Simon Ince. Vic and Bill, in particular, were guiding influences for my career. I can now wave my arms about the state of science and whip up some fine-tasting Dutch-oven cornbread at the same time.

I thank Hal Malde, whose own paper on the Bonneville Flood won the Kirk Bryan Award 25 years ago and inspired my own research. He spent a week in the field with me and enthusiastically encouraged more work in territory that he had already so thoroughly and insightfully covered. I only hope that I have the self-assurance and the opportunity to do likewise for the recipient of the Kirk Bryan Award in the year 2020.

I thank fellow grad students Lisa Ely, Kirk Vincent, Sara Rathburn, and Julie Woodward for helping me measure hundreds of boulders in all kinds of places in all kinds of weather. More graduate students, faculty, and other geologists than I can hope to name helped guide the project from start to end.

I thank John Costa for hiring me on at the USGS after I graduated and then allowing me the time and resources to get the paper out.

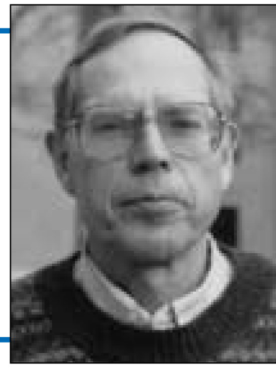
But most of all I thank Karen Demsey, who measured more boulders than anyone, who has more than put up with the hardships and uncertainties of being a spouse of a graduate student and marginally employed scientist while at the same time being a successful geologist, and a wonderful mother and soulmate.

I am truly lucky and thankful for the doors that have been opened for me, many of them by you all, and for the remarkable privilege of accepting the 1995 Kirk Bryan Award.
Thank you.

STRUCTURAL GEOLOGY AND TECTONICS DIVISION CAREER CONTRIBUTION AWARD

presented to

BURRELL CLARK BURCHFIEL



Citation by GREGORY A. DAVIS

He has conducted field studies in the U.S. Cordillera, the Alpine belt of eastern Europe, the Caledonides of Scandinavia, the Peruvian, Bolivian, and Colombian Andes, and north-central China and Tibet. A past editor of *Tectonics,* he is currently on the editorial boards of *Tectonophysics* and front-line journals in Norway, Switzerland, Germany, and the People's Republic of China. His students have worked in mountain systems on both margins of our continent as well as in Norway, Sweden, Hungary, Greece, Turkey, China, Tunisia, Guatemala, Venezuela, and Bolivia. He is, in my studied opinion, the preeminent tectonicist in the world today—one whose global researches over the past three decades have fundamentally shaped the way in which we view orogenic processes.

And thus begins my introduction to you of Burrell Clark Burchfiel—our Division's 1995 Career Contribution Awardee.

Currently Schlumberger Professor of Geology at MIT, Clark's academic education, like his geological research, spanned our continent. A California native, Clark undertook undergraduate and master's studies at Stanford. At Stanford he played football, but not enough (apparently) to keep him from receiving a B.S. degree in geology with distinction. Then off to Yale, where his interests in structural geology and tectonics were shaped by such legendary figures as Chester Longwell, John Rodgers, and visiting professor S. Warren Carey. His Ph.D. degree from Yale in 1961 was adorned by that university's Silliman Prize. Clark's academic career on the blackboard side of lecterns began at Rice University, where he rose through the ranks to become Carey Croneis Professor of Geology. After a highly productive 16 years in Houston, Clark accepted a position at MIT, where he has been since 1977.

Although initially Cordilleran-oriented, Clark's interests in contrasting orogens have led him to the Andes, and to the southern Appalachian, Alpine, Caledonian, and Himalayan collisional belts. I suspect that the international interests of Clark's principal Yale adviser, John Rodgers, made such a global approach to Clark's research a matter of destiny. In all of these areas his modus operandi has been to integrate superb field mapping with ancillary studies in geophysics and, more recently, geodesy. The consistent goal? To understand the origin and mechanics of continental orogenesis in both collisional and cum-oceanic settings. In publications that number well over 100, Clark—alone and with different combinations of colleagues—has contributed seminal ideas regarding widely varied topics, including but not all-inclusively: the landslide origin of megabreccias and the pull-apart origin of Death Valley (both 1966); the two-sided geometry of the Cordilleran orogen (1968); the plate tectonic evolution of the U.S. Cordillera (1972–present); contrasting modes of extensional tectonics (1982); synconvergent crustal extension in the High Himalaya and eastern Tibet (1985–present); evidence for intracrustal detachment in California and Tibet (1989–present); and studies of contrasting modes of plate subduction and convergence with special application to the Carpathians, the Caledonides, and the Cordilleran Antler orogeny (1974–present). He is currently involved in neotectonics and GPS investigations on the Tibetan plateau and in the Tien Shan of northwestern China.

Apart from his research, Clark has contributed mightily to our science through his efforts as a graduate adviser and as an active participant in the earth sciences hierarchy. At Rice and MIT he has collectively advised some 44 Ph.D. students and 15 M.S. students (Burchfiel "clones" as they have been affectionately called by the students themselves). His students, among them Jim Tull, Elizabeth Miller, John Sutter, George Dunne, Scott Cameron, Dan Lux, Michael Carr, Kip Hodges, Brian Wernicke, Doug Walker, John Bartley, Jon Spencer, Elizabeth Schermer, and Gary Axen—to name just a few whom I know personally—have continued his legacy of superb tectonics research and, for the majority, the academic training of a third generation of fine students. Clark has been a member of the National Academy of Sciences since 1985. He has been active as panelist and chair of various Academy, NRC, and GSA committees, and as such has contributed toward policy-making recommendations that aid and advance structural geology and tectonics.

No citation would be complete without mention of Clark as a person—a gentle man who will not tarnish the personality or abilities of others, an outdoorsman extraordinaire who is as physically fit now as he was decades ago, the loving father of four fine sons, and the soulmate of wife and scientific partner Wiki Royden.

In closing, it is with awe at his many contributions and pride in being his friend and sometimes collaborator that I present to you Clark Burchfiel, our 1995 Career Contribution Awardee. I can honestly think of no one more deserving of this great honor!

Response by BURRELL CLARK BURCHFIEL

I want to thank Greg for his introduction, but I have to admit I am not sure that I recognize the person he describes. As most of you know, Greg Davis has been one of my closest friends and collaborators especially through much of the early part of my career. Many of the contributions he mentioned in his citation really must be shared with him.

This award is greatly appreciated, particularly because it is given by the Structural Geology and Tectonics Division, the Division I regard as not only containing my peer group in the GSA but a Division that contains so many outstanding earth scientists, many of whom could be standing here in my place. At the same time it's an elating and humbling experience.

I have been fortunate to have known all of the previous award winners, some quite well, and all are outstanding scientists, adding to my surprise when Ed Beutner called me to inform me of being voted the Career Contribution Award. Having known the former winners, one of the first thoughts that crossed my mind was: "I'm too young. All the previous recipients have been retired." My second thought was "Is there some message here?" I hope not, because I still enjoy my science as much as ever and look for many more years of teaching and research.

Receipt of the Career Contribution Award has made me reflect on my career, and I find there have been several important events that influenced and changed my career direction. Most of these were influenced by certain individuals, and I feel that to those people I owe a significant debt. In some small way I would like to repay a few of those debts here. The first two people I would like to mention by describing briefly their contribution to my career, because their involvement reflects not only on my career, but also on my relations with my students and former students and on how academic times have changed over the past 40 years.

As an undergraduate at Stanford University I received what I consider one of the finest undergraduate educations I could have received anywhere, and because of that experience I retain a great fondness for Stanford. I recall that after taking only the two beginning geology courses, Bill Travers, whom many of you know for his many contributions to geology, and I went to Professor Simon Mueller and told him we wanted to be field geologists. Did he have a project that we could work on? Si knew that we did not have any of the basic training to do field work, but he did not tell us that. In order to find something we were qualified to do, he spent several days reviewing possible field studies. We selected a stratigraphic and structural study in Jacalitos Canyon west of Coalinga, California, and Si said he would supervise the work. Bill and I spent many weekends mapping, or, really, learning how to map, in the dry washes of the eastern Coast Ranges. Si took at least two of his weekends to come visit us in the field and supervise our "research" effort. Si's marvelous grasp of field techniques and infectious love for field work first kindled my life-long love for field studies. But, as I look back on this experience now, I realize how much time Si spent to supervise two very rank greenhorns.

The second story I would like to relate came later at Stanford when I was considering a future either in graduate school or working for an oil company. I had a very easy route ahead of me by staying at Stanford. I would have been in charge of directing the teaching assistants in the laboratory sessions of the very popular physical science course taught by several faculty members, because I had TA'ed laboratory sessions in this course for two years. One day Dr. Hubert Schenck, who was directing my master's thesis, asked me, "What are you going to do after your master's degree?" I explained the two options I was considering, and he said, "No! You are going to Yale to study with John Rodgers." I told him that was impossible, because I did not consider my grades good enough, having spent much of my undergraduate days as a scholarship football player, which demanded much time and did not foster a burning desire for academic excellence. He told me to apply. I did, and was accepted to Yale with full support. (I found out later that Hubert Schenck and John Rodgers knew each other well from service in the Far East during and following the second world war.) The Yale experience completely changed the direction of my future. The main point is that my career would not be what it has been if Hubert Schenck had not taken the time or interest in my future.

I can never repay Si Mueller and Hubert Schenck, but their example has remained a major influence in my philosophy of student-faculty relations. It's an example that I have tried to emulate; however, I have found it increasingly more difficult to do so. As the years have progressed, I have witnessed the constant erosion of faculty time as the pressures at universities have become more focused on research, research funding, publication, and university, national, and international committee work. Unfortunately, at the same time the support facilities at universities and other organizations have declined. I have seen this erosion not only in my own academic life, but also in that of my colleagues, particularly my younger colleagues. Many times I have asked where this is leading and when academic life will cease to be an enjoyable career choice. When will we reach the point where the personal involvement of the Muellers and Schencks in students' careers become seriously impaired? Their involvement in my career was pivotal, and I have never forgotten it.

Yale graduate school was another strong influence on my career in more ways that I can enumerate here. If it was Si Mueller who kindled my interest in field work, it was from John Rodgers that I received my desire to try to understand the processes of mountain building by studying the mountain belts of the world. John has set an example that is hard to match. One of John's contributions was in absentia. While he was on sabbatical leave, his replacement was Professor S. W. Carey. Carey's lectures about great crustal mobility made an impression on me that lasts to this day.

After 16 years at Rice University, where Carey Croneis, a man whose intellect and interpersonal skills I greatly admired, hired me into the department he founded and built, I received a call from Frank Press inviting me to interview at MIT. I remember my reply: "There is about a 5% chance that I would come to MIT, but if you still want to have me visit, I will." The rest is history. Frank wanted me to build a field-oriented program in geology at MIT. I have had many terrific and supportive colleagues at MIT, but I must especially thank Bill Brace, who as department chairman was instrumental in building the core of the tectonics group at MIT.

Two final acknowledgments. First, I have been blessed over the years by association with a truly outstanding group of graduate students, both at Rice University and MIT, who have been and continue to be my colleagues. It has been a great pleasure to have had the opportunity to walk in the mountains with all of them, and I am tremendously proud of their accomplishments. In my relations with them I hope the influence of Si Mueller, Hubert Schenck, and John Rodgers has been passed on in some way. Our publications gather dust, but scientific motivation and curiosity instilled in students are perpetuated.

Last but not least, I must acknowledge my closest collaborator during the past 15 years, my wife, Leigh Royden. Our scientific collaboration has been exciting and a great joy to me, second only to our personal collaboration in raising two wonderful children. I suggest that it may be some time before another recipient of the Career Contribution Award from the Structural Geology and Tectonics Division can boast 5-year-old and 22-month-old sons.

Again, my thanks to Greg for his kind citation and my sincerest thanks to the Division for this award.

In Memoriam

Arthur A. Baker
Bethesda, Maryland

George E. Ericksen
Reston, Virginia
January 14, 1996

Charles L. Gazin
Richmond, British Columbia, Canada
December 23, 1995

Teiichi Kobayashi
Tokyo, Japan
January 13, 1996

Lincoln R. Page
Melvin Village, New Hampshire
January 14, 1996

Adam R. Wasem
Bonsall, California
January 13, 1996

Memorial Preprints

The following memorial preprints are now available, free of charge, by writing to GSA, P.O. Box 9140, Boulder, CO 80301.

George K. Biemesderfer
R. H. Nagell, Susan Biemesderfer Werner

Robert C. Bright
G. B. Morey, Charles L. Matsch

James B. Cathcart
Warren I. Finch, James D. Cathcart, James R. Herring, Guerry H. McClellan, Thomas M. Scott, Steven J. Van Kauwenbergh

Harold Williams Fairbairn
Charles M. Spooner

Marion M. Fidlar
William F. Oline

Louis Franklin
Dean C. Hamilton, Robert W. Patterson

Grayson E. Meade
Vance T. Holliday

H. Wesley Peirce
Larry D. Fellows

William G. Pierce
Joseph I. Ziony, Willis H. Nelson

Carl Tolman
Dorothy Jung Echols

A Most Interesting Job

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

"May you live in interesting times" is the ancient Chinese curse that partly describes life in a Congressional office and the process leading up to my placement there. I hesitate to use the word "interesting" if only because the term lends itself to many interpretations, and I heard "What an interesting year to be in Washington!" from at least a thousand people during the two-week orientation before this fellowship truly began. As it turns out, everyone was right.

Earth scientists whose funding comes from Uncle Sam may also find the times "interesting," given the inexorable decline in federal research dollars. As a geologist from the hinterland suddenly thrust into a suit and sitting in an office on Capitol Hill, however, I find the world of Congress interesting in a much richer sense. The nation's lands and its resources are a vital part of the current debate on the budget. For example: Are taxpayers really getting ripped off if mining companies can purchase public land at $2.50 or $5 per acre to mine hard-rock minerals? (Reform of the 1872 Mining Law is included in the budget bill.) Will exploration and drilling in a small part of the Arctic National Wildlife Refuge destroy a caribou herd in northern Alaska? (Provisions to open up part of ANWR are also in the budget bill.) Will budget cuts at the Environmental Protection Agency (EPA) put the nation's health in jeopardy? (The recently vetoed EPA appropriations bill included 4%–14% cuts in the agency's budget compared to last year, depending on how one calculates the number.)

It is the conflict between exploitation of natural resources, efforts to preserve them, and the federal role in managing resources on public lands that first interested me in the world of policy and this fellowship in particular. It is therefore no accident that I've landed in the office of a western senator: Pete V. Domenici, Republican from New Mexico. After all, most of our public lands lie beyond the 100th meridian, and the historical battle between development and preservation in a land with limited resources lives on today in the west.

As John Wesley Powell observed more than 100 years ago, development—or lack thereof—in the arid states still depends largely on water. A newly minted hydrogeologist, I get to observe some of this policy-making first-hand while working for a senator from a dry state with traditional ties to natural-resource development. Indeed, my first task in Senator Domenici's office was not to memorize rules of Senate floor procedure, nor answer constituent mail, but rather to read a USGS water resources report on modeling the ground-water system in the middle Rio Grande aquifer (since that time, I've answered mail and learned a bit about arcane floor rules in the Senate).

The path to Senator Domenici's office would therefore seem obvious, given my inclination toward natural resource issues. Senator Domenici chairs both the Energy and Water Development Subcommittee (Senate Appropriations Committee), and the Energy Research and Development Subcommittee (Senate Energy and Natural Resources Committee), serves on various other subcommittees within the Appropriations and Energy and Natural Resources committees, serves on the Committee on Indian Affairs, and in his spare time manages to chair the Budget Committee. Yet, as reported in these pages by previous GSA congressional science fellows, finding the right job is neither obvious nor easy (but it's a lot of fun!). Fortunately, the AAAS, which has administered the Congressional Science and Engineering Fellowship Program since 1973, provided a stellar two-week orientation upon our arrival in September and enough guidance and support during the interview process so that we all landed on our feet. By "we" I mean the 30 science and engineering fellows on Capitol Hill this year, including chemists, physicists, biologists, materials scientists, psychologists (six of them!), veterinarians, agronomists, geneticists, electrical engineers, and a podiatrist, among others.

The orientation was essentially a two-week cram course on science and politics, featuring appearances from Capitol Hill luminaries such as Senator Bill Bradley (D—NJ), Representative Sherwood Boehlert (R—NY), and former Democratic Senator from Colorado Tim Wirth (now Undersecretary for Global Affairs at the State Department). In addition, we learned about the role of science and technology in different departments and agencies from Secretary of the Air Force Sheila Widnall, National Institute of Standards and Technology Director Arati Prabhakar (a former Congressional Science Fellow), and John Gibbons, Director of the White House Office of Science and Technology Policy (OSTP).

Joseph Stiglitz, Chairman of the Council of Economic Advisors, gave us the economist's perspective of science and technology in the brave new world of "sustainable growth," referring to the

Interesting Job *continued on p. 40*

Launching an Environmental Science Major: Experience at Northwestern

Seth Stein, Northwestern University, Evanston, IL 60208-2150

In the January *GSA Today*, P. Feiss's thoughtful article "The Survival of Academic Geology Programs" discussed how academic geology programs might adapt to pressures by university administrators unsympathetic to the earth sciences. His article reflects a common topic of discussion among earth scientists. One often-discussed approach is an increased "environmental" (a term that can mean almost anything) component of the undergraduate curriculum.

Having led such an effort several years ago while serving as department chair, I am often asked by colleagues elsewhere about what we did, how well it worked, and whether I would recommend a similar effort at their institutions. In this spirit, I offer here a brief personal perspective on the approach taken in this department which may be of interest to others considering various options.

In early 1991, following a meeting of science department chairs in which we considered how to better attract science-oriented undergraduates to Northwestern, I suggested that an interdisciplinary environmental science major might attract good students whose interests crossed lines between the standard departmental majors. Professors John Walther and Donna Jurdy joined me in planning the program.

Initial discussions brought me to a realization that, I suspect, inhibits many such proposals. Clearly, our department would have to shoulder most of the considerable effort required to overcome the bureaucratic barriers in establishing a new major. On the other hand, although the major would benefit the university as a whole, it would offer little direct advantage to the geology department. The only immediate benefit would be increased enrollments in our environmentally relevant advanced undergraduate courses. From past experience, even a highly successful program seemed unlikely to improve our traditionally chilly relations with the administration.

Nonetheless, largely from a vague sense of "good university citizenship," we decided to plan the program. We realized that a faculty, rather than administration, proposal would face opposition, and new resources would not be available. We had to develop a viable major "on a shoestring." Our proposal thus had several key features, as follows.

1. *Building on an existing major.* The existing geology major provided an excellent basis. It included a broad background in mathematics, physics, and chemistry. Moreover, many earth sciences courses are intrinsically "environmental" (an obvious fact that is, surprisingly, often unappreciated outside geology departments).

2. *Intellectual rigor.* We wanted the major to offer students adequate preparation for either graduate study in science and engineering, or professional school. We thus tried to provide as strong an intellectual base as possible, given the necessary tradeoff due to the ill-defined but broad scope of environmental science and the constraints on the number of courses requirable. Thus, relative to the geology major, environmental science basic requirements are less physics (two rather than three quarters), less mathematics (one rather than two years), and less introductory earth science (surface processes but not interior processes), but more chemistry (i.e., through organic chemistry) and some biology. Students also select three classes on explicitly environmental topics, and two social science courses from an approved list in economics, political science, or sociology.

3. *Accommodating students of various interests.* Beyond the basic courses, the major requires four advanced courses chosen from an approved list in biology, chemistry, geology, statistics, and civil engineering. Students can thus design a program that meets their own interests within the broad environmental area.

4. *Minimum impact on the geology department.* Given our small (then 13 full-time equivalent) faculty, we could not ask most colleagues to assume additional burdens. The program was thus based initially on existing courses. The primary additional responsibility would be on the program director. We recognized that the program would probably have more majors than our small geology major, and that new courses would be added later.

5. *Involvement of other departments.* Although the major had to involve other departments, it would be unrealistic to expect new courses, at least initially. We thus sought advice on suitable courses in other departments from sympathetic colleagues, especially from geography, biology, environmental engineering, and chemistry. We proposed that once the program began, it would be administered as an interdepartmental major by a committee of faculty from various departments who would modify the initial program as needed.

In summer 1991, we made a formal proposal for the major. The proposal faced opposition that favored "dumbing down," on the theory that reducing basic science requirements would attract more students. After heated discussion, the department prevailed and the proposed major was instituted in fall 1992. It was promptly successful, in large part due to John Walther's able directorship during the crucial first two years. Following Walther's move to Southern Methodist University, directorship of the program, by then established, passed to geography professor John Hudson (who had assisted us in the planning) and then to geology professor Robert Speed.

Earth scientists at other institutions often ask several questions about our experience.

Is the program working? I would say "yes." The program has a healthy and growing major population, currently about 50 students. Although there are problems, including the fact that some biologically oriented students have trouble with some advanced geology courses, faculty members teaching in the program seem pleased.

Was organizing the program worth the effort? I would say "maybe." The program achieved increased enrollment in upper division courses, but it has not perceptibly improved our standing in the university. For example, the department was not permitted to hire two distinguished environmental scientists whom we hoped would greatly strengthen our research effort. There may, of course, be intangible or long-term benefits which are not yet apparent.

Does the program's future look good? My sense is "yes." Enrollment is growing, new courses are being added by various departments, and consideration is being given to expanding the program by providing explicit "tracks" for students of differing interests. Although the founding faculty from this department are no longer involved, others both from geology and other departments have become involved.

If you think your geology departments might try such a program, keep in mind that the size and scope depend both on the department size and internal resources and on the resources available elsewhere on campus and nearby. The expected return depends on the department's relation with the administration. Our experience suggests that programs like ours will successfully attract majors and increase enrollments in some upper division courses. Whether other significant benefits should be expected is hard to predict. There is also some risk that the success of an environmental major might encourage an administration to view the geology department largely in terms of its teaching role in the program, rather than viewing the program as one component of a broad research and teaching mission. Departments considering environmental teaching initiatives may thus wish to weigh the required effort and the anticipated returns. As in all matters educational, no single model will apply to diverse institutions. ■

Equity, Access, and Participation Issues in the Earth Sciences

Ed Geary, Coordinator for Educational Programs, GSA

Over the past two decades, the geoscience profession has made significant strides in increasing the number of women who have chosen to pursue majors and careers in our field, and with the recent publication of the National Science Education Standards for grades K–12, earth science is now established as one of three scientific content areas to be taught in every grade. Despite these successes, our community has been much less successful in increasing the number of minority and physically challenged scientists and engineers in our discipline, nor have we been very successful in sparking and maintaining an interest in earth science among K–12 minority students.

At a recent conference in Boulder, Colorado, funded by the Amoco Foundation, 17 people met to discuss how to improve interest and participation in geosciences among members of underrepresented groups. The goal of the conference was to begin the development of a strategic, long-term plan to enhance minority access and participation in the earth and space sciences. African-American, Hispanic-American, Native-American, and Caucasian American educators and scientific professionals from across the country attended the meeting. Participants included K–12 teachers, faculty from two- and four-year institutions, representatives of professional societies, engineers, consultants, and a graduate student.

Following lively and informative discussions on topics ranging from careers and role models to science literacy, technology, and partnerships, the group focused on one key question: "How do we get beyond the rhetoric?" For years, we have discussed the problems and identified the barriers to increased participation of underserved populations in the earth sciences, and yet we have made little progress in improving the situation. There are, of course, some bright spots. Over 95% of students supported by the American Geological Institute (AGI) Minority Scholars program receive geoscience degrees, and the National Association of Black Geologists and Geophysicists (NABGG) has become a valuable support network for African-American geoscientists. Outside of our community, there have been many more successes. Mathematics, Engineering, and Science Achievement (MESA) programs exist in many states and are successfully increasing the number of minority students who pursue scientific and technical degrees in college. The American Association for the Advancement of Science (AAAS) Black Churches Project has reached thousands of students through hands-on workshops, tutorials, and homework help programs. Family math and family science programs have grown rapidly in number and have been successful in involving parents in their children's education.

From these discussions several important points emerged:

- We (the earth science community) must be able to articulate what we have to offer to underserved individuals, organizations, and communities.
- We need to look at problems in different ways. Different communities have different needs, and the "one size fits all" model is not adequate to address these.
- We need to recognize that the impetus for participation must come primarily from the populations and cultures we wish to work with, not from our own community. Our focus should be on learning about and responding to the needs and interests of these different groups, not promoting our own agenda.

In response to these points, participants developed the following list of recommendations.

- ✔ Compile and disseminate to earth science educators, scientists, and organizations a list of minority resources. The list should include programs, products, and reference materials that focus on different underserved populations and cultures.
- ✔ Convene a conference to gather information and materials on innovative courses and curricula that address equity, access, and participation issues for different underserved populations and cultures. This conference should lead to a compilation and publication of innovative courses and curricula in both paper and CD formats.
- ✔ Explore the development of a GeoHostel for K–12 teachers of underserved students.
- ✔ Create a set of biographic profiles on minority geoscientists, engineers, and technicians. Disseminate these profiles to publishers and to AGI in support of their career project.
- ✔ Learn more about the National Science Foundation–supported pre-service science teacher education collaborations and how we might assist them.
- ✔ Work with AAAS, MESA, 4H, Boy and Girl Scouts, AGI, and other organizations to strengthen existing minority outreach efforts.
- ✔ Conduct media workshops for minority geoscientists.
- ✔ Expand and strengthen Partners for Education Program (PEP) linkages with and outside the earth science community.
- ✔ Explore the creation of programs to improve access to and effective utilization of computer and information technologies by underserved students, teachers, and parents.

Work has already begun on many of these recommendations, and a preliminary list of minority resources should be available by March 1996. We invite your comments, suggestions, and help as we work to improve minority access and participation in the earth sciences. ■

Interesting Job *continued from p. 37*

collision between growth and finite resources. We listened to an entertaining forum discussion among reporters and editors from the *Washington Post*, National Public Radio, *Science* magazine, and press liaisons from OSTP and the Food and Drug Administration, on the topic of communicating science in the media. An important lesson from that group was that science news generally does not sell very well, or at least that what we as scientists regard as important is rarely regarded that way by Jane and John Q. Public.

Last, but probably most important from the perspective of science fellows looking for jobs, we heard from former fellows and congressional staffers about dos and don'ts, how to interview, how to fit into a world where the average staffer age is 26 and where having a Ph.D. may be regarded as more of a curiosity than a benefit.

As instant political experts, we then embarked on the interview process and tried to find potentially stimulating offices where there was a real chance to work on interesting issues, and to fit politically. It was this three-week experience, interviewing in both House and Senate, with Republicans and Democrats, conservatives and liberals, that gave me a feel for what lay ahead. Natural-resource issues in the West seem to include a volatile mix of regional and national interests: public-lands ranchers vs. environmentalists, traditional wood-gathering communities vs. protectors of the spotted owl, applicants for mining patents vs. assailers of the 1872 Mining Law. This tension results in a Congress roughly divided East vs. West on environmental and natural resources issues. As a native easterner who has worked almost entirely in the West I find the juxtaposition especially appealing. After considering a committee office vs. an individual legislator's ("personal" office), I opted for a personal office that appeared to offer ample opportunity to sample many aspects of political life in the Senate. Apparently, I will get that in spades, because in addition to budget and legislative issues of today and the near future, Senator Domenici is up for reelection in 1996, and the presidential election looms on the horizon.

So what do I do? In addition to monitoring progress on the middle Rio Grande aquifer project, I have been able to try my hand at tracking a variety of energy issues that are pertinent to New Mexico and other fossil fuel–producing states. These include a bill that alters the way royalties are collected from onshore oil and gas wells on federal lands (New Mexico is the second largest onshore natural gas producer behind Wyoming); a bill to allow formation of cooperatives for independent natural gas producers (modeled after agricultural cooperatives); proposed regulations concerning nitrogen oxide emissions from coal, oil, and gas-fired power plants; and bills reforming or altering the overall regulatory framework for electric utilities. My work has been mainly to understand these issues well enough to condense the details into one or two page summaries of the key points, or provide a five or ten minute briefing. Luckily I have lots of help on everyday legislative matters. The office employs legislative assistants (LAs) for all policy areas; three LAs focus primarily on environmental, natural resource, and energy and water issues, so I can add my technical background to their superior grasp of the law and politics to best serve the senator.

One of the true joys of the job is to plug into the incredible information network available to Congress and get facts, opinion, history, and political views on any subject concerning Congress. This may entail a call to the Congressional Research Service, a government agency, think tanks, lobbyists, universities, or state geologists' offices (and they all return my calls!). As I start to learn names and faces, I depend increasingly on fellow staffers and Capitol Hill veterans for more of an "in-the-loop" perspective of legislation. A Rolodex and phone have replaced hand lens and pick as the geologist's most important tools in this job.

Graduate school survivors will recall that one of the most daunting requirements for graduation was to assemble your entire thesis committee in one room long enough for you to defend your thesis or dissertation. This skill came in handy as I recently helped organize a meeting of the Congressional Oil and Gas Forum (Senator Domenici is a co-chair). Comprising a bipartisan and bicameral group of legislators, the forum is concerned about domestic oil and gas issues and was organized to serve as an educational caucus for Congress. Considering that each legislator's schedule is mapped out carefully in 15 minute to two hour increments every day of the week, yet may change at a moment's notice at the whim of the majority or minority leaders, it took serendipity plus hard-earned organizational skills to produce a successful meeting.

As a reminder to fellow earth scientists who are not necessarily obliged to consider the impacts of their work in purely personal terms, Congress, by its activity or inactivity tends to incite emotional reactions. The letters, faxes, phone calls, and E-mail flooding the office every day are a constant reminder that people are affected and react quickly and often viscerally, judging by some of the earthier missives I have read. Legislative decisions often impact jobs and traditional ways of life, particularly natural resource–based local economies utilizing public lands. Incentives to develop resources, as in the form of royalty relief for oil drilling in deep water, or the historic access to public lands afforded miners via the 1872 Mining Law, create a hue and cry by a curious union of environmentally minded legislators and free-marketers opposed to "corporate welfare." Indeed, the underlying questions raised in the 1994 election of what the government should or should not fund, tax, regulate, or support affects directly earth scientists involved in all spheres of our discipline, and we should pay heed. What defines "corporate welfare" and what may be considered wise use of public resources are the critical questions, and the decisions are not easy. The following conversation between Alice Rivlin (then deputy budget director in the White House) and President Clinton concerning agricultural subsidies, as reported in Bob Woodward's *The Agenda* is telling in that regard:

> "Mr. President," Rivlin said enthusiastically, "I've got a slogan for your reelection." Taking off on his campaign promise to "end welfare as we know it," she proposed: "I'm going to end welfare as we know it for farmers."
>
> Clinton stiffened, looked at her, and snapped, "Spoken like a true city dweller.... Farmers are good people. I know we have to do these things. We're going to make these cuts. But we don't have to feel good about it."

Substitute "ranchers" or "miners" or "oil drillers" or even "government scientists" for "farmers" in the passage above and you get the picture.

Without a doubt, this is an "interesting" place to work. Traditionally, the strength of the earth scientist stems from an ability to interweave various disciplines and arrive at a cogent understanding of the natural world. Weaving a description of Congress into a coherent picture might require an entire career. At the very least, I hope that this year I can transmit through these pages some understanding of Congress and its relation to the earth sciences that is not readily apparent on the evening news. ■

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

ENVIRONMENT MATTERS

Institute for Environmental Education

The Geological Approach to Understanding the Environment

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In his rather subjective history of geology, Wood (1985) argued that this science peaked in its intellectual development during the late 19th century. This period was followed by a decline of geology, as modern physics, chemistry, and biology surpassed it in the 20th century. In the 1960s a reawakening occurred, but this reawakening was not in traditional geology. Instead, Wood argued, a new earth science was born, centered on the global view and scientific methodology of geophysics. Wood faulted geology for its bond with Earth, a bond that has resulted in what he described as a "failure to separate man's experience from the object he wishes to study" (Wood, 1985, p. 7). Presumably if geologists were more detached from their objects of study they could be more scientific, more like other modern physical scientists.

Wood's vision of science is paralleled by hierarchical classifications that rate sciences according to their mathematical sophistication (Alvarez, 1991). Such classifications place the predictive and experimental sciences at the top and historical descriptive sciences farther down the ladder. It is presumably the aspiration of the humble denizens of the lower depths to move upward along the ladder. Of course, these classifications are themselves arbitrary value judgments based on nontestable criteria. (What experiment do we perform to show that one science is "better" than another?) The classifications are, in a word, "nonscientific."

A more productive view, in my opinion, is to see various sciences as complementary. The strength of mathematical physics is in the power of its predictive capabilities. However, there is a kind of blindness that accompanies this power: predictions can be powerfully wrong as well as powerfully right. Geology does not bring such predictive power to the understanding of nature. What it does bring is a broad connection to reality, an experience of the past that may be fuzzy, but is not likely to be blind. Blindness is avoided by the very bond with Earth that Wood (1985) so disparaged. This bond extends through space and, especially, through time. For geology, history really matters.

Geology does not predict the future. Its intellectual tradition focuses on the contingent phenomena of the past. This idea of contingency has its own philosophical underpinnings, no less glorious than those of the predictive sciences (Gould, 1989). Contingency holds that individual events matter in the sequence of phenomena. Change one event in the past, and the sequence of subsequent historical events will change as well. Physicists, who seek timeless, invariant laws presumed to be fundamental for nature, are only beginning to address the importance of contingency through their recognition of "complex" and "emergent" phenomena in nature; geologists have understood such concepts for centuries. Physics is not the science of all nature, despite the etymology of its name. Rather, physics is the science "devoted to discovering, developing and refining those aspects of reality that are amenable to mathematical analysis" (Ziman, 1978).

The reasoning process of physics and its allied sciences is analytical. This means that first principles are assumed and that consequences are deduced according to structured logic, often mathematical, from those principles. This deduction is what physicists mean by a "prediction." It is a popular misconception that scientific prediction is a prophecy of future events.

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IEE *continued from p. 41*

Quite the contrary! Prophecies are the province of mystics, not scientists. Scientific predictions are logical deductions, completely developed in the ideal world of scientific theory. For physics, the one contact with reality comes in the match of this deduced consequence ("prediction") with a measured property of nature. The match is confirmed by the method of an experiment, which is a defined element of the real world controlled so as to check the investigator's theories about that limited aspect of reality. Unlike the ideal physical systems studied in such experiments, the phenomena of the earth science cannot be used to verify or confirm theoretical predictions (Oreskes et al., 1994).

Geology takes the whole world as it is. Controlled experiments in the sense of the physicist are impossible. This taking of the world "as is" can be thought of as a kind of realism. It is central to a naturalistic mode of inquiry that appears to underpin the philosophy of T. C. Chamberlin (Schultz, 1976), arguably the most influential American geologist of the past century. Of course, Chamberlin is famous mainly for his "Method of Multiple Working Hypotheses" (Chamberlin, 1890). Written at the height of geology's scientific status, this paper is remarkable not so much for advocating a somewhat unworkable methodology as for its emphasis on the role of hypotheses in geological reasoning.

In the 20th century, philosophy of "science" was transformed into a philosophy of analytical physics. In much of its modern form it is quite irrelevant to geology (Frodeman, 1995). As other sciences became analytical, geology maintained a tradition in synthetic thinking, which is the continuous activity of comparing, connecting, and putting together thoughts and perceptions. The focus is on deriving hypotheses from nature rather than on applying elegant theories. The geologist uses analysis as well, but not to provide ultimate answers for intellectual puzzles predefined by limiting assumptions imposed upon the real world. Rather, analysis in geology allows the investigator to consider the consequential effects of hypotheses. It is important that the latter be suggested by our experience with nature, through what Gilbert (1886) termed "analogy," rather than by our theories of nature.

Also important in this tradition of geological realism are notions of common sense and fallibility. These classical reasoning processes of geologists, so well described by Gilbert, Chamberlin, and others, have long served to discover the operations of natural processes in nature. In their various forms they comprise a tradition, the elements of which include a reverence for field work, a humility before the "facts" of nature, a continuing effort "to discriminate the phenomena observed from the observer's inference in regard to them," a propensity to pose hypotheses, and a willingness to abandon them when their consequences are contradicted by reality.

SCIENCE AND SOCIETY

Society's growing interest in the applied problems of the environment is illustrated by the U.S. Global Change Research Program, which was developed in 1989 as a strategy to enhance the appropriate research activities of various federal agencies. In 1989 federal funding of global change research was $133.9 million (Committee on Earth and Environmental Sciences, 1989). Successive annual increases brought program funding to $1.8 billion in 1995. The program's initial stated goal was "to provide a sound scientific basis for national and international decision making on global change issues" (Committee on Earth and Environmental Sciences, 1989). By 1993 this goal had been restated: "to produce a predictive understanding of the Earth system to support national and international policy making activities across a broad spectrum of global, national and regional environmental issues" (Committee on Earth and Environmental Sciences, 1993).

Geology plays a very minor role in the U.S. Global Change Research Program. I believe that this has much to do with the focus on prediction, on understanding a somewhat unreal "earth system" (rather than understanding the real Earth), and on modeling from first principles (rather than understanding the natural and perturbed habits of the planet). The idea of science hierarchies also plays a role, as does the organization of certain scientists around big-money projects and sophisticated technologies. However, these are rather petty issues. Society supports research on global change issues because people want to have a habitable planet in the future. Society desires unbiased, nearly certain scientific information on which to base critical decisions that must be taken in regard to future activity. In other words, the science is done in support of some action that must eventually be taken. The key question to society's decision makers is which action to take, given the great expense and possible social disruption associated with some alternatives.

There is, I fear, a fundamental flaw in this traditional approach. The predictions of science can only be certain for the puzzles as recognized at this instant. There may well be "blind spots" in the current recognition. Complete certainty for the real world is scientifically impossible, nor, it can be argued, is it even desirable (Baker, 1992). Moreover, future action is sure to change the rules of any puzzle now conceived, unless the scientists restrict policy

IEE *continued on p. 43*

IEE *continued from p. 42*

options to those they have modeled. (Although some scientists may believe this to be ideal, those scientists have probably had little experience with the challenges of policy making in a democracy.) Most disturbing, however, is the view that science provides factual information and that those facts, perhaps adjusted for uncertainties, serve to underpin decisions. This approach to environmental action, so well exemplified by the high-level-waste disposal issue (National Research Council, 1990) is, in its consequences, a formula for environmental inaction.

The strength of science is in its continual process of discovery, not in its factual by-products. If science were ever to achieve certainty, then science would indeed be finished. There is no science in a collection of facts known with certainty. Science's success arises from its ability to probe the unknown, not from its archival collection of the already known. In a world of contingent natural and social phenomena, to use science as a mere source of facts is to render science irrelevant to the process of planning for and responding to tomorrow's environmental challenges.

We are rapidly developing a crisis of confidence between science and society. The latter, largely through its political institutions, both sustains and utilizes science. Much of the public believes factual information to be the sole product of science and considers failures of scientific apparatus, and environmental degradation in general, to reflect failures of science itself. This view has partly arisen because many of the national spokespersons of science have represented only one philosophical perspective on the broad and rich nature of the scientific enterprise. That perspective, largely derived from analytical physics, places its maximum emphasis on developing conceptual idealizations of nature. The public does not understand these idealizations, nor is it being supplied with the concrete perceptions of reality that compel action. Paralyzing inaction characterizes important environmental issues like global warming and nuclear waste disposal.

The science of geology has long concerned itself with the real-world natural experience of the planet we inhabit. Its methodology more directly accords with the commonsense reasoning familiar to all human beings. Because its study focuses on the concrete particulars of nature rather than on abstract generalizations, its results are also more attuned to the perceptions that compel people to take action, and to the needs of decision makers who must implement this action. The natural record of geologic change is the greatest repository of available information on change in Earth's real-world environments. The knowledge of this record derives from the reading of Earth's indices or signs, the scientific interpretation of which defines the task of the geologist. I argue that this "conversation with Earth" has at least as much to provide in understanding the environment as does the detached analytical science that has heretofore been overcommunicated to the public. It is time for geologists to make known their pragmatic approach to sustain a habitable planet by sharing their naturalist reasoning processes with the public.

CONCLUSION

J. Hoover Mackin was one of many intellectual heirs of geology's pragmatic tradition. Mackin cherished the reasoning processes of geology, writing (Mackin, 1963, p. 161):

> I'm sure that geology is a science, with different sorts of problems and methods, but not in any sense less mature than any other science … anyone who hires out as a geologist, whether in practice, or in research, or in teaching, and then operates like a physicist or a chemist, or, for that matter, like a statistician or an engineer, is not living up to his contract.

As geologists face the changing political context for their science, as they increasingly work on the pressing environmental problems that so concern our modern society, they can derive great strength from their intellectual traditions. It is their science that works to understand the natural experience of Earth. Despite the sophisticated modeling predictions, despite the new laboratory procedures, failure to recognize the seminal value of this experience remains the biggest blind spot in our modern technological society. It is the responsibility of geologists, confident in the status of their science, to bring this experience into the modern scientific discourse. Moreover, there is a need to go beyond the providing of scientific information alone. The information must be used wisely. Its limitations and its strengths need to be made clear to the decision makers. Only by participation in the whole process, from initial problem recognition, through scientific study, and then through societal action, will the geological approach reveal its full potential. In this time of environmental change, it is time that geologists emerge as leaders of the science best able to help society cope with that change.

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Note: Excerpted and modified from Baker, Victor R., 1994, Geological Understanding and the Changing Environment: Transactions of the Gulf Coast Association of Geological Societies, v. XLIV, p. 13–20. ■

April IEE-sponsored Events

The Roy Shlemon Mentors in Applied Geology program offers undergraduate seniors and graduate students the opportunity to learn about professional and intellectual challenges of careers in a broad range of applied environmental geosciences. The first workshops under this program will be presented in April at the GSA Cordilleran and Rocky Mountain section meetings. For more information, see the announcements for these meetings in the January and February issues of GSA Today.

For more information about the Institute for Environmental Education, or to become a member of IEE's Geology and Environment Public Outreach Program, contact Daniel Sarewitz, IEE Program Manager, P.O. Box 9140, Boulder, CO 80301, (303) 447-2020, E-mail: iee@geosociety.org.

GSA Welcomes PRI and AEG as Associated Societies

Associated Society status has been accorded to the Paleontological Research Institution (as of October 1994) and the Association of Engineering Geologists (as of November 1995) by the GSA Council. They are the fifteenth and sixteenth (respectively) societies to associate with GSA.

The Paleontological Research Institution (PRI) was organized in 1932 as a nonprofit entity to provide geoscientists an opportunity to conduct research on fossils and stratigraphy. The general goal of the institution is to increase understanding of the history of life on Earth through education, research, and its publications, notably *Bulletins of American Paleontology* and *Palaeontographica Americana*. PRI maintains a research facility and library in Ithaca, New York. Officers of the nearly 700 member organization are President John C. Steinmetz, Vice President Richard E. Petit, Secretary Henry W. Theisen, Treasurer Pamela Waite, and Past President J. Thomas Dutro, Jr.

The Association of Engineering Geologists (AEG) began as the California Association of Engineering Geologists in 1957, but was reconstituted as the Association of Engineering Geologists in 1963. The purpose of this international, nonprofit organization is the development of engineering geology solutions to societal problems through technical meetings, publications, and auxiliary activities. Currently, GSA has joined with AEG in publication of *Environmental and Engineering Geoscience*, a quarterly journal focused on topics in engineering, environmental, and ground-water geology.

This 3000 member organization is led by President Susan Steele Weir, Vice President Eldon M. Gath, Secretary Paul B. DuMontelle, Treasurer James H. May, and Past President Richard E. Gray.

GSA offers associated society status "for purposes of cooperation in annual, sectional, or divisional meetings, in publications, or in other appropriate ways." The Geological Society of America particularly looks forward to ventures of mutual interest in promoting the geosciences with both the Paleontological Research Institution and the Association of Engineering Geologists. ■

International Division News

James Skehan, S. J.

In preparation for the GSA Annual Meeting in Denver (October 1996), the International Division has proposed a program, "Tectonic Evolution of the Urals and Surrounding Basins" under the direction of James H. Knapp, convener and his European co-conveners. Jim Knapp is a Research Scientist at the Institute for the Study of the Continents at Cornell University.

The International Division, relatively new and small, has not yet reached a level of funding that would give us access to matching funds from the GSA Foundation in support of travel costs for non–North American speakers in symposia, etc. Following in the footsteps of my mendicant predecessors, I ask that you keep the International Division in mind as you make contributions to the GSA Foundation supplementary to the Division's dues. We wish also to increase our membership (at $5/yr) so as to expand our pool of those who are eligible for membership in committee activities in support of the Division's programs.

Friends of the Pan African (FOPA), a new working group of the International Division, was launched at the GSA Annual Meeting in Seattle (1994) and brings together scientists concerned with the geodynamics of Africa, with a special focus on isotope geochronology and metamorphic and structural geology. Contact Christopher I. Chalokwu, Dept. of Geology, Auburn University, Auburn, AL 36849.

CALENDAR

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

1996 Penrose Conferences

April

April 17–22, **Tectonic Evolution of the Gulf of California and Its Margins,** Loreto, Baja California Sur, Mexico. Information: Paul J. Umhoefer, Department of Geology, Box 4099, Northern Arizona University, Flagstaff, AZ 86011, (520) 523-6464, fax 520-523-9220, E-mail: pju@nauvax.ucc.nau.edu.

October

October 8–14, **Exhumation Processes: Normal Faulting, Ductile Flow, and Erosion,** Island of Crete. Information: Uwe Ring, Institut für Geowissenschaften, Universität Mainz Becherweg 21, D-55099 Mainz, Germany, 011-49-6131-392164, fax 011-49-6131-394769, E-mail: ring@mzdmza.zdv.uni-mainz.de.

1996 Meetings

April

April 18–21, **Dinofest International,** University Activity Center, University of Arizona Main Campus, Tempe. Information: ASU Public Events, (602) 965-5062. See this month's Sage Remarks page.

May

May 30–June 2, **Friends of the Pleistocene Pacific Northwest Field Conference:** Quaternary Glaciation and Tectonism on the Western Olympic Peninsula, Washington. Information: Glenn Thackray, Idaho State University, (208) 236-3560, E-mail: thacglen@isu.edu; or Frank Pazzaglia, University of New Mexico, E-mail: fjp@unm.edu.

June

June 8–9, **Geological Society of Malaysia 11th Annual Geological Conference:** Economic Geology and Tectonics of Malaysia and the Southeast Asian Region, Kota Kinabalu, Sabah. Information: Annual Geological Conference 1996, Geological Society of Malaysia, c/o Dept. of Geology, University of Malaya, 59100 Kuala Lumpur, Malaysia, phone 60-3-757-7036, fax 60-3-756-3900.

June 9–12, **GEORAMAN-96:** Raman Spectroscopy Applied to the Earth Sciences, Nantes, France. Information: David C. Smith, Museum National d'Histoire Naturelle, Lab. de Minéralogie, 61 Rue Buffon, 75005 Paris, France, phone 33-1-4079-3527, fax 33-1-4079-3524.

June 15–21, **Clay Minerals Society 33rd Annual Meeting,** Gatlinburg, Tennessee. Information: S. Y. Lee, Environmental Sciences Division, Oak Ridge National Laboratory, P.O. Box 2008, Bldg. 1505, MS-6038, Oak Ridge, TN 37831-6038, (615) 574-6316, fax 615-576-8646.

September

September 15–19, **Society for Organic Petrology 13th Annual Meeting,** Carbondale, Illinois. Information: John Crelling, Dept. of Geology, Southern Illinois University, Carbondale, IL 62901, (618) 453-7361, fax 618-453-7393, E-mail: jcrelling@geo.siu.edu.

September 23–27, **Balkan Geophysical Society First Congress,** Athens, Greece. Information: Congress Secretariat, Erasmus Horizon, Ltd., 34, Vassileos Georgiou B', 11635 Athens, Greece, phone 30-1-72-57-531 or 30-1-72-57-693-5, fax 30-1-72-57-532.

September 24–29, **Association of Engineering Geologists 39th Annual Meeting,** New Brunswick, New Jersey. Information: Dave Muscalo, P.O. Box 416, Butler, NJ 07405, phone and fax (201) 492-1157, E-mail: dmuscalo@aol.com. *(Call for papers deadline: May 1, 1996.)*

September 27–29, **27th Binghamton Geomorphology Symposium:** The Scientific Nature of Geomorphology, Urbana-Champaign, Illinois. Information: Bruce L. Rhoads or Colin E. Thorn, Dept. of Geography, University of Illinois, Urbana,

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GSA ANNUAL MEETINGS

1996

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

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

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

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

Call for Papers and First Announcement will be in the April issue of *GSA Today.*

EARTH SYSTEM SUMMIT Denver

1997

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

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

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

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

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

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

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

For general information on any meeting call the
GSA MEETINGS DEPARTMENT
1-800-472-1988 ***or*** **(303) 447-2020, ext. 133** ***or E-mail:*** **meetings@geosociety.org**
or see GSA's world wide web page at **http://www.geosociety.org**

GSA SECTION MEETINGS — 1996

SOUTH-CENTRAL SECTION, *March 11–12, 1996.* University of Texas, Austin, Texas. Information: Mark Cloos, Department of Geological Sciences, University of Texas, Austin, TX 78712, (512) 471-4170, fax 512-471-9425, E-mail: cloos@maestro.geo.utexas.edu.

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

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

ROCKY MOUNTAIN SECTION, *April 18–19, 1996.* Rapid City Civic Center, Rapid City, South Dakota. Information: Colin Paterson, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 East St. Joseph St., Rapid City, SD 57701-3995, (605) 394-5414, E-mail: paterson@silver.sdsmt.edu. *Preregistration Deadline: March 8, 1996.*

CORDILLERAN SECTION, *April 22–24, 1996.* Red Lion Hotel at Lloyd Center, Portland, Oregon. Information: Michael Cummings, Department of Geology, Portland State University, P.O. Box 751, Portland, OR 97207-0751, (503) 725-3022. E-mail: michael@ch1.pdx.edu. *Preregistration deadline: March 15, 1996.*

NORTH-CENTRAL SECTION, *May 2–3, 1996.* Iowa State University, Ames, Iowa. Submit completed abstracts to: Kenneth E. Windom, Department of Geological and Atmospheric Sciences, Iowa State University, 253 Science I Building, Ames, IA 50011-3210, (515) 294-2430, E-mail: kewindom@iastate.edu. *Preregistration Deadline: March 29, 1996.*

Student Travel Grants

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

Cordilleran .... Bruce A. Blackerby
(209) 278-2955

Rocky Mountain ..... Kenneth E. Kolm
(303) 273-3932

North-Central .... George R. Hallberg
(319) 335-4500

South-Central .... Rena M. Bonem
(817) 755-2361

Northeastern .... Kenneth N. Weaver
(410) 554-5532

Southeastern .... Harold H. Stowell
(205) 348-5098

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IL 61801, (217) 333-1880, fax 217-244-1785, E-mail: b-rhoads@ux1.cso.uiuc.edu or cetgeo@ux1.cso.uiuc.edu.

September 29–October 4, **Federation of Analytical Chemistry and Spectroscopy Societies (FACSS) 23rd Annual Conference,** Kansas City, Missouri. Information: FACSS, 201B Broadway St., Frederick, MD 21701-6501, (301) 846-4797. *(Deadline for 100 word brief: March 29, 1996.)*

October

October 2–4, **Gulf Coast Association of Geological Societies and Gulf Coast Section SEPM Meeting,** San Antonio, Texas. Information: Thomas E. Ewing, Venus Exploration, 700 N. St. Mary's, San Antonio, TX 78205, (210) 222-9481, E-mail: sa96@aol.com.

October 13–15, **27th Underwater Mining Institute,** Washington, D.C. Information: Karynne Chong Morgan, Underwater Mining Institute c/o Marine Minerals Technology Center, 811 Olomehani St., Honolulu, HI 96813-5513, (808) 522-5611, fax 808-522-5618, E-mail: 70673.534@compuserve.com. *(Abstract deadline: March 31, 1996.)*

October 30–November 1, **Earthquake Resistant Engineering Structures First International Symposium,** Thessaloniki, Greece. Information: Sue Owen, ERES 1996 Conference Secretariat, Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton SO40 7AA, UK, phone 44-1703-292-223, fax 44-1703-292-853, E-mail: wit@wessex.witcmi.ac.uk. *(Abstract deadline: March 31, 1996.)*

Send notices of meetings of general interest, in format above, to Editor, *GSA Today,* P.O. Box 9140, Boulder, CO 80301, E-mail: editing@geosociety.org.

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Positions Open

STATE GEOLOGIST OF ALABAMA

The University of Alabama invites nominations and applications for the position of State Geologist of Alabama. The state geologist is the chief administrative officer of the Geological Survey, established in 1848, and also serves as state oil and gas supervisor and secretary of the State Oil and Gas Board. The Survey is one of the major such organizations in the country with a total current budget of approximately $5.1 million. In addition to proven administrative ability, candidates must have as a minimum a master's degree in geology and substantial experience in some phase of geology and petroleum exploration and/or production. Preference will be given to candidates with the Ph.D. in geology or a closely-related earth science discipline. The salary is negotiable. Nominations and applications (including resumes) should be sent before April 8, 1996, to: Dr. Chester Alexander, Chairman, Search Committee for State Geologist, Office for Academic Affairs, The University of Alabama, Box 870114, Tuscaloosa, Alabama 35487-0114, calexand@rosie.aalan.ua.edu.

The Geological Survey/State Oil and Gas Board of Alabama is an Affirmative Action/Equal Opportunity Employer.

GEOLOGICAL ENGINEERING MONTANA TECH

The Department of Geological Engineering at Montana Tech invites applications for a tenure-track position in hydrogeology/geochemistry. The appointment will be at the rank of Assistant Professor starting in August 1996. A Ph.D. is required at the time of appointment. Registration as a Professional Geologist or Engineer is not required at the time of appointment, but is a prerequisite for tenure and promotion to the rank of professor. The candidate must possess the demonstrable ability to blend aqueous or/and isotope geochemistry and hydrogeology. The successful candidate will be expected to teach a rigorous introductory course in groundwater hydrogeology and other core courses in the undergraduate program, as well as courses in their areas of specialization. He or she should have a strong commitment to teaching, as well as to research and publication. Montana Tech is a unit of the University of Montana with an enrollment of approximately 2,000 students. The college has a strong tradition of undergraduate and graduate engineering instruction and research related to the mining and energy industries, with more recent emphasis on hydrogeological and environmental engineering. Montana Tech also offers degrees in chemistry and geochemistry, mathematics, computer science, occupational safety and health, business, and in the liberal arts. Montana Tech is located at Butte, in beautiful and geologically interesting southwestern Montana. There

REMINDERS

Materials and supporting information for any of the following nominations may be sent to GSA Executive Director, Geological Society of America, P.O. Box 9140, Boulder, CO 80301. For more detailed information about the nomination procedures, refer to the October 1995 issue of *GSA Today,* or call headquarters at (303) 447-2020, extension 188.

JOHN C. FRYE ENVIRONMENTAL GEOLOGY AWARD

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

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

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

NATIONAL AWARDS

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

STRUCTURAL GEOLOGISTS

Houston, Texas

Amoco's Exploration and Production Technology Group in Houston, Texas is soliciting applications for two structural geologists to join an existing team within its Geoscience Technology Division. The Structural Geology Team is a small group of geoscientists and associated support staff that provide business-driven technical service, consulting and technology development in the fields of structural geology and remote sensing for Amoco's worldwide exploration and production operations.

The new positions will have primary responsibility in the areas of fault characterization, fault and fracture networks, and the sealing properties of faults. Overall responsibilities will, however, be broader, and will benefit from experience in rock mechanics, microstructural analysis, kinematic analysis and field structural geology.

One of these two positions will fill a need to support customer-focused structural analyses and consulting requests from Amoco's worldwide business units. Prospective candidates should have a Master's or Ph.D. degree in geology or geophysics, with an emphasis on structural geology. The second position is an R&D assignment in the areas of primary responsibility listed above, and is expected to bring new directions and capabilities to our technology development portfolio. For this position, a Ph.D. degree with experience in the relevant subject area is required. For either position, prospective candidates should have a broad background in structural geology, good business focus and interpersonal skills, and a quantitative orientation with strong computer skills. Candidates either at entry level or with experience will be considered.

Amoco offers a highly competitive salary/benefits package. For confidential consideration, send resume with salary history to:

Amoco Corporation

Amoco Corporation
P.O. Box 3092
JS#9, M/C 1.126
Houston, TX 77253-3092

Equal Opportunity Employer -
No Phone Calls or Agencies, Please.

are abundant opportunities for outdoor recreation in the immediate area. Application deadline is April 15, 1996. Filling this position is contingent upon funding. Applicants should forward a resume; a description of their teaching and research interests; and the names, addresses, and telephone numbers of three references to: Chair, Search Committee, Department of Geological Engineering, Montana Tech, 1300 West Park St., Butte, Mont. 59701-8997. Montana Tech is an affirmative-action/equal opportunity employer.

ENVIRONMENTAL STUDIES / DEPT. OF GEOLOGY
BOWLING GREEN STATE UNIVERSITY

The Center for Environmental Studies and the Department of Geology invite applications for a joint tenure-track position in Geology and Environmental Studies. The successful candidate will have experience in interdisciplinary approaches to environmental studies and an environmentally oriented research program that can lead to tenure in the Dept. of Geology. Fields of expertise and research interests should include one or more of the following: soils, geomorphology, glacial geology, engineering geology, and/or hydrology. A working knowledge of and experience with teaching applications of GIS and/or computer modeling is desirable. Ph.D. in Geology, Environmental Science, Environmental Engineering, or related field is required for appointment. The successful candidate will teach undergraduate and graduate courses in Environmental Science and Geology, maintain an active research program, and supervise master's level graduate students. Senior level Environmental courses include field-based projects requiring students to integrate geological data into interdisciplinary studies. Facilities include: remote sensing laboratory; Sun and Silicon Graphics workstations; large format digitizer; HP650C E-size plotter; SPARC 1000 server; ARC/INFO; ERMapper; AVS; complete geochemistry laboratory (XRD; SEM; AAS; TEM); geophysical facilities (magnetometer, gravity meter, shallow seismic, resistivity, GPS); microscopy laboratory, including transmitted, reflecting, cathodoluminescence, and fluid inclusion microscopes; complete sample preparation facilities; and field vehicles.

Applications, including a complete resume with a statement of teaching and research interests and 3 original letters of recommendaiton, should be sent to: Dr. J. J. Mancuso, Department of Geology, Bowling Green State University, Bowling Green, OH 43403. Deadline is March 15, 1996 or until the position is filled. Bowling Green is an AA/EEOC employer. Applicants from under-represented/protected groups are urged to apply.

THE UNIVERSITY OF TEXAS AT EL PASO
ASSISTANT/ASSOCIATE PROFESSOR
SEDIMENTARY GEOLOGIST
DEPARTMENT OF GEOLOGICAL SCIENCES

UTEP's Dept. of Geological Sciences is seeking a sedimentary geologist with primary interests in clastic sedimentary processes & depositional environments. We are seeking a person with active research interests in the origin, characteristics, transport, & deposition of clastic sediments. Reservoir or aquifer characterization & modeling are also appropriate fields of research interest. UTEP graduates enter both the resource & environmental fields; the person in this position should be able to teach courses in sedimentology, sedimentary petrology, & physical stratigrahy/despositional systems appropriate to these career paths. Research excellence & ability to obtain funding for research will be of fundamental importance. In addition, a commitment to excellence in both undergraduate & graduate instruction is essential. Position is tenure-track & qualified persons will be considered for Assistant, Associate or Full Professor appointment. Position is available 09-01-96. Ph.D. required at time of appointment.

UTEP offers bachelors, masters, & Ph.D. degrees in geological sciences. The dept & many of its faculty participate in the new multi-disciplinary Environmental Science & Engineering Ph.D. Program. The Dept of Geological Sciences offers many modern laboratory & classroom facilities located in one of the most diverse & striking geological terrains in the world.

Submit letter of interest describing research & teaching interests to pursue at UTEP, resume, & listing of three references (name, addresses, phone, & fax numbers) to Dr. Charles G. Groat, Chair Search Committee, UTEP, Department of Geological Sciences, El Paso, TX 79968-0555. The University does not discriminate on the basis of race, color, national origin, sex, religion, age, or disability in employment or the provision of services.

Services & Supplies

Opportunities for Students

JOI/USSAC Ocean Drilling Fellowships. JOI/U.S. Science Advisory Committee is seeking doctoral candidates of unusual promise and ability who are enrolled in U.S. institutions to conduct research compatible with that of the Ocean Drilling Program. Both one-year and two-year fellowships are available. The award is $20,000 per year to be used for stipend, tuition, benefits, research costs and incidental travel, if any. Applicants are encouraged to propose innovative and imaginative projects. Research may be directed toward the objectives of a specific leg or to broader themes. The award aims to encourage student participation on board ODP's drillship, *JOIDES Resolution.*

April 15, 1996 is the shipboard fellowship application deadline for the following legs: Leg 170 Costa Rica, Leg 171 Barbados LWD-Blake Nose, Leg 172 NW Atlantic Sediment Drifts, Leg 173 Iberia, Leg 174 New Jersey Margin, and Leg 175 Benguela Current.

Staffing for these legs will begin during the next few months. Students interested in participating as shipboard scientists must apply to the ODP Manager of Science Operations in College Station, TX. A shipboard scientist application form and leg descriptions are included in the JOI/USSAC Ocean Drilling Fellowship application packet. For more information and to receive an application packet contact: Andrea Johnson, JOI/USSAC Ocean Drilling Fellowship Program, Joint Oceanographic Institutions, Inc., 1755 Massachusetts Ave., NW, Suite 800, Washington, DC 20036-2102 (telephone: 202-232-3900, ext. 213; Internet: ajohnson@brook.edu).

POSITION ANNOUNCEMENT

Science Counsel
National Ground Water Association

The not-for-profit National Ground Water Association (NGWA) seeks a recognized ground water professional with at least 10 years high-level experience to provide sound scientific and technical direction and support internally, as well as external visibility at scientific forums. The position requires an articulate, well-rounded ground water professional with a strong desire to lend their vision and energy to maintain the quality of NGWA programs

The preferred candidate will have an M.S. or Ph.D. in hydrogeology, civil/environmental engineering, geology or a closely related discipline, a thorough grasp of water resources issues, and scientific and engineering literature of these areas. The position reports directly to the Executive Director. Relocation to Columbus is highly desirable.

Interested individuals are urged to respond by April 1 with a resume, names and addresses of four professional references, a one-page statement of professional interests and qualifications for the position (including identification of past and current NGWA involvement), and an identification of compensation expectations. The candidate should also describe how he or she could provide exemplary service to the organization without relocating to Columbus if no move is contemplated. Applications should be sent to:

national ground water association

Kevin McCray
Executive Director
National Ground Water Association
2600 Ground Water Way
Columbus, OH 43219

NGWA is an equal opportunity employer.

UK UNIVERSITY OF KENTUCKY
Kentucky Geological Survey

GEOLOGIST V/ GEOLOGIC EDITOR

The Kentucky Geological Survey seeks to fill the position of Geologic Editor. Responsible for the supervision of editorial and technical drafting staff, the editing of technical manuscripts and maps, and the preparation of a variety of materials for publication.

Minimum requirements are a Ph.D. and three years related work experience, or the equivalent (Master's and 9 years, etc.). Requires documented research experience in geology, demonstrated writing skills and documentable editorial experience. Knowledge of computer drafting techniques needed. Successful applicants should be familiar with the processes involved in printing both manuscripts and maps, and also be capable of presenting complex information in a simple, readable, and accurate manner. Deadline for receipt of letter of application and resume is March 30, 1996, but may be extended if additional applications are necessary.

Applicants must be able to perform all essential job functions as identified in position description; copy available to candidates selected for interview. Reply to #313203, Human Resources/Employment, 112 Scovell Hall, Lexington, KY 40506-0064.

The University of Kentucky is an equal opportunity employer and encourages applications from minorities and women.

Send abstracts for the Denver meeting via the WWWeb

Jim Clark, GSA Production and Marketing Manager

Starting on or about May 1, abstracts for this year's Annual Meeting in Denver can be sent to GSA via the World Wide Web (Web). At that time, our new electronic system for abstract submission will be available, to be used at first for annual meeting abstracts only. In development for more than a year, the system has been tested extensively. Note that you can only send abstracts to GSA via the Web. They may **not** be sent by ordinary E-mail.

For the present, this system will accept only abstracts containing pure ASCII content; no graphics, tables, symbols, Greek, superscripts, etc. may be included. If you must use any of that in your abstract, use the paper form for now. We hope to be able to include non-ASCII material in the future, but for most users the technology for that is not yet in place.

However, if your entire content—title, addresses, and abstract body—is pure ASCII and you have access to the Web, the new system will make life much easier by eliminating the more onerous tasks usually connected with preparation of paper forms: scrambling for blank forms; printing and reprinting, then cutting and pasting to fit boxes; making multiple copies to send; and often paying a heavy toll for express-service delivery to meet the deadline.

We recommend that you compose your abstract in your favorite word processor. When you have finished, "save" it as "text." This will convert your data into pure ASCII. Then copy and paste this into the appropriate fields of the GSA Web form. Complete the personal information on the form, and you'll be ready to send it. We've included instructions, pull-down lists, and helpful hints on the Web form to save you time and confusion. There's even an error checker to make certain you include all the information we must have.

The best part is that it takes only a few seconds to send an abstract, and even less to get feedback from GSA. There will be no more mystery about whether we received your submission. You'll receive an *immediate* confirmation of receipt from GSA, with an abstract number assigned, while you're still on the Web.

The new system will not yet replace the familiar paper version of GSA's abstract form. Rather, the two systems will operate in parallel for another year, or until it is clear that most authors prefer the electronic method. Paper forms already have been distributed for 1996, and still can be obtained from GSA's Abstracts Coordinator (E-mail ncarlson@geosociety.org).

About March 1, you will be able to test our new system, strictly on a "get acquainted" basis. *Nothing* you send via this form before May 1 will be saved at GSA or considered by GSA for any meeting. Although you will receive an acknowledgment of receipt on any test abstracts you send, that is just part of the test, too, and is meaningless.

To get acquainted with the form from March 1 to May 1, go to GSA's Home Page on the Web (http://www.geosociety.org). There you'll find the link, "TEST DRIVE GSA's Web Abstract Form." Just follow the instructions from there. If you discover any glitches in our system during a test, please send a detailed E-mail message to: pubs@geosociety.org. Please include your telephone number so we can call if more details are needed.

On or about May 1, the TEST DRIVE link will change to "SUBMIT an Abstract." When you see that message, you'll know we're in live mode, ready to take your abstract for the Denver meeting.

The success of this new system will determine whether, and how soon, it may be used for meetings of GSA Sections, as well. Watch this publication for further announcements. ■