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The Record of Terrestrial Impact Cratering

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ABSTRACT

Approximately 150 terrestrial impact structures are currently known, representing a small, biased sample of a much larger population. The spatial distribution indicates concentrations in cratonic areas—in particular, ones where there have been active search programs. The majority of the known impact structures are <200 m.y. old, reflecting the increasing likelihood of removal by terrestrial geologic processes with increasing geologic age. There is also a deficit of structures <20 km in diameter, due to the greater ease with which smaller features can be removed. Their form is similar to impact craters on other planetary bodies, although comparisons must be made with caution, because of the modifying effects of erosion. Erosion and burial by postimpact sediments can affect estimates of the most fundamental parameters, such as diameter. The contents of compilations of terrestrial impact structures such as presented here, therefore, vary in reliability, with respect to the principal characteristics of individual structures, and are subject to ongoing revision. Nevertheless, it is possible to estimate a cratering rate similar to independently derived rates, based on astronomical observations.

INTRODUCTION

The first studies of a terrestrial impact structure, of the now famous Meteor or Barringer Crater, Arizona, in the early 1900s by D. M. Barringer and colleagues, produced more controversy than acceptance. There was, however, a gradual increase in the number of recognized small craters with meteorite fragments until the 1960s, when so-called shock metamorphic effects became reliable criteria for assigning an impact origin to specific enigmatic terrestrial structures (e.g., see papers in French and Short, 1968). This resulted in a major increase in the number of recognized impact structures. The results of the planetary exploration programs of the 1970s demonstrated the ubiquitous nature of impact in the solar system, and studies of terrestrial impact structures provided a source of ground truth data for the interpretation of the planetary cratering record. These led to a more general acceptance of terrestrial impact structures by the geoscience community, but impact was regarded largely as a “planetary” process, with little relevance to Earth history.

This began to change in the early 1980s, following the discoveries of evidence of impact at the Cretaceous-Tertiary (K-T) boundary. Originally hotly debated, the discoveries at the K-T boundary and of the Chicxulub structure in Yucatán, Mexico, have led to increasing consensus that, at least in this case, large-scale impact can result

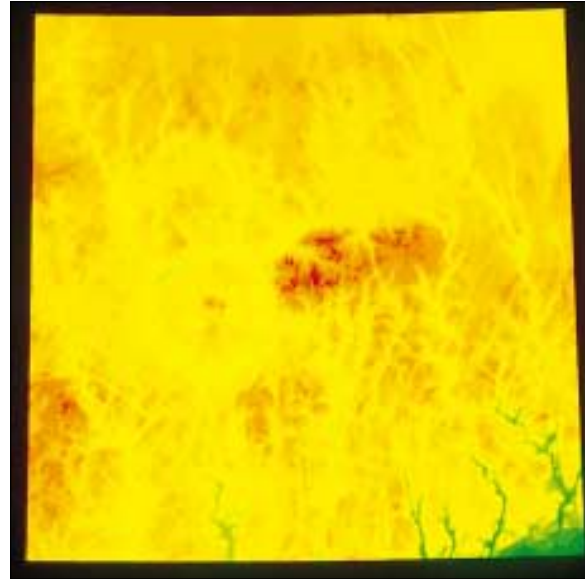


Figure 2. Topography of the Manicouagan complex impact structure, Quebec, Canada. The original diameter of this 214 ± 1 Ma structure is estimated to have been 100 km. Erosion, however, has removed the rim, and the structure appears as a series of circular features with positive and negative relief, beginning with a 150-km-diameter outer fracture zone, seen most easily in the western and southern sectors, and culminating in slightly off-center topographic peaks. The annular Manicouagan reservoir (dark green area slightly left of center) is ~65 km in diameter and at ~360 m elevation. Elevations in the center are as much as ~1100 m (brown).



Figure 3. World map indicating locations of currently known terrestrial impact structures. Note concentrations of impact structures in Australia, North America, and northern Europe—western Russia.

in sufficient deterioration to the environment to result in a mass extinction. The progress of the debate regarding the involvement of large-scale impact at the K-T boundary can be gauged from papers in Silver and Schultz (1982) and Sharpton and Ward (1990). Currently, there is considerable activity in the area of the hazard to human civilization posed by impact (e.g., papers in Gehrels, 1994).

The presence of impact structures, however, still does not figure highly in general descriptions of the terrestrial geologic environment. The highly active geologic environment of Earth has served to remove, mask, and modify the terrestrial impact record throughout geologic time, making it less obvious and harder to read than that of the other terrestrial planets. The known impact record is a biased sample of a larger population and is the result of the combination of impact and endogenic terrestrial geologic processes. About 150 terrestrial impact craters or crater fields, consisting of clusters of relatively small craters, are currently known, and about three to five new ones are discovered each year. The last widely circulated listing of terrestrial impact craters by Grieve and Robertson (1987) is a world map, sponsored by the International Union of Geological Sciences Commission on Comparative Planetology, which lists 116 features. Here, we update that listing and review the basic character of the terrestrial impact record. We pay

particular attention to the inherent biases in the record, as they must be accommodated when drawing inferences from the known record.

THE KNOWN RECORD

Planetary impact craters are recognized by their morphology. Terrestrial impact craters are recognized not only by their morphology but also by their geologic structure. In the most highly eroded examples, terrestrial impact craters no longer have an obvious crater form and are recognized by their geologic characteristics. They are no longer craters, by definition, and are best referred to as impact structures. To avoid confusion and arbitrary definitions, we refer to all terrestrial impact craters as impact structures, regardless of their state of erosion.

All known terrestrial impact structures (Table 1) have evidence of an impact origin, through the documented occurrence of meteoritic material and/or shock metamorphic features. To various degrees they also have several other aspects in common, such as form, structure, and geophysical characteristics. Some of the known terrestrial structures have some of these aspects but lack documented shock metamorphic features. Although some of these are more than likely impact-origin features, they are not included in Table 1, for consistency. Events



Figure 1. Oblique aerial photograph of the 1.2-km-diameter Barringer or Meteor Crater. This relatively well preserved example of a simple impact structure still retains some of its ejecta blanket, seen here as the hummocky deposits exterior to the rim.

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Daniel Sarewitz Appointed IEE Program Manager

A belief that environmental problems can and should define a leading edge in the science for the foreseeable future and a well-developed interest in forming better linkages between science and society characterize the attributes sought for the Program Managership in GSA's Institute for Environmental Education (IEE). Daniel R. Sarewitz not only fulfilled these attributes, but brings to the position broad-based experience in public policy as well as education.

Sarewitz previously served as a Congressional Science Fellow under GSA sponsorship (1989-1990) in the office of U.S. Congressman George E. Brown, Jr. Additionally, Sarewitz has served as science consultant to the U.S. House of Representatives Committee on Science, Space, and Technology, and he generated numerous policy-related publications, opinion papers, and speeches in concert with these Washington-based activities.

However, it was the vigorous, proactive role that Dan Sarewitz envisioned for IEE and GSA in dealing with environmental issues, as well as his sound working knowledge of GSA, that most deeply impressed the Search and Executive Committees in making the appointment. In particular, his desire to see GSA take an active role as media-

tor in discussions on environmental issues offers a real challenge for the IEE enterprise. Sarewitz will use the GEPOP (Geology and Environment Public Outreach Program) membership in addressing this and other IEE matters.

Sarewitz received his B.S. degree, with honors, in geology from Haverford College in 1978, his M.S. from Oregon State University in 1983, and his Ph.D. in geology in 1986 from Cornell University. In addition to his congressional experience, he has served as a post-doctoral research associate and lecturer at Cornell. More recently he has devoted his talents to freelance writing and has just completed a book dealing with science, technology, and politics that will be published in spring 1996. He joined the GSA headquarters staff in September. ■



Daniel
Sarewitz

GSA Honors 50-Year Fellows

Ralph S. Cannon, Jr.
Doak C. Cox
William H. Easton
Ross R. Heinrich
Clifford N. Holmes
Harold L. James
John B. Lyons
Paul R. Shaffer
Frank C. Whitmore, Jr.
Mary C. Vogt Woodland
Hatten S. Yoder, Jr.

In Memoriam

Cesare Emiliani
Palm Beach Gardens, Florida

Laurence M. Gould
Tucson, Arizona
June 21, 1995

G. Duncan Johnson
Macon, Georgia
July 26, 1995

About People

GSA Fellow **Clarence Allen**, California Institute of Technology, Pasadena, will receive the 1995 Medal of the Seismological Society of America, awarded for outstanding contributions in seismology or earthquake engineering.

Member **Robert G. Marvinney**, Readfield, Maine, has succeeded Fellow **Walter A. Anderson** as Maine's state geologist and director of the Department of Conservation's Maine Geological Survey.

The Geological Association of Canada has instituted a medal for public awareness of geoscience in honor of GSA Fellow **E. R. Ward Neale**, Calgary, Alberta, Canada.

Fellow **Stuart Rojstaczer**, Duke University, Durham, North Carolina, has been named director of the university's new Center for Hydrological Science.

Member and former GSA Congressional Science Fellow **Craig M. Schiffries**, Washington, D.C., has been appointed director of the Board on Earth Sciences and Resources of the National Research Council.

Fellow **Peter Wyllie**, California Institute of Technology, Pasadena, has been elected president of the International Union of Geodesy and Geophysics for 1995-1999.



GSA ON THE WEB

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

1995 GSA Annual Meeting Technical Program: for New Orleans NOW AVAILABLE! Go to **Meetings** and choose **1995 Annual Meeting**. The *GSA Annual Meeting Program* is available in both Macintosh and DOS operating system formats. You will be able to select one or both for download. This area also contains information about field trips, continuing education, exhibits, travel, lodging, and registration.

If you want to know more about the GSA Employment Service or about becoming a GSA Campus Representative, check the **Membership** section, which also has information

on nominating a member to fellowship and on obtaining forms for applying to become a GSA Member or Student Associate.

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

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

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

GSA Congressional Science Fellow Named for 1995–1996

Peter F. Folger has been selected as the tenth GSA Congressional Science Fellow. He will work as a special legislative assistant on the staff of a committee or member of the U.S. Congress from September 1995 through August 1996.

As a Congressional Science Fellow, Folger hopes to work on issues spanning resource development and environmental preservation, as well as public health policies, and to gain experience in the knowledge-transfer process between the scientific community and policymakers. Folger expects to apply his experiences in private industry, government research, and academia to the complicated issues of formulating a proper balance between resource development and economic and environmental impact.

Folger received his Ph.D. in geological engineering in 1995 from the Colorado School of Mines. His principal research interests and training are in the fields of hydrogeology, economic geology, and geochemistry, with special emphasis on water quality and radon concentration. From 1989 to 1991, his industry experience included managing a geochemical programs group and working as a project geologist at the Rocky Flats Plant in Colorado. Prior to that, he was a geologist for AMAX Exploration for two years. Folger received an A.B. with distinction in geology from Dartmouth College in 1982, and a masters in geology in 1988 from the University of Montana.

The Fellowship

The Congressional Science Fellowship gives a geoscientist first-hand experience with the legislative process and the opportunity to view science policy issues from the lawmaker's perspective. At the same time, the Fellow assists in the analysis of public policy



Peter F. Folger

issues by providing scientific and technical expertise.

Funded by GSA and by a grant from the U.S. Geological Survey, the fellowship demonstrates the value of science-government interaction and relates the need for informed involvement to the earth science community. The program places highly qualified, accomplished scientists with the offices of individual members of Congress or committees for a one-year assignment. Fellows perform in much the same way as regular staff members; they have the opportunity to be involved in varied legislative, oversight, and investigative activities. They offer their special knowledge, skills, and competence for the opportunity to acquire experience and the chance to contribute to the formulation of national policy. The Fellow reports periodically to the GSA membership and to the U.S. Geological Survey during the one-year period.

Requirements for the fellowship include exceptional competence in some area of the earth sciences, cognizance of a broad range of matters outside the Fellow's particular area, and a strong interest in working on a range of public policy problems. Fellows attend a two-week orientation conducted by the American Association for the Advancement of Science. ■

Membership Input Needed on GSA Long-Range Planning

A special long-range planning session has been called by President Dave Stephenson during the New Orleans Annual Meeting. Council members and section representatives will be considering issues and challenges facing the Society, including:

- the focus of GSA as a generalist society
- improved member services and member-related issues and concerns
- the role of GSA and the decade of revolution in the earth sciences.

The membership is invited to participate in this process, and President Stephenson would like to hear from you directly. Recent surveys and studies have been helpful; however, your personal participation is an important part of the process in providing vision and future direction for the Society. Please direct your thoughts or comments by **October 31** to:

President Dave Stephenson
Geological Society of America
P.O. Box 9140, Boulder, CO 80301
Fax: 303-447-1133, E-mail: gsa@geosociety.org

GSA Committee on Geology and Public Policy

EVENTS AT THE 1995 ANNUAL MEETING

Wednesday, November 8, Ernest N. Morial Convention Center, New Orleans, Louisiana

Earth Scientists on Capitol Hill (12:00–1:00 p.m.)

GSA's ninth Congressional Science Fellow Jill S. Schneiderman has worked in the office of Senator Thomas Daschle (D—SD) for the past year. Schneiderman was involved in national environmental and natural resource policies, particularly forest and mining issues, and Missouri River and water-quality issues.

At this open session, Schneiderman will report about her experiences on the Hill and discuss some means by which earth scientists may become more effective in the public policy sphere. Geology and Public Policy Committee members will comment on how scientists can provide expertise to the U.S. Congress, on the role of the GSA Science Fellow program, and on the process to apply for the fellowship.

Funded by GSA and by a grant from the U.S. Geological Survey, the GSA fellowship demonstrates the value of science-government interaction, and relates the need for informed involvement to the earth science community. ■

Geology and Public Policy Forum (1:00–2:30 p.m.)

**GEOLOGY'S FUTURE:
PERSPECTIVES FROM THE U.S. GEOLOGICAL SURVEY, STATE SURVEYS,
ACADEMIC INSTITUTIONS, AND THE PRIVATE SECTOR**

The annual GSA Geology and Public Policy Committee forum will take a look into the future and discuss the role of geology and geologists in light of changing public and government attitudes toward science, research, and environmental priorities. Recent issues being addressed in Congress may have serious consequences for the direction of our profession.

The U.S. Geological Survey and some state surveys have been targeted for complete elimination or severe budget cutbacks. The value of their projects for the public benefit is being questioned. Academic institutions are revisiting and revising curricula to place less emphasis on the dwindling resource recovery industry and to make those curricula more relevant to today's job market. A scan of recently advertised academic positions indicates a trend toward the fields of environmental geology and hydrogeology. In the private sector, more geologists are finding work in the environmental consulting arena than in most other areas. At the same time, environmental legislation passed to date is being closely scrutinized by Congress, and government-funded restoration programs are coming under fire for being wasteful and showing lack of progress.

While the current reinvention of government can be viewed as a threat to geologists and to scientists in general, we can also seize it as an opportunity to revitalize the role of our science in the future. As scientists dealing with the planet on which we live, we should play an instrumental part in its use and sustainability. However, unless we can better define our potential contributions and the importance of geological information, we may be left behind as society advances further into the information and technology age. The geoscience community must become more active and vocal at this critical time.

Forum participants include:

- Patrick Leahy, Chief Geologist, U.S. Geological Survey, Reston, Virginia
- Victor R. Baker, Professor of Geology, Department of Geosciences, University of Arizona, Tucson
- John J. Amoroso, Independent Oil Consultant, Houston, Texas
- William L. Fisher, University of Texas–Austin, retired State Geologist of Texas, and former Assistant Secretary of Interior
- Richard E. Wright, Wright Associates, Inc., Middletown, Pennsylvania

The forum will be in panel discussion format. Each participant will have 15 minutes, followed by comments and observations of panel members. Questions and comments from the audience will conclude the forum. ■



The Geological Society of America

Congressional Science Fellowship 1996–1997

The Geological Society of America is accepting applications for the 1996–1997 Congressional Science Fellowship. The Fellow selected will spend a year (September 1996–August 1997) in the office of an individual member of Congress or a congressional committee for the purpose of contributing scientific and technical expertise to public policy issues and gaining firsthand experience with the legislative process. The American Association for the Advancement of Science conducts an orientation program to assist the Fellow seeking a congressional staff position in which he or she can work on major legislative issues.

Criteria

The program is open to highly qualified postdoctoral to mid-career earth scientists. Candidates should have exceptional competence in some area of the earth sciences, cognizance of a broad range of matters

outside the Fellow's particular area, and a strong interest in working on a range of public policy problems.

Award

The GSA Congressional Science Fellowship carries with it a \$42,000 stipend, and limited health insurance, relocation, and travel allowances. The fellowship is funded by GSA and by a grant from the U.S. Geological Survey. (Employees of the USGS are ineligible to apply for this fellowship. For information about other programs, contact AAAS or the Geological Society of America.)

To Apply

Procedures for application and detailed requirements are available in the geology departments of most colleges and universities in the United States or upon request from: Executive Director, Geological Society of America, P.O. Box 9140, Boulder, CO 80301.

DEADLINE FOR RECEIPT OF ALL APPLICATION MATERIALS IS FEBRUARY 1, 1996

WASHINGTON REPORT

Bruce F. Molnia

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

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

CODATA Survey on Transborder Data Flow—Will You Help?

Since the inception of *GSA Today* in 1991, many Washington Reports and Forums have dealt with numerous aspects of scientific data, its availability, and its flow. During these five years, a global technology explosion has occurred, the result of which is virtually instantaneous electronic global data and information exchange. Desktop computers provide inexpensive data storage, handling, and processing capability that exceeds the capacity of

the largest computer in existence less than a quarter of a century ago.

A whole new generation of data problems and issues has also evolved. Scientists commonly encounter barriers in gaining access to data relevant to their research. These barriers, both technical and nontechnical, have been a topic of increasing concern in recent years. Sheer volume has been one factor, but by no means the only one. The integration of multidisciplinary data on an international basis to address prob-

lems such as global environmental degradation or disease epidemics raises new challenges.

To understand many aspects of these issues, the National Academy of Sciences—National Research Council (NAS-NRC) has organized a study, chaired by R. Stephen Berry of the University of Chicago, to investigate the barriers and other issues in the transborder flow of scientific data. The primary focus of the study is on data in electronic forms, a topic of increasing

complexity and importance in scientific research and international collaboration. The study will outline the needs for data in the major research areas of current scientific interest in the natural sciences. Additionally, the study will characterize legal, economic, policy, cultural, and technical factors and trends that influence access to data. The study will attempt to identify and analyze barriers to international access to scientific data that could have the most adverse impact in the natural sciences. The emphasis will be on factors common to all disciplines.

According to Berry and Paul F. Uhlir, Director of the NRC Committee on Data for Science and Technology (CODATA), the goal of the study is to help improve access to scientific data and services internationally. The result of the study will be formulation of recommendations that will be presented to the federal government and the scientific community. The recommendations will identify approaches that could help overcome barriers to data access internationally.

CODATA is an interdisciplinary committee organized under the International Council of Scientific Unions (ICSU), a nongovernmental organization created in 1931 to promote international scientific activity and its application to humanity in the different branches of science. According to CODATA's charter, the committee is concerned with all types of quantitative data resulting from experimental measurements or observations in the physical, biological, geological, and astronomical sciences. CODATA's general objectives include improvement of the quality and accessibility of data, as well as the methods by which data are acquired, managed, and analyzed; facilitation of international cooperation among those collecting, organizing, and using data; and promotion of an increased awareness in the scientific and technical community of the importance of these activities.

In order to obtain broad input from the users and suppliers of scientific data, the study committee has developed an "Inquiry to Interested Parties," requesting information on: barriers to data access, pricing of data, protection of intellectual property, problems of less developed countries, scientific data for global problems, use of electronic networks, and other technical issues. *GSA Today* readers interested in providing input to the study are invited to respond to this inquiry, which is presented on p. 193. The inquiry can also be found on CODATA's World Wide Web home page, which can be accessed at the following address: <http://www.cisti.nrc.ca/codata/welcome.html>.

Berry and Uhlir ask that you assist them by responding to and returning the inquiry. You may skip any questions that you do not feel you can address meaningfully, and you can add any points that you would like them to know or consider. Please send your response and any related documenta-

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Data Flow continued on p. 193

Data Flow continued from p. 192

tion by January 31, 1996, to: Paul Uhlir, USNC-CODATA, NAS/NRC, 2101 Constitution Avenue, N.W., Washington, DC 20418, (202) 334-3061, fax 202-334-2154; Internet: BITS@NAS.EDU.

Inquiry to Interested Parties on Issues in the Transborder Flow of Scientific Data

Please provide the following information:

Name, Address, Telephone/fax/E-mail (optional).
Brief description of your data activities and discipline background.
Are you answering this questionnaire as a scientific data: user, producer, distributor, vendor, system manager, network operator, policymaker, or other? Check all that apply.

1. *Barriers to Data Access.* Some restrictions on access to scientific data frequently are considered necessary to protect various interests as well as the integrity of the data. In your experience, have restrictions on data been a problem? Can you identify any specific impacts or trends? Please explain.

2. *Pricing of Data.* If you use data for scientific research, please tell us: (a) What data sets you have recently used for which you or your institution paid nothing, and in what form you got these data (e.g., World Wide Web, other on-line, CD-ROM, diskette, tape, film, paper, etc.)? (b) What data have you recently used for which you paid any amount (including the cost of reproduction or communication connectivity); in what form did you get these data, how were you charged (e.g., flat rate, charge per use, etc.), and how much? (c) What data would you like to use for your research, but consider them too expensive/costly? What is the cost of such data and what is their value (apart from cost)? (d) For the data listed under (c) above, what arrangements could help make these data available to you? In what form would you like to be able to get these data? If you supply data for scientific research (and perhaps for other uses), please tell us: (e) Are you a profit-making enterprise?; if not, what is the form and intent of your organization? (f) What kind of data do you supply that are used by scientific researchers? (g) Besides scientific researchers, what kind of other users of your data are there, if any? (h) Do you provide special pricing for research/academic users? If so, what is your pricing policy? (i) What are the media you use to distribute your data (e.g., paper, film, tapes, diskettes, CD-ROMs, on-line, etc.)? (j) If you sell or otherwise market your data, what is your perception of the price elasticity and demand for the data you distribute? What changes would you make to your data products and services if demand were to increase?

3. *Protection of Intellectual Property.* (a) What are the principal legal and technical mechanisms actually used for protecting unauthorized uses of data in your country/institution/discipline area? (b) Can you provide any information about how such legal or technical mechanisms are implemented or enforced? What are the positive and negative impacts?

4. *Less Developed Countries.* (a) In your experience, what have been the principal problems associated with transferring data into or out of "less developed countries," including those nations from the former Soviet Union? (b) What can be done to help alleviate

these problems, especially by the international scientific community?

5. *Electronic Networks.* (a) Has the development and growth of the Internet and other electronic networking services affected the way you access or distribute data internationally? Please give specific examples if you can. (b) How do you think the situation with electronic networks will change in the next 5–10 years or so, and what are the likely impacts to your activities?

6. *Other Technical Issues.* (a) Besides those associated with electronic networks, what are the most important technical benefits or problems you have experienced in either disseminating or accessing data internationally? (b) What changes do you anticipate over the next 5–10 years, and what are the likely impacts to your activities?

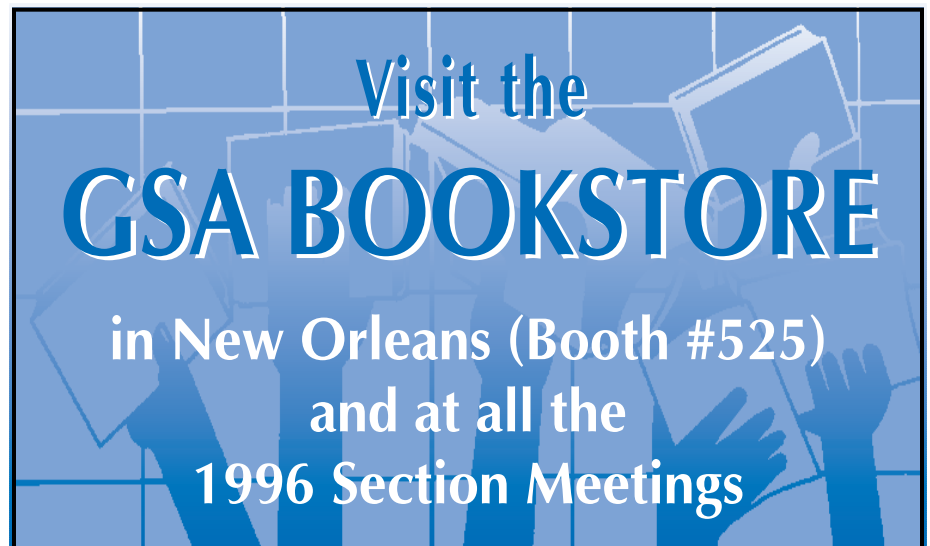
7. *Scientific Data for Global Problems.* (a) In your view, what is the role of international scientific data for addressing global problems, now and in the future? Please elaborate. (b) What can be done to enhance the

availability or exchange of scientific data to better address these concerns?

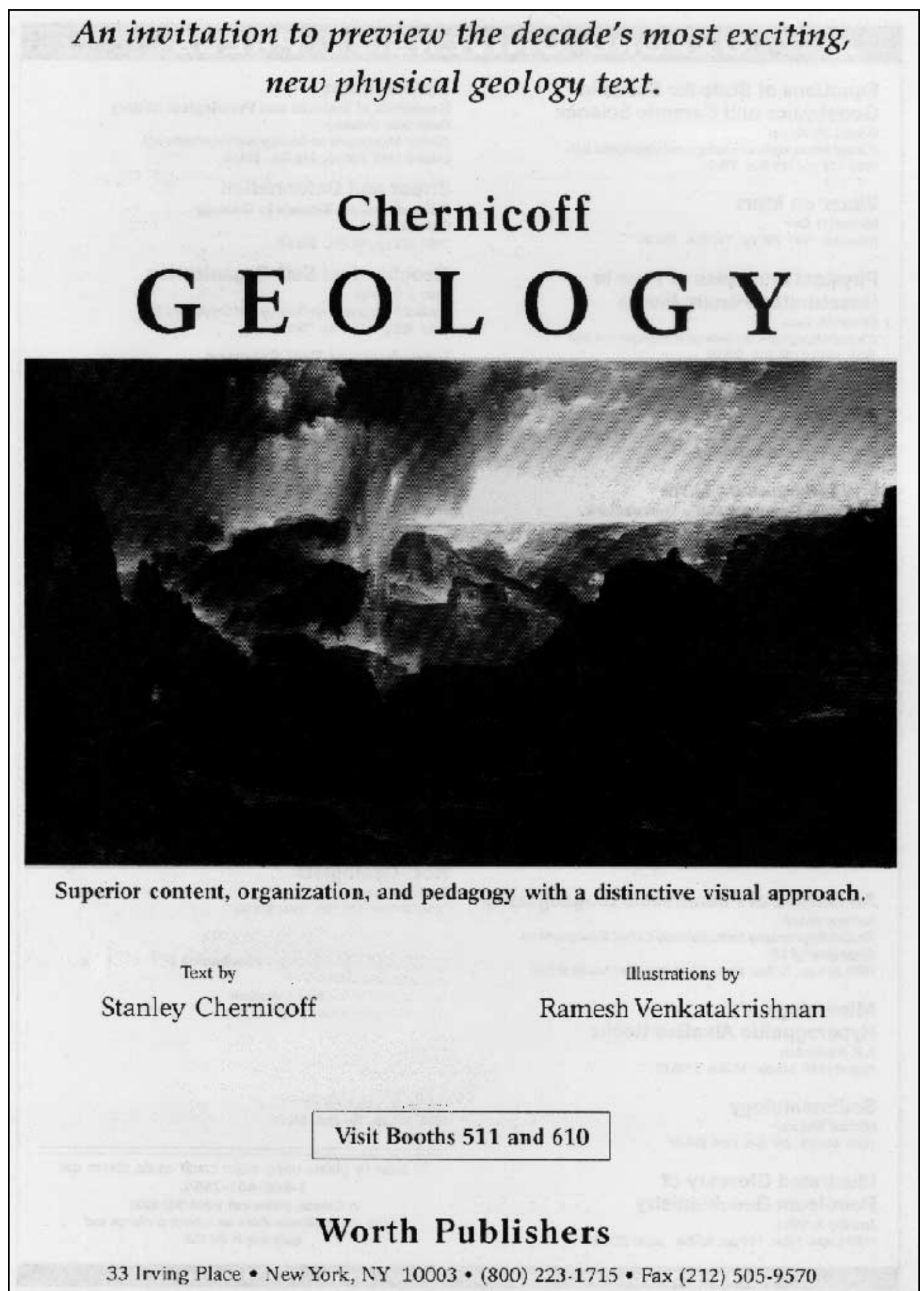
8. *Other Issues.* Do you have any specific concerns or examples of successes that you believe should be considered in this study? In addition, we would welcome your suggestions

for other institutions or individuals to contact with regard to these questions, as well as any references to key documents.

Thank you for your cooperation.
NRC Committee on
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associated with such phenomena as the 1908 Tunguska explosion, the late Pliocene meteorite debris found over ~300,000 km² of the South Pacific (Kyte et al., 1988), the North American microtektite strewn field, and others are also not included in Table 1.

In compiling Table 1, we used the literature, supplemented by our own observations, on (most commonly) the presence of shock metamorphic effects at a particular structure. There is, however, a judgmental component in that the documentation of shock metamorphic effects must be convincing. For some cases for which there have been claims of shock metamorphism, we have not included the structure. For example, we do not include the Sevetin structure in the former Czechoslovakia, although there was a report of shock metamorphism in quartz (Vrána, 1987). Our own observations and recent transmission electron microscope studies have indicated that this deformation is not shock produced (Cordier et al., 1994). In a few cases of reports of shock metamorphism, it is not clear with what structure they are associated. For example, for Bee Bluff, Texas, sometimes known as Uvalde, there are two separate reports of shock metamorphism, but it has been suggested that the shocked materials are detrital and not specific to Bee Bluff (Sharpton and Nielsen, 1988). Until this issue is resolved, we do not list Bee Bluff. Given the discovery rate and the time lag between initial discovery and publication, Table 1 is already out of date.

Any listing of the diameters of terrestrial impact structures is a mix of interpretations from topographical, geological, and geophysical data. Individual diameter estimates can differ. As more data become available for individual impact structures, estimates of their original diameter are revised. The most controversial estimate of diameter is probably for the buried Chicxulub structure (Table 1), which is the source crater for the K-T boundary deposits. We list ~170–180 km (Pilkington et al., 1994); but it has been suggested that Chicxulub may be as large as ~300 km (Sharpton et al., 1993). Additional data acquisition, including reflection seismic, planned for the near future should resolve the issue. Data compilations of rim diameters of terrestrial impact craters, such as Table 1, should be used with some caution. They are dynamic in nature and subject to revision.

MORPHOLOGY

Relatively uneroded terrestrial impact structures display the basic progression, from simple to complex forms with increasing diameter, that is observed on other terrestrial planets. Simple craters have the form of a bowl-shaped depression with a structurally upraised rim. The rim area is overlain by ejecta deposits, and the crater floor represents the top of a subsurface breccia lens. The canonical example is Barringer or Meteor Crater (Fig. 1). Because of its young age, Barringer has a partially preserved exterior ejecta deposit. Most simple craters, however, are considerably more degraded than Barringer; in some cases, the rim area has been completely removed by erosion and the interior filled with postimpact sediments.

Simple structures on Earth have diameters of as much as 4 km. Terrestrial impact structures with diameters >4 km generally have a complex form. As with craters on other planetary bodies, however, there is some overlap of forms near the transition diameter.

Crater name	Location	Lat	Long	Age (Ma)	Diam. (km)
Acraman	South Australia, Australia	32°1'S	135°27'E	>450	90
Ames	Oklahoma, USA	36°15'N	98°12'W	470 ± 30	16
Amguid	Algeria	26°5'N	4°23'E	<0.1	0.45
Aorounga	Chad, Africa	19°6'N	19°15'E	<0.004	12.6
Aouelloul	Mauritania	20°15'N	12°41'W	3.1 ± 0.3	0.39
Araguainha Dome	Brazil	16°47'S	52°59'W	247.0 ± 5.5	40
Avak	Alaska, USA	71°15'N	156°38'W	>95	12
Azuara	Spain	41°10'N	0°55'W	<130	30
B.P. Structure	Libya	25°19'N	24°20'E	<120	2.8
Barringer	Arizona, USA	35°2'N	111°1'W	0.049 ± 0.003	1.19
Beaverhead	Montana, USA	44°36'N	113°0'W	~600	60
Beyenchime-Salaatin	Russia	71°50'N	123°30'E	<65	8
Bigach	Kazakhstan	48°30'N	82°0'E	6 ± 3	7
Boltysh	Ukraine	48°45'N	32°10'E	88 ± 3	24
Bosumtwi	Ghana	6°30'N	1°25'W	1.03 ± 0.02	10.5
Boxhole	Northern Territory, Australia	22°37'S	135°12'E	0.0300 ± 0.0005	0.17
Brent	Ontario, Canada	46°5'N	78°29'W	450 ± 30	3.8
Campo Del Cielo*	Argentina	27°38'S	61°42'W	<0.004	0.05
Carswell	Saskatchewan, Canada	58°27'N	109°30'W	115 ± 10	39
Charlevoix	Quebec, Canada	47°32'N	70°18'W	357 ± 15	54
Chesapeake Bay	Virginia, USA	37°15'N	76°5'W	35.5 ± 0.6	85
Chicxulub	Yucatán, Mexico	21°20'N	89°30'W	64.98 ± 0.05	170
Chiyli	Kazakhstan	49°10'N	57°51'E	46 ± 7	5.5
Chukcha	Russia	75°42'N	97°48'E	<70	6
Clearwater East	Quebec, Canada	56°5'N	74°7'W	290 ± 20	26
Clearwater West	Quebec, Canada	56°13'N	74°30'W	290 ± 20	36
Connolly Basin	Western Australia, Australia	23°32'S	124°45'E	<60	9
Couture	Quebec, Canada	60°8'N	75°20'W	430 ± 25	8
Crooked Creek	Missouri, USA	37°50'N	91°23'W	320 ± 80	7
Dalgaranga	Western Australia, Australia	27°43'S	117°15'E	0.027	0.02
Decaturville	Missouri, USA	37°54'N	92°43'W	<300	6
Deep Bay	Saskatchewan, Canada	56°24'N	102°59'W	100 ± 50	13
Dellen	Sweden	61°55'N	16°39'E	89.0 ± 2.7	19
Des Plaines	Illinois, USA	42°3'N	87°52'W	<280	8
Dobele	Latvia	56°35'N	23°15'E	300 ± 35	4.5
Eagle Butte	Alberta, Canada	49°42'N	110°30'W	<65	10
El'gygytgyn	Russia	67°30'N	172°0'E	3.5 ± 0.5	18
Flynn Creek	Tennessee, USA	36°17'N	85°40'W	360 ± 20	3.55
Gardnos	Norway	60°39'N	9°0'E	500 ± 10	5
Glasford	Illinois, USA	40°36'N	89°47'W	<430	4
Glover Bluff	Wisconsin, USA	43°58'N	89°32'W	<500	8
Goat Paddock	Western Australia, Australia	18°20'S	126°40'E	<50	5.1
Gosses Bluff	Northern Territory, Australia	23°50'S	132°19'E	142.5 ± 0.5	22
Gow	Saskatchewan, Canada	56°27'N	104°29'W	<250	5
Granby	Sweden	58°25'N	15°56'E	470	3
Gusev	Russia	48°21'N	40°14'E	65 ± 2	3.5
Gweni-Fada	Chad, Africa	17°25'N	21°45'E	<345	14
Haughton	Northwest Territories, Canada	75°22'N	89°41'W	23 ± 1	24
Haviland	Kansas, USA	37°35'N	99°10'W	<0.001	0.02
Henbury*	Northern Territory, Australia	24°35'S	133°9'E	<0.005	0.16
Holleford	Ontario, Canada	44°28'N	76°38'W	550 ± 100	2.35
Ile Rouleau	Quebec, Canada	50°41'N	73°53'W	<300	4
Illumetsa	Estonia	57°58'N	25°25'E	>0.002	0.08
Ilyinets	Ukraine	49°6'N	29°12'E	395 ± 5	4.5
Iso-Naakkima	Finland	62°11'N	27°9'E	>1000	3
Jänisjärvi	Russia	61°58'N	30°55'E	698 ± 22	14
Kaalijärvi*	Estonia	58°24'N	22°40'E	0.004 ± 0.001	0.11
Kalkkop	South Africa	32°43'S	24°34'E	<1.8	0.64
Kaluga	Russia	54°30'N	36°15'E	380 ± 10	15
Kamensk	Russia	48°20'N	40°15'E	49 ± 18	25
Kara	Russia	69°12'N	65°0'E	73 ± 3	65
Kara-Kul	Tajikistan	39°1'N	73°27'E	<5	52
Kärdla	Estonia	58°59'N	22°40'E	455	4
Karla	Russia	54°54'N	48°0'E	<10	12
Kelly West	Northern Territory, Australia	19°56'S	133°57'E	>550	10
Kentland	Indiana, USA	40°45'N	87°24'W	<97	13
Kursk	Russia	51°40'N	36°0'E	250 ± 80	5.5
La Moinerie	Quebec, Canada	57°26'N	66°37'W	400 ± 50	8
Lappajärvi	Finland	63°12'N	23°42'E	77.3 ± 0.4	23
Lawn Hill	Queensland, Australia	18°40'S	138°39'E	>515	18
Liverpool	Northern Territory, Australia	12°24'S	134°3'E	150 ± 70	1.6
Lockne	Sweden	63°0'N	14°48'E	>455	7
Logancho	Russia	65°30'N	95°50'E	25 ± 20	20
Logoisk	Belarus	54°12'N	27°48'E	40 ± 5	17

*Crater fields. Diameter given is of largest of the multiple structures.

Some of this can be ascribed to differences in target rock properties, complex craters occurring in sedimentary targets at diameters >2 km. Complex crater forms are characterized by structurally complex and faulted rim areas, a flat annular trough, and uplifted topographically high central structures (Fig. 2). Studies at terrestrial impact structures indicate that the central structures contain rocks uplifted from deeper levels (e.g., Grieve and Pesonen, 1992). Various lines of evidence indicate that complex structures result from changes in the nature of the later stages of the cratering process with respect to simple craters. Although some details are not well understood, the basic principles of cratering mechanics in the formation of simple and complex craters have been established (e.g., Melosh, 1989).

Terrestrial complex impact structures also show the second-order forms observed on other planetary bodies, such as central peak craters, peak-ring craters, and ring basins. Care must be

exercised, however, when comparing morphologic elements of individual terrestrial impact structures and, in particular, when comparing terrestrial and planetary craters (Pike, 1985). Original morphologic elements can be enhanced, modified, or removed by erosional processes on Earth, processes that affect the relative dimensional relations between morphologic elements. Some of the basic relations, such as depth/diameter, for relatively pristine terrestrial impact structures are given in Grieve and Pesonen (1992).

It is not known if there are examples of true multiring basins on Earth. The largest known terrestrial impact structures are Chicxulub, Sudbury, and Vredefort (Table 1). Chicxulub is buried by ~1 km of platform sediments (Hildebrand et al., 1991). Sudbury is eroded and highly tectonized but may have had an interior ring (Stöffler et al., 1994). Vredefort is also highly eroded—only the crater floor preserved—and there is no direct indication of its original morphology (Therriault et al.,

1993). The lack of definitive evidence for multiring impact structures on Earth illustrates that caution is necessary when appraising the form of terrestrial impact structures. All exposed terrestrial impact structures have been modified by erosion. Some buried structures, which formed in areas of continuous postimpact sedimentation, presumably have preserved their original morphology. They are, however, poorly known, because their form can be reconstructed only from spot information, such as from drill holes, and from geophysical interpretations.

SPATIAL DISTRIBUTION

All known terrestrial impact structures (Fig. 3) are entirely on land, with the exceptions of Montagnais, Chesapeake Bay, Chicxulub, and Ust-Kara (Table 1). The status of Ust-Kara has also been questioned. It is poorly exposed, and Nazarov et al. (1991)

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TABLE 1. (continued)

Crater name	Location	Lat.	Long.	Age (Ma)	Diam. (km)
Lonar	India	19°58'N	76°31'E	0.052 ± 0.006	1.83
Lumparn	Finland	60°12'N	20°6'E	~1000	9
Macha*	Russia	59°59'N	118°0'E	<0.007	0.3
Manicouagan	Quebec, Canada	51°23'N	68°42'W	214 ± 1	100
Manson	Iowa, USA	42°35'N	94°33'W	73.8 ± 0.3	35
Marquez	Texas, USA	31°17'N	96°18'W	58 ± 2	13
Middlesboro	Kentucky, USA	36°37'N	83°44'W	<300	6
Mien	Sweden	56°25'N	14°52'E	121.0 ± 2.3	9
Mishina Gora	Russia	58°40'N	28°0'E	<360	4
Mistastin	Newfoundland-Labrador, Canada	55°53'N	63°18'W	38 ± 4	28
Mizarai	Lithuania	54°1'N	24°34'E	570 ± 50	5
Montagnais	Nova Scotia, Canada	42°53'N	64°13'W	50.50 ± 0.76	45
Monturaqui	Chile	23°56'S	68°17'W	<1	0.46
Morasko*	Poland	52°29'N	16°54'E	0.01	0.1
New Quebec	Quebec, Canada	61°17'N	73°40'W	1.4 ± 0.1	3.44
Newporte	North Dakota, USA	48°58'N	101°58'W	<500	3
Nicholson	Northwest Territories, Canada	62°40'N	102°41'W	<400	12.5
Oasis	Libya	24°35'N	24°24'E	<120	11.5
Obolon'	Ukraine	49°30'N	32°55'E	215 ± 25	15
Odessa*	Texas, USA	31°45'N	102°29'W	<0.05	0.17
Ouarkiz	Algeria	29°0'N	7°33'W	<70	3.5
Piccaninny	Western Australia, Australia	17°32'S	128°25'E	<360	7
Pilot	Northwest Territories, Canada	60°17'N	111°1'W	445 ± 2	6
Popigai	Russia	71°30'N	111°0'E	35 ± 5	100
Presqu'île	Quebec, Canada	49°43'N	74°48'W	<500	24
Pretoria Saltpan	South Africa	25°24'S	28°5'E	0.220 ± 0.052	1.13
Puchezh-Katunki	Russia	57°6'N	43°35'E	175 ± 3	80
Ragozinka	Russia	58°18'N	62°0'E	55 ± 5	9
Red Wing	North Dakota, USA	47°36'N	103°33'W	200 ± 25	9
Riachao Ring	Brazil	7°43'S	46°39'W	<200	4.5
Ries	Germany	48°53'N	10°37'E	15 ± 1	24
Rio Cuarto*	Argentina	30°52'S	64°14'W	<0.1	4.5
Rochechouart	France	45°50'N	0°56'E	186 ± 8	23
Roter Kamm	Namibia	27°46'S	16°18'E	3.7 ± 0.3	2.5
Rotmistrovka	Ukraine	49°0'N	32°0'E	140 ± 20	2.7
Sääksjärvi	Finland	61°24'N	22°24'E	~560	6
Saint Martin	Manitoba, Canada	51°47'N	98°32'W	220 ± 32	40
Serpent Mound	Ohio, USA	39°2'N	83°24'W	<320	8
Serra da Cangalha	Brazil	8°5'S	46°52'W	<300	12
Shunak	Kazakhstan	47°12'N	72°42'E	12 ± 5	3.1
Sierra Madera	Texas, USA	30°36'N	102°55'W	<100	13
Sikhote Alin	Russia	46°7'N	134°40'E	0	0.03
Siljan	Sweden	61°2'N	14°52'E	368.0 ± 1.1	52
Slate Islands	Ontario, Canada	48°40'N	87°0'W	<350	30
Sobolev	Russia	46°18'N	138°52'E	<0.001	0.05
Söderfjärden	Finland	62°54'N	21°42'E	~600	5.5
Spider	Western Australia, Australia	16°44'S	126°5'E	>570	13
Steen River	Alberta, Canada	59°30'N	117°38'W	95 ± 7	25
Steinheim	Germany	48°2'N	10°4'E	15 ± 1	3.8
Strangways	Northern Territory, Australia	15°12'S	133°35'E	<470	25
Sudbury	Ontario, Canada	46°36'N	81°11'W	1850 ± 3	250
Suvasvesi N	Finland	62°42'N	28°0'E	<1000	4
Tabun-Khara-Obo	Mongolia	44°6'N	109°36'E	>1.8	1.3
Talemzane	Algeria	33°19'N	4°2'E	<3	1.75
Teague	Western Australia, Australia	25°52'S	120°53'E	1630 ± 5	30
Tenoumer	Mauritania	22°55'N	10°24'W	2.5 ± 0.5	1.9
Ternovka	Ukraine	48°1'N	33°5'E	350 ± 00	15
Tin Bider	Algeria	27°3'N	5°7'E	<70	6
Tookoonooka	Queensland, Australia	27°0'S	143°0'E	128 ± 5	55
Tvären	Sweden	58°46'N	17°25'E	>455	2
Upheaval Dome	Utah, USA	38°26'N	109°54'W	<65	10
Ust-Kara	Russia	69°18'N	65°18'E	73 ± 3	25
Vargeao Dome	Brazil	26°50'S	52°7'W	<70	12
Veevers	Western Australia, Australia	22°58'S	125°22'E	<1	0.08
Vepriai	Lithuania	54°1'N	24°34'E	>160 ± 30	8
Vredefort	South Africa	27°0'S	27°30'E	2006 ± 9	300
Wabar*	Saudi Arabia	21°30'N	50°28'E	0.006 ± 0.002	0.1
Wanapitei	Ontario, Canada	46°45'N	80°45'W	37 ± 2	7.5
Wells Creek	Tennessee, USA	36°23'N	87°40'W	200 ± 100	12
West Hawk	Manitoba, Canada	49°46'N	95°11'W	100 ± 50	2.44
Wolfe Creek	Western Australia, Australia	19°18'S	127°46'E	<0.3	0.88
Zapadnaya	Ukraine	49°44'N	29°0'E	115 ± 10	4
Zeleny Gai	Ukraine	48°42'N	32°54'E	120 ± 20	2.5
Zhamanshin	Kazakhstan	48°20'N	60°58'E	0.9 ± 0.1	13.5

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attributed its impact lithologies to its twin structure, Kara (Table 1). Several structures now on land were formed under water in epicontinental seas or on continental margins. No impact structures are known from the world's ocean basins. Oceanic structures undoubtedly exist, but the present level of knowledge of the ocean floors is insufficient for identification. Ocean-floor spreading and subduction also play a role in the obliteration of oceanic impact craters. Not all known structures are exposed at the surface. Many contain postimpact sediments and ~30% are completely buried by cover rocks. The latter were generally discovered through geophysical anomalies that are associated with impact structures (Pilkington and Grieve, 1992), and they were subsequently explored through drilling.

The spatial distribution of known impact structures is not random. There are concentrations in North America,

Australia, and Northern Europe through to the western part of the former Soviet Union (Fig. 3). These are largely cratonic areas, either exposed Precambrian Shield or platform sediments overlying shield, where there have been programs to identify and study impact craters. We cannot emphasize enough the importance of the influence on the local rate of discovery of programs to identify impact structures. Increased awareness of impact structures and their characteristics in Fennoscandia led to the confirmation, since 1992, of an impact origin for Gardnos, Lockne, Iso-Naakkima, Lumparn, and Suvasvesi (Table 1). There has been a similar recent upsurge in identification of impact structures in southern Africa. Few impact structures have been found outside cratonic areas, which are the most suitable surfaces for the preservation of such structures in the terrestrial geologic environment. A few structures have been heavily tectonized—e.g., Beaverhead and Sudbury (Table 1)—or occur in mountainous

areas—e.g., Gardnos and Kara-Kul (Table 1), where they were formed after the mountain belts formed.

TEMPORAL DISTRIBUTION

Approximately 40% of known terrestrial impact structures have been dated isotopically, generally from the analysis of impact melt rocks. Most of the materials (~90%) affected by impact in a cratering event, however, are subjected to insufficient shock pressures and postshock temperatures to significantly disturb isotopic dating systems (Deutsch and Schärer, 1994). The bulk of isotopic dates are K-Ar or, more recently, ⁴⁰Ar/³⁹Ar plateau dates. Fine-grained, commonly clast-rich, impact melt rocks are not particularly easy to date isotopically, because of inherited Ar from the clasts. In only a few cases is the grain size or compositional variation of impact melt rocks sufficient to permit use of such dating techniques as Rb-Sr isochrons (Deutsch and Schärer, 1994). In a few cases, precise U-Pb dates

have been obtained from shocked zircons (Krogh et al., 1993) and from new zircons crystallized from impact melts (Hodych and Dunning, 1992).

The remainder of known terrestrial impact structures have biostratigraphic or stratigraphic dates. Some postimpact biostratigraphic dates are minimum age estimates—e.g., Lockne (Table 1; Grahn and Nolvak, 1993). Most stratigraphic dates, however, are maximum age estimates, the age being listed only as less than the age of the target rocks; e.g., Eagle Butte is formed in Cretaceous rocks and listed as <65 Ma (Table 1). In the worst cases, a crude constraint on the age is provided by the degree of erosion. For example, the age of the Slate Islands is based on the similarity of its erosional level to that of Charlevoix, which has been isotopically dated (Table 1). They are similar in size and occur in areas of broadly similar geologic history. Erosional rates, however, can vary considerably, particularly in areas that have been glaciated. In addition, some craters have been buried, preserved, and only recently exhumed—e.g., the old, but relatively small Brent, Janisjärvi, and Sääksjärvi structures (Table 1).

Impact age estimates, therefore, are a mixture of determinations that vary in accuracy and precision. Caution must be exercised when using these ages to calculate parameters such as cratering rate estimates and as input into time-series analyses for searches for periodicities and links to other geologic processes (e.g., Stothers and Rampino, 1990). Some broad trends, however, are clear. The temporal distribution of known terrestrial impact structures is biased toward younger ages; over 60% are younger than 200 Ma (Fig. 4). This is a function of erosion. As surface features in a highly active geologic environment, terrestrial impact structures can be removed relatively rapidly. The rate at which this occurs varies with the geologic history of the area. For example, it has been estimated that structures with diameters ≤20 km can be effectively removed in as little as 120 m.y. in exposed shield areas that have been glaciated (Grieve, 1984). Conversely, the interior of Australia, which has had a remarkably stable geologic history, has a relatively high number of Proterozoic-aged impact structures (~30% of the known structures in Australia; Table 1), and the Russian platform has a relatively high number of impact structures of Mesozoic age (Table 1), because of postimpact burial by platform sediments.

SIZE DISTRIBUTION

Terrestrial impact structures are as much as ~300 km in diameter (Table 1). As noted earlier, there is considerable uncertainty in some diameter estimates. In some cases, erosion has removed all topographic expression, and what remains is a geologic anomaly, with a roughly circular shape. In a few cases, the original negative topographic expression of the crater has been replaced by positive topography. For example, Gosses Bluff (Table 1) is a 5-km-diameter, topographically high ring of erosionally resistant sandstones. Other data indicate that the original diameter of the structure was 22 km and that what remains is the erosional remnant of the interior of a central uplift.

There is a bias in the size-frequency distribution of terrestrial impact structures. In the Phanerozoic impact record, the cumulative size frequency of terrestrial impact structures at large

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diameters is similar to that on other terrestrial planets (Fig. 5). At diameters less than ~20 km, however, the cumulative size-frequency distribution falls off, indicating the increasing effects of removal and, to a lesser extent, burial of smaller structures. At simple structures the geological effects of impact are visible to a depth of about one-third the final rim diameter (Grieve and Pesonen, 1992). Thus, the geologic evidence for the largest terrestrial simple impact structures can be removed by <1.5 km of erosion. At larger complex structures, the depth:diameter ratio is shallower, but the absolute depths are often greater. The uplift of originally deeper rocks in the center of complex structures provides an additional geologic manifestation of the event. The amount of stratigraphic uplift undergone by the deepest lithologies exposed in the central structures of complex impact structures is about one-tenth the final rim diameter. Thus, even when the topography and interior impact lithology at a complex impact structure have been completely removed by erosion, it will still be recognizable as a roughly circular geologic anomaly. The shape of the cumulative size-frequency distribution in Figure 5 appears to be an inherent property of the terrestrial record. It has persisted as more impact structures have been added to the known sample over the years.

CRATERING RATE

The most complete record of impact cratering is that of relatively large, geologically young impact structures in cratonic areas, such as North America and northern Europe-western Russia, that have been studied intensively. Therefore, rate estimates are based on a relatively small number of impact structures. Earlier estimates of the terrestrial cratering rate can be found in Shoemaker (1977) and Grieve and Dence (1979). On reexamination, Grieve (1984) concluded that the original sample of 15 impact structures used by Grieve and Dence (1979) may have been affected by erosion and was incomplete. From a reanalysis of the original data, the estimate of the cratering rate was revised upward to 5.5

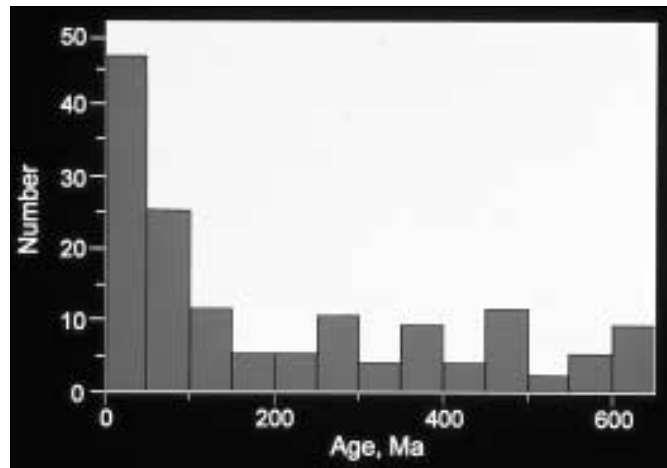


Figure 4. Histogram of age estimates of terrestrial impact structures in the Phanerozoic, binned by 50 m.y. Note that the majority of the known structures are <200 Ma, due to the effects of terrestrial geologic processes on the preserved record.

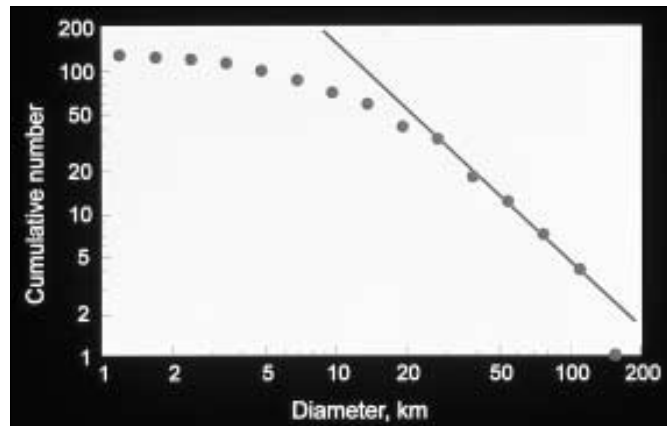


Figure 5. Log-log plot of the cumulative number of Phanerozoic-aged impact structures above a particular diameter, binned by increments of $\sqrt{2}$. Note the power-law distribution down to diameters of ~20 km, below which the size-frequency distribution falls off, indicating a deficit of smaller impact structures.

$\pm 2.7 \times 10^{-15} \text{ km}^2/\text{yr}$ for diameters $\geq 20 \text{ km}$ and impact structures dated at $\leq 120 \text{ Ma}$. This rate estimate is comparable to the earlier estimate of Shoemaker (1977) and is very similar to an estimate based on astronomical observations of Earth-crossing asteroids and comets of $4.9 \pm 2.9 \times 10^{-15} \text{ km}^2/\text{yr}$ (Shoemaker et al., 1990). The uncertainties attached to all these estimates are large, $\pm 50\%$, reflecting concerns about completeness of search and small number of statistics.

CONCLUSIONS

Largely because of the K-T debate, there have been attempts to discredit the presence of shock metamorphic effects, particularly in quartz, as a reliable diagnostic criterion for the occurrence of a terrestrial impact event (e.g., Rice, 1987; Carter et al., 1990; Lyons et al., 1993). These have been partially out of context and have attributed the term "shock" to features that are not considered diagnostic of shock metamorphism. This has led to some confusion in nonexperts. Shock metamorphic effects are well defined and diagnostic of impact (see retrospective by French, 1990). In the terrestrial environment, the shock metamorphism of quartz has been particularly useful, because of its ubiquitous nature and the relatively wide range of shock pressures over which diagnostic shock effects are produced. These were extensively reviewed in Stöffler and Langenhorst (1994).

The number and the level of detail of studies of individual terrestrial impact structures vary greatly. In compiling the data for Table 1, we were, therefore, conservative, on the basis of the assumption that it is easier to add a new structure than to remove an old structure from a listing because new data indicate that the identification of shock metamorphism was in error. There is always some risk in compiling such lists as Table 1, particularly with respect to their subsequent use. We have, however, specifically focused here on the inherent biases in the terrestrial impact record that are largely the result of terrestrial geologic activity. Although we have tried to be as accurate as possible with the information in Table 1, the compilation of data involves a wide range of sources, and it is almost inevitable that there will be some errors. Because the data compilation forms the basis of more detailed

studies of the character of terrestrial impact structures, we would appreciate hearing of any errors or omissions in Table 1. To report such errors or to receive information on the various details of particular terrestrial impact structures currently in our databases, please contact, by E-mail, crater@gsc.nrcan.gc.ca.

ADDENDUM

Since the original writing of this article, shock metamorphic effects have been observed at two additional structures. They are Goyder, Northern Territory, Australia, 13°29'S, 135°03'E, >136 Ma, 3 km; and Mjøltnir, Barents Sea, 73°48'N, 29°40'E, ~135 Ma, 39 km.

ACKNOWLEDGMENTS

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GSA Grants Support Research

June R. Forstrom, Research Grants Administrator

Grants for Graduate Students

The purpose of the general research grants program is to provide partial support of master's and doctoral thesis research for graduate students at universities in the United States, Canada, Mexico, and Central America. GSA strongly encourages women, minorities, and persons with disabilities to participate fully in this grants program. Applicants need not be members of GSA. This program is supported in part by the Geological Society of America Foundation and the National Science Foundation.

Applications must be on current GSA forms available in geology departments in the United States and Canada, or from the Research Grants Administrator, GSA, P.O. Box 9140, Boulder, CO

80301-9140. Evaluations from two faculty members are required on GSA appraisal forms. The deadline is February 15 each year for grants awarded in April. In 1995, 579 proposals were received; 218 of them were funded. A total of \$319,512 was awarded.

Specialized Grants

Recipients of special named awards are selected by the Committee on Research Grants from applicants to the general research grants program; the same application forms are used, and they must also be postmarked by February 15. It is not necessary for applicants to indicate that they wish to be considered for a specialized grant. The committee considers all qualified applicants when selecting recipients for special awards.

The Gretchen L. Blechschmidt Award supports research by women interested in achieving a Ph.D. in the geological sciences and a career in academic research, especially in the fields of biostratigraphy and/or paleoceanography, and who have an interest in sequence stratigraphy analysis, particularly in conjunction with research into deep-sea sedimentology.

The aim of the John T. Dillon Alaska Research Award is to support research that addresses earth science problems particular to Alaska, especially field-based studies dealing with the structural and tectonic development, and those that include some aspect of geochronology (either paleontologic or radiometric) to provide new age control for significant rock units in Alaska.

The Robert K. Fahnestock Memorial Award is made annually to the applicant with the best application in the field of sediment transport or related aspects of fluvial geomorphology.

The Lipman Research Award was established to promote and support

graduate research in volcanology and petrology in the western United States and Alaska.

The Bruce L. "Biff" Reed Award is for graduate students pursuing studies in the tectonic and magmatic evolution of Alaska and its mineral deposits.

The Harold T. Stearns Fellowship Award is awarded annually in support of research on one or more aspects of the geology of Pacific islands and of the circum-Pacific region.

Division Grants

Seven of the 12 GSA divisions award grants for outstanding student research within the respective division's field of interest. The Committee on Research Grants will select candidates from the general research grant applicants for awards by the Engineering Geology, Geophysics (Allan V. Cox Award), Hydrogeology, Sedimentary Geology, and Structural Geology and Tectonics Divisions.

The Coal Geology Division awards the A. L. Medlin Scholarship Award and a Field Research Award to students who submit the best proposals of research projects in the field of coal geology. Guidelines are available from the Division secretary, Cortland F. Eble, Kentucky Geological Survey, 228 Mining and Minerals Resources Bldg., University of Kentucky, Lexington, KY 40506-0107.

The Planetary Geology Division offers two Student Paper Awards in the field of planetary geology each year. For details contact the Section secretary: Cassandra R. Coombs, Department of Geology, College of Charleston, 66 George Street, Charleston, SC 29424-0001.

The Quaternary Geology and Geomorphology Division established its J. Hoover Mackin and Arthur D. Howard Research Grants to support graduate student research on Quaternary geology or geomorphology. Applications for these grants are available from the secretary of the division, J. Steven Kite, Department of Geology and Geography, West Virginia University, P.O. Box 6300, Morgantown, WV 26506-6300. The deadline for applications is February 15, 1996, for grants awarded in April.

Five GSA divisions—Archaeological Geology, Geoscience Education, History of Geology, International, and Planetary Geology—do not currently award grants for student research.

Section Grants for Undergraduate and Graduate Students

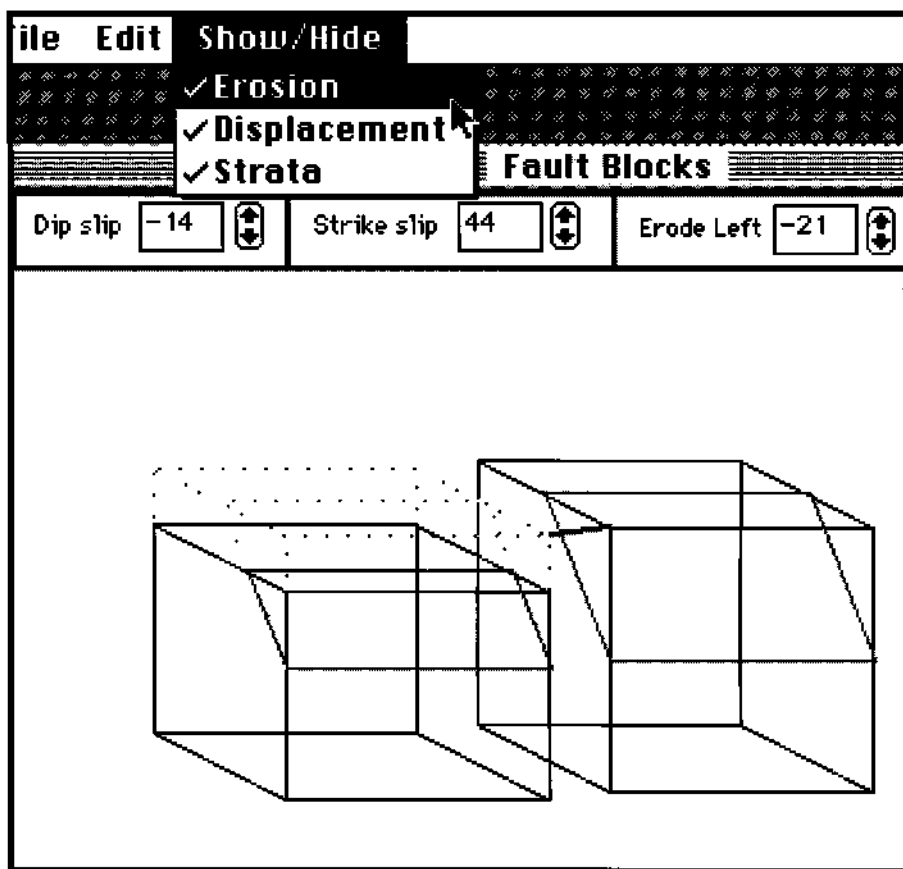
Recipients for graduate research grants from the South-Central Section are selected from applicants to the GSA general research grants program who are recommended by the Committee on Research Grants to the Management Board of the South-Central Section for final selection. Eligibility is restricted to graduate students attending a college or university within the geographic area of the South-Central Section.

The South-Central Section also awards grants to undergraduate students; applications for these awards are available from the Section secretary, Rena M. Bonem, Department of Geology, Baylor University, P.O. Box 97354, Waco, TX 76798-7354. The deadline for undergraduate applications is October 15, for grants awarded in late December.

The North-Central Section awards grants to undergraduate students within the geographic boundary of the Section. For further information contact the Section secretary, George R.

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Research continued on p. 199

GSA Division and Section Grants Awarded in 1995

June Forstrom, GSA Grants Administrator

DIVISION RESEARCH GRANTS

Seven of the 12 GSA divisions offer grants for outstanding student research within the fields of the respective divisions. Recipients of these grants for 1995 are listed below. Two divisions offer other student awards. The Archaeological Geology Division awards a \$500 student travel grant for attendance to present a paper at the GSA Annual Meeting, and the Planetary Geology Division gives two best paper awards for presentations at the annual Lunar and Planetary Science Conference. The three divisions that do not currently offer any awards to students are Geoscience Education, History of Geology, and International.

ARCHAEOLOGICAL GEOLOGY DIVISION

The Archaeological Geology Division presented a student travel grant in the amount of \$500 for attendance at the GSA Annual Meeting in New Orleans. Andrew H. Ivester of the University of Georgia received the award for his paper, "Late Quaternary Paleoenvironmental Record from Sediments at White Paintings Rock Shelter, Tsodilo Hills, Botswana," to be presented in the Archaeological Geology Theme Session.

COAL GEOLOGY DIVISION

The Coal Geology Division presented the annual Antoinette Lierman Medlin Scholarship Award to Penny Alano of University of Kentucky, for her proposal, "Sulfur Distribution and Association in the Lower Block and Buffaloville Coals of the Brazil Formation in Daviess County, Indiana: Implications for the Depositional Environment." The division presented the Medlin Field Research Award to Michael Frank of University of Regina, for his proposal "The Organic Petrology of the Willow Bunch and Estevan Lignite, Ravenscrag Formation, Southern Saskatchewan." The division considers proposals from any full-time graduate student who is conducting research in coal geology.

ENGINEERING GEOLOGY DIVISION

The student research grant awarded by the Engineering Geology Division for an outstanding research proposal was presented to David Spencer Graham of Northeastern Illinois University

for his project "Cadmium Contamination of Typical Illinois Landfills and a Low-Cost Composite Liner for Reducing Leachate Toxicity."

GEOPHYSICS DIVISION

The Geophysics Division presented the Allan V. Cox Student Research Award this year for an outstanding student research proposal submitted to the GSA Research Grants Program to Daniel Kikkert, a master's candidate at the University of Utah, for his project titled "Imaging and Attenuation of the Western U.S. Cordillera Using Combined Waveform Data from Western U.S. Seismic Networks."

HYDROGEOLOGY DIVISION

Awards for outstanding student research from the Hydrogeology Division were presented this year to four students: Sonia Anita Nagorski, University of Montana, for "Metals Partitioning and Geochemical Controls at the Surface Water and Hyporheic Zone Interface of a Stream with an Adjacent Highly Contaminated Floodplain"; Alison Borden Schwab, University of Maryland, College Park, for "The Use of Lithium Isotopes as a Hydrologic Tracer in a First-Order Stream"; Mary Ellen Tuccillo, University of Virginia, for "Iron and Manganese Dynamics in Surface Aquifer Sediments and Groundwater"; and Norman G. Van Broekhoven, University of Texas, Austin, for "The Rates, Sources and Mechanisms of Groundwater Recharge in Lobo Flat and Ryan Flat in Trans-Pecos, Texas."

PLANETARY GEOLOGY DIVISION

The Planetary Geology Division presents the Stephen E. Dwornik Best Student Paper Awards annually to students who are pursuing advanced degrees in Planetary Sciences. The awards are presented each year for papers given in March at the Lunar and Planetary Science Conference. Recipients of the 1995 awards are Laura Griffith of Washington University, St. Louis, for the best oral presentation, for her paper "Calculating the Effects of Hydrothermal Alteration on Mars," and Erich Fischer of Brown University for the best poster presentation for "A Model for Lunar Soil Optical Alteration Due to Space Weathering." Recipients of the awards are presented with a citation and a \$500 cash prize in an awards ceremony held at NASA Headquarters in Washington, D.C., early in the summer.

QUATERNARY GEOLOGY AND GEOMORPHOLOGY DIVISION

The Quaternary Geology and Geomorphology Division awarded grants to three students in 1995. The Arthur D. Howard Research Grant was awarded to Adam Light, University of Colorado, for "Amino Acid Paleothermometry: A North/South Transect of the Lake Bonneville Basin, Utah, Since the Last Glacial Maximum." The J. Hoover Mackin Grants went to Michael R. Kaplan, University of Colorado, for

"Late Quaternary Ice-Sheet Dynamics in Frobisher Bay, Eastern Canadian Arctic: A Paleoclimatic Signal?", and Joseph M. Licciardi, Oregon State University, for "Chronology of High-Frequency (10³ yr) Late-Pleistocene Climate Change, Western North America."

SEDIMENTARY GEOLOGY DIVISION

The Sedimentary Geology Division presented its 1995 award for an outstanding student research proposal to Linda Elisabeth Sohl, Ph.D. candidate at Columbia University, for her project "The 'Snowball' Earth Revisited: A Paleomagnetic Test for Equatorial Glaciation in the Neoproterozoic of Australia."

STRUCTURAL GEOLOGY AND TECTONICS DIVISION

The Structural Geology and Tectonics Division presented its 10th annual awards for outstanding student research this year to Kurt N. Constenius, University of Arizona, for his project "Structure and Timing of the Deer Creek Detachment Fault System, Wasatch Mountains, Utah," and Timothy Paulsen, University of Illinois at Urbana-Champaign, for "The Structural Geometry, Kinematics, Strain, and Tectonic Significance of the Mount Raymond Thrust: A Major Transverse Zone at the Southern Margin of the Wyoming Salient, Sevier Orogenic Belt, Utah." Both recipients are Ph.D. candidates. ■

SECTION RESEARCH GRANTS

NORTH-CENTRAL SECTION

The North-Central Section of GSA awarded grants for undergraduate research projects to students who attend a college or university within the North-Central Section geographic area. Research proposals are submitted and evaluated competitively. Recipients are: Mikael S. Brown, Iowa State University; Cynthia Marie Gray, Kent State University; Steven Holdaway, Illinois State University; Nicholas D. Loomis, University of Wisconsin—Eau Claire; James J. Luepke, University of Missouri; Todd A. Myse, University of Wisconsin—Eau Claire; Candace K. Schwantes, University of Wisconsin—River Falls; and Jennifer Tobias, University of Wisconsin—Eau Claire.

SOUTH-CENTRAL SECTION

The South-Central Section of GSA presented its annual research awards to three qualified graduate students in the section in 1995. Recipients are students who attend a college or university in the South-Central Section geographic area and have submitted applications to the GSA Research Grants Program. The awards presented this year went to Brent A. Couzens, Texas A&M University, Ian C. Jones, University of Texas—Austin, and Jonathan K. Linn, University of Kansas—Lawrence.

The South-Central Section also awarded grants to two undergraduate students (in fall 1994): Shelley Rae Van Dusen of the University of Texas—El Paso, and Alexander Walter of Kansas State University.


SOUTHEASTERN SECTION

GSA's Southeastern Section awarded research grants to two undergraduate students and 11 graduate students this year. Undergraduate students who received grants are Heather Clark, Appalachian State University, and Kim McIntosh, Georgia Southern University. The following graduate students were awarded research grants: Thomas Harris Barry, Auburn University; Margaret C. Brewer, University of Kentucky; Mark Colberg, University of Georgia; Joshua W. Holloman, Auburn University; Andrew Mehlop, University of North Carolina—Chapel Hill; Haydee Gleason Phelps, North Carolina State University—Raleigh; Malcolm Todd Sadler, Auburn University; Eric Sager, East Carolina University; Matt Schirmer, University of Georgia; Tisha C. Springer, University of West Virginia; and David Taylor, University of Alabama, Tuscaloosa.


NORTHEASTERN SECTION

The Northeastern Section initiated a student grants program this year that includes awards to both undergraduate and graduate students. This year all of the grants were awarded to undergraduate students. The 1995 recipients are Joseph J. Bouchard, University of Connecticut; K. Aubrey Hottell, Millersville University; Michael O'Neill, Acadia University; and Jeanette Ostergaard, Kean College. ■

The Cordilleran and Rocky Mountain Sections do not offer grants for student research.



Announcing
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Natural Resources in the Earth Sciences



The American Association of Petroleum Geologists in cooperation with the National Earth Science Teachers Association will award \$5000 at the May 1996 AAPG national convention in San Diego to an individual teacher for excellence in the teaching of natural resources in the earth sciences.

The award will include \$2,500 for use under the teacher's supervision for educational purposes and \$2,500 for personal use by the teacher. Also included will be an expense paid trip to San Diego to receive the award at the May 1996 AAPG convention.

Requirements:

1. Minimum of three years full time teaching experience at any level K-12.
2. Teaching at least one unit per year on natural resources. Natural resources are defined as Earth materials used by civilization past and present such as:
 - a. inorganic substances found in the Earth such as water, mineral ores, building stone and aggregate, rocks, and sediments.
 - b. organic materials such as oil, gas, coal, and soil.
3. Teaching should include the scientific study of these resources, their origin, discovery, extraction, and historical and present use. It should also include the preservation of the environment, reclamation, and the conservation of resources.
4. Entries will include the teacher's philosophy of the teaching of natural resources, a description of the unit with outline, vita, and two letters of recommendation; one from a colleague and one from an administrator.
5. Unit will be evaluated on depth and breadth of concepts (resource origin, discovery, processing, usage, and reclamation) creativity of presentation, and balanced treatment of information regarding societal need and environmental issues.
6. For further information and entry forms contact:
American Association of Petroleum Geologists
Attn: Linda Farrar
P.O. Box 979
Tulsa, OK 74101-0979

Entries must be postmarked by December 15, 1995. Winner will be announced March 1, 1996.

Research continued from p. 197

Hallberg, University of Iowa Hygienic Laboratory, 102 Oakdale Campus, H101 OH, Iowa City, IA 52242-5002.

The Southeastern Section awards grants for both undergraduate and graduate GSA student members who are enrolled in institutions within the geographical boundaries of the Section. The grants are competitive. Application forms can be obtained from the Section secretary, Harold H. Stowell, Department of Geology, Box 870338, University of Alabama, Tuscaloosa, AL 35487-0338. The deadline for 1996 applications is February 15, 1996. The grants will be awarded in April.

The Northeastern Section offers research grants for undergraduate and graduate students who are enrolled at institutions within the Section and are student members or associates of GSA. Contact the Section secretary, Kenneth N. Weaver, Maryland Geological Survey, 2300 St. Paul St., Baltimore, MD 21218, for application forms. Applications must be postmarked no later than February 7 for grants to be awarded in April.

The remaining two sections—Rocky Mountain and Cordilleran—do not currently offer research grants. ■

CALL FOR PAPERS

Planetary Geoscience Student Paper Award

The Award

Planetary geologist Stephen E. Dwornik established the award in 1991 to provide encouragement, motivation, and recognition to outstanding future scientists. Two awards are given annually, each winner receiving a citation and \$500. The program is administered through the Planetary Geology Division of the Geological Society of America. The GSA Foundation manages the award fund. Arrangements for travel by the recipients to the awards ceremony at NASA headquarters in Washington, D.C., are handled by the Planetary Geology and Geophysics Program, NASA.

Criteria

Students who are U.S. citizens and are enrolled in a college or university at any level of their education in the field of planetary geosciences may submit abstracts for the Student Paper Award. Student applicants must be the senior author of the abstract, and the paper may be presented orally or in a poster session. Papers will be judged on the quality of the scientific contribution, including methods and results; clarity of material presented; and methods of delivery, oral or display. Two awards are given: one for the best oral presentation, the other for the best poster presentation.

To Apply

The application form and instructions may be found in the Call for Papers for the 1996 Lunar and Planetary Science Conference, March 18–22, to be held in Houston, Texas. For further information contact Program Services Division, Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston, TX 77058-1113, phone (713) 486-2166, fax 713-486-2160, E-mail: simmons@lpi.jsc.nasa.gov. Only one abstract per student will be considered. **Deadline: January 10, 1996.**

BOOK REVIEW

Cracking Rocks and Defending Democracy: Kirtley Fletcher Mather, Scientist, Teacher, Social Activist, 1888–1978. By Kennard Baker Bork. Pacific Division of AAAS, San Francisco, 1994 (available from California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118, for \$35.20, including shipping).

This 340-page biography effectively chronicles the life and times of an exceptionally wise and energetic man, who pursued a remarkably broad array of interests and causes with burning zeal. In Kirtley Fletcher Mather's 90-year life span, he was deeply involved in many of the momentous changes that occurred between 1888 and 1978.

As an earth scientist with a Ph.D. from the University of Chicago, Mather served as a geology professor at the University of Arkansas, Queens University in Ontario, Denison University, and for 30 years at Harvard University. He was a key leader in the American Association for the Advancement of Science and in the American Academy of Arts and Sciences, and was renowned for his lively lectures and hundreds of publications. At the same time he was an effective and articulate practicing Christian and a leading spokesman for peace and social justice throughout the world.

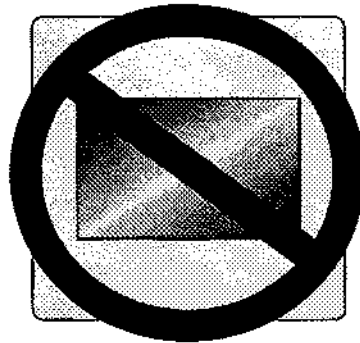
The life, career, and characterization of this remarkable man have been thoroughly recorded by Kennard Baker Bork, professor of geology and geography at Denison University. The 18 chapters of Bork's book are divided more or less equally into detailed accounts of the various phases of Mather's life and the principal scientific, philosophical, and social issues that he addressed in the course of his long career. One of the highlights of the book is the description of his key role as a pro-evolution witness in the famed Scopes Trial in 1925 on the issue of Darwinian evolution. As a geologist, Mather was a generalist. His early concentration on petroleum exploration expanded into various aspects of geomorphology and glaciology in the later parts of his geologic career. As a man of religion, Mather could most aptly be characterized as a "practical Christian," emphasizing the application of the Golden Rule and the manifestation of Christian love in everyday living. Perhaps his greatest hallmark was his emphasis on the close and positive relationship between religious faith and science. As an educator, Kirtley Mather was a keen advocate of the liberal arts approach to higher education and lifelong learning. Finally, as a social and political activist, Mather had, as Bork puts it, "a one-world perspective, combined with a deep belief in American democratic principles."

It seems to me that the unique life and career of Kirtley Fletcher Mather have much of importance to say to contemporary earth scientists as we approach the 21st century. As we indeed seem destined to become one world in the many senses of that term, our civilization stands in need of wise and comprehensive generalists like Kirtley Mather. Kennard Bork has done us a great favor by acquainting us so thoroughly with Mather as an outstanding model for us all.

Donald L. Everhart
Grand Junction, CO 81509-3906

(see p. 200 and 201
for notes on Mather.)

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Washburn Photographs Illuminate Geologic Features

In the summer of 1933 a young Harvard student, inspired by Tarr and Martins's *Alaskan Glacier Studies*, made a flight over the Malaspina Glacier at the foot of Mount St. Elias in southeastern Alaska and reported extraordinary evidence of both plastic flow and thrust faulting in this huge piedmont glacier. His geology professor, Kirtley F. Mather, urged him to ask the Geological Society of America for a grant of sufficient size to meet the cost of a thorough photographic study of both the Malaspina Glacier and the South Crillon Glacier, near which a Harvard-Dartmouth expedition was to have its base camp the following year.

The committee for the newly established Penrose fund responded with two grants in 1934, totaling \$1310, and another, for \$500, in 1946. These grants in essence launched the careers of Bradford Washburn and Richard Goldthwait, and the photographs on these pages are among the best that Washburn has taken in the past 60 years. He went on to found Boston's Museum of Science and to map Mount McKinley, the Grand Canyon, and Mount Everest. The late Richard Goldthwait, based at Ohio State University, became one of this century's most distinguished specialists in glacial geology.

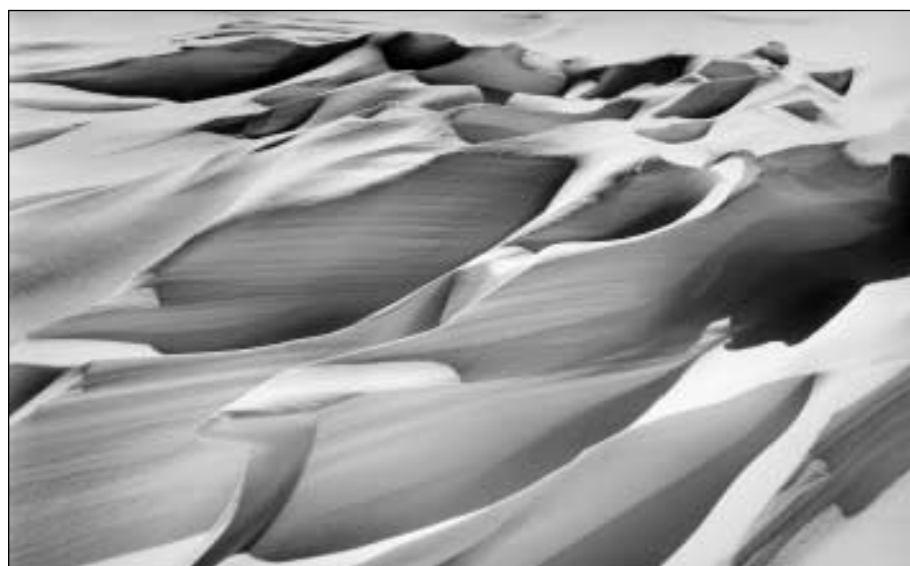
Sales of prints of these and Washburn's other pictures (Bradford Washburn, Museum of Science, Science Park, Boston, MA 02114-1099) help to finance his ongoing photographic work. He is now 85 years old.



Brad Washburn in a Fairchild 71 monoplane ready for a 1937 take-off in Valdez, Alaska, with his 50-lb Fairchild K-6 aerial camera.



The dramatic north face of Mount Huntington (12,240 ft), Alaska (April 11, 1978).

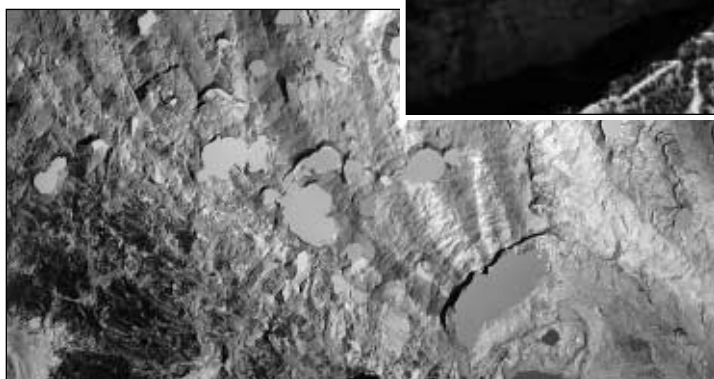


Sastrugi near Silverthrone Pass, Alaska Range (March 1945).



The great Denali fault, looking eastward from just east of Anderson Pass (September 18, 1938).

The Bright Angel Fault and trail, Grand Canyon, Arizona (August 1973).



The motionless, dying snout of the Chitina Glacier in Alaska's St. Elias Range, seen vertically from an altitude of 15,000 ft (August 6, 1938).

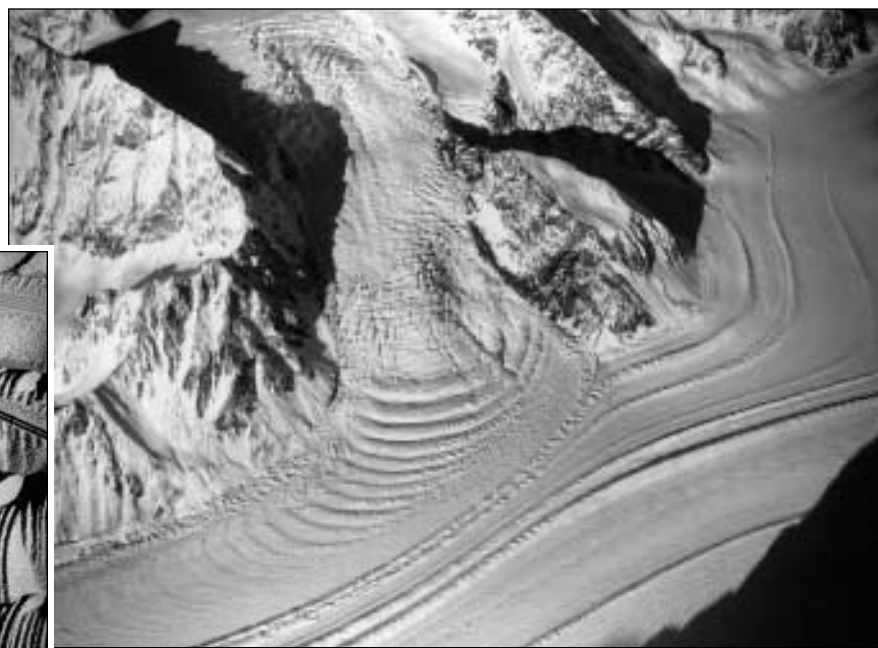


Mineral Spring, 8 miles northeast of Copper Center, Alaska (August 14, 1947), seen vertically from 10,000 ft.

"After the Storm"—
Snow formations on the
East Ridge of the Dold-
enhorn (11,950 ft),
Bernese Overland,
Switzerland
(July 24, 1960).



Marblecake Moraines, Malaspina Glacier, Alaska (July 19, 1966).



The Russell icefall and Yentna Glacier,
Alaska Range,
(October 4, 1964).

Dredge
Tailings,
Goldstream
Creek,
Fox, Alaska
(September 27,
1938).



Logan Glacier, Mount Logan (19,500 ft) and King Peak (16,970 ft) (August 6, 1938).

Editor's Note

Reading Brad Washburn's 1935 article (*GSA Bulletin*, v. 46, p. 1879–1890) on his photographic studies of southern Alaska is a real education, both in terms of the contrasts in the *Bulletin* then and now and in terms of what Washburn and Goldthwait discovered. Keep in mind that this was the very first aerial geological reconnaissance of the southern Alaskan glaciers. Washburn (1935) stated, "It is hard to overestimate the value of the airplane in Alaskan glacial work. In four peaceful hours on this August afternoon, we not only succeeded in relocating and taking photographs of every important glacier along 150 miles of rough Alaskan coast, but were also able to make an aerial reconnaissance of the whole southern third of the Malaspina and its tributary valleys—an area which would have required many months to cover on foot. When we returned to our base camp ... that evening, we were certain that we had discovered in the surface of the Malaspina a magnificent new demonstration of the qualities of glacial ice.... As a medium for the study of moraines such a composite glacier is ideal. The remarkable convolutions developed in the numerous medial moraines are significant indications of the flow of ice." The subheadings of Washburn's article reveal what they found: "Contorted Medial Moraines," and "Shearing in Medial Moraines," and "Thrust-Faulting in Glacial Ice." In financing Washburn's study, the Penrose fund supported a major breakthrough in the understanding of the large-scale patterns of

flow of glacier ice, an understanding that formed a basis for much future insight into flow of ice, metamorphic rocks, and, for that matter, the asthenosphere.

A related piece, on p. 196, is a review of a recent biography of Kirtley Mather, Washburn's professor at Harvard. One of Mather's lasting contributions to the science was a compendium of four centuries of writing about geology, from Leonardo da Vinci to C. R. Van Hise. (K. F. Mather and S. L. Mason, *A Source Book in Geology*, New York, McGraw-Hill, 1939). Mather inspired Brad Washburn and many other geology students during his long teaching career.

—Eldridge Moores

Robert L. Fuchs



Additional Industry Grants for SAGE

Two recent Second Century Fund grants, from Amoco Foundation Inc. and Burlington Resources/Meridian Oil Foundation have been designated to support specific SAGE projects.

Amoco Funds MAP Planning Conference

The percentage of Hispanic, African-American, and Native American students who choose to take elective courses in science and mathematics is shrinking, and fewer minority students are pursuing majors in science and mathematics. This is occurring in spite of studies that show a better job must be done in attracting, training, and supporting minority students in order to maintain an economically competitive high-technology work force. The earth sciences are no exception to these disappointing trends.

GSA is developing a conference series that will address both scientific literacy and career issues for minority students in the earth sciences. A recent planning grant from Amoco Foundation Inc. will be used to bring together approximately 20-25 key stakeholders from the earth science, science education, and minority communities; this group will comprise teachers, scientists, students, and administrators. Scheduled for a two and one-half day period in December 1995, the agenda calls for participants to discuss and refine the Minority Access and Participation (MAP) conference series goals, plan the conference series format, and develop a strategic plan.

Amoco Corporation is the 13th largest industrial corporation in the United States, one of the largest publicly traded producers of crude oil and natural gas in the world, and the largest owner and producer of natural gas reserves in the United States and Canada. The Company has exploration and production contracts in about 25 countries, and employs 43,000 persons worldwide. In addition to the production, refining, and sale of oil and gas, Amoco is a leading producer of many kinds of specialty chemicals. Founded in 1889, Amoco is one year younger than GSA.

Burlington Resources/Meridian Oil Foundation and Project Earth VIEW

A recent survey of SAGE Partners indicated a need for classroom teaching aids, particularly low-cost slide sets. Coincidentally, GSA has received slide collections donated by two members, Richard H. Durrell and Albert J. Copley, numbering more than 7000 slides. These collections provide a broad visual asset base from which slide sets can be arranged to depict geologic features, land forms, and processes.

Project Earth VIEW will make slide sets on a variety of earth science topics available at minimal handling cost to K-16 educators, scientists, and engineers. Each set will include brief descriptions of the slides and suggestions for activity extensions connected to the emerging National Science Education Standards and the National Geography Standards. The slide sets can be customized to fit individual educators' needs, and will support science education partnerships and earth science investigations at all grade levels. A grant from the Burlington Resources/Meridian Oil Foundation will allow the SAGE staff to begin organizing, producing, and disseminating initial slide sets and developing the CD-ROM slide catalogue.

The Burlington Resources/Meridian Oil Foundation is the major channel of philanthropy for Burlington Resources Inc. and Meridian Oil Inc. Burlington Resources Inc. is a New York Stock Exchange-listed company which was spun off a few years ago from the Burlington Northern Railroad when that company divested itself of various resource businesses that it owned. A principal, wholly owned subsidiary is Meridian Oil, which is one of the largest independent oil and gas exploration and production companies in the United States. Headquartered in Houston, Meridian Oil is the fifth largest holder of natural gas reserves in the United States, has production in all major gas-and oil-producing states, and employs more than 1800 people. The company is a leader in developing new gas and oil production technologies, notably in the exploitation of coal-bed methane in the San Juan Basin and other areas. ■

Pardee Coterie for Planned Givers

[co-te-rie... a group of persons with a unifying common interest or purpose]

The GSA Foundation has formed the Pardee Coterie to recognize those who have made planned gifts that will support GSA and its programs. Members of the Pardee Coterie and spouses will meet once each year, generally at the annual meeting, for a meal and a talk or discussion on a topic of current interest to scientists and supporters of geology. The group is distinctly informal—no bylaws, no officers, no committees.

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

The inaugural gathering of the Pardee Coterie will take place in New Orleans on Wednesday, November 8, at 9 a.m. The location is Brennan's restaurant at 417 Royal Street. The speaker and discussion leader is Dan Sarewitz, Institute for Environmental Education Program Manager and former GSA Congressional Science Fellow.

Those who have made planned gifts to the Society or the Foundation such as the Pooled Income Fund, charitable remainder trusts or gift annuities, or bequests have automatically been included in the Pardee Coterie roster of members. Others who have included GSA in their wills or are contemplating planned gifts are asked to notify the Foundation by calling or by mailing the accompanying coupon. Membership in the Pardee Coterie will follow promptly. ■

GSA Employees Participate in Second Century Fund

Employees at GSA headquarters will be joining GSA members in support of the Second Century Fund. Terry Moreland, Membership Services Manager and chair of the Second Century Fund employee campaign, has set a goal of 100% participation by the Boulder staff, noting that 10% of the employees have already made pledges well before any fund drive announce-

ment. "There is a very strong esprit de corps among GSA's staff members, which makes my job that much easier," Moreland said. "Besides, the department heads have promised to prepare a 'culinary treat' for all when the goal is reached and, since this particular army marches on its stomach, I feel the goal is already in sight!" ■

Donors to the Foundation, July 1995

Birdsall Fund
Ralph C. Heath
Thomas L. Holzer
Jeffrey M. Kremasky

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Unrestricted
Richard H. Mahard*
Jay G. Marks
Esther B. Tuttle
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Women in Science
Roger L. Duba

* Gifts of \$150 or more
(Century Plus Roster)

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Supporting The Advancement of Research

GSA Foundation
3300 Penrose Place, P.O. Box 9140
Boulder, CO 80301, (303) 447-2020

Enclosed is my contribution in the amount of \$_____ for

Foundation Unrestricted
 GSA Unrestricted
 _____ Fund

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

A charitable gift annuity might be a good idea for me. I'm doing some retirement planning and would like a copy of the booklet entitled *The Charitable Gift Annuity*.

PLEASE PRINT

Name _____

Address _____

Address _____

City/State/ZIP _____

Phone _____

CALL FOR NOMINATIONS

1996 John C. Frye Environmental Geology Award

In cooperation with the Association of American State Geologists (AASG), GSA makes an annual award for the best paper on environmental geology published either by GSA or by one of the state geological surveys. The award is a \$1000 cash prize from the endowment income of the GSA Foundation's John C. Frye Memorial Fund.

The 1996 award will be presented at the autumn AASG meeting to be held during the GSA Annual Meeting in Denver.

CRITERIA FOR NOMINATION

Nominations can be made by anyone, on the basis of 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, (4) **nominations must be sent to Executive Director, GSA, P.O. Box 9140, Boulder, CO 80301. Deadline: April 1, 1996.**

BASIS FOR SELECTION

Each nominated paper will be judged on the uniqueness or significance as a model of its type of work and report and its overall worthiness for the award. In addition, 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).

1995 AWARD RECIPIENT NAMED

The 1995 award will be presented at the GSA Annual Meeting in New Orleans to Mike Lowe, Bill D. Black, Kimm M. Harty, Jeffrey R. Keaton, William E. Mulvey, E. Fred Pashley, Jr., and Scott R. Williams for their paper "Geologic Hazards of the Ogden Area, Utah." This article was published in Utah Geological Survey Miscellaneous Publication 92-3, *Field Guide to Geological Excursions in Utah and Adjacent Areas of Nevada, Idaho, and Wyoming*. The report was a thorough environmental treatment of the area's geologic hazards, with technical detail, introductory explanations for laypersons, and a vivid road log.

Call for Nominations for 1996 Penrose and Day Medals and Honorary Fellows

Nominations for GSA's Penrose and Day Medals and for Honorary Fellowships of the Society are due at headquarters by **February 1, 1996**. Members and Fellows of the Society are encouraged to participate in this important process by nominating candidates for these high honors.

Penrose Medal

The Penrose Medal was established in 1927 by R.A.F. Penrose, Jr., to be awarded in recognition of eminent research in pure geology, for outstanding original contributions or achievements that mark a major advance in

the science of geology. The award is made only at the discretion of the Council. Nominees are selected by the Council, may or may not be members of the Society, and may be from any nation. Penrose's sole objective in making the gift was to encourage original work in purely scientific geology. **Scientific achievements should be considered rather than contributions in teaching, administration, or service. Mid-career scientists who have already made exceptional contributions should be given full consideration for the award.**

Day Medal

The Day Medal was established in 1948 by Arthur L. Day to be awarded annually, or less frequently, at the discretion of the Council, for outstanding distinction in contributing to geologic knowledge through the application of physics and chemistry to the solution of geologic problems. Day's intent was to recognize outstanding achievement and inspire further effort, rather than reward a distinguished career. **Scientific achievements should be considered rather than contributions in teaching, administration, and service.**

Honorary Fellows

Geologists who have distinguished themselves in geological investigations or in notable service to the Society may be elected as Honorary Fellows. In practice, nearly all candidates are non-North Americans who live and work outside of North America. The most noteworthy exceptions were astronauts.

Most Honorary Fellows have been elected after many years of outstanding and internationally recognized contributions to the science.

Nominations continued on p. 204

PENROSE MEDAL, DAY MEDAL, OR HONORARY FELLOWSHIP

THE GEOLOGICAL SOCIETY OF AMERICA Nomination for Penrose Medal, Day Medal, or Honorary Fellowship (please circle one)

NAME OF CANDIDATE: _____

ADDRESS: _____

Telephone: _____

REQUIRED INFORMATION (Please attach)

BIOGRAPHICAL INFORMATION

Suggested sources: *American Men and Women of Science*
Who's Who in America
GSA Service Record (obtainable from headquarters)
Other _____

SUMMARY OF SCIENTIFIC CONTRIBUTIONS TO GEOLOGY

Not more than 200 words.

SELECTED BIBLIOGRAPHY

No more than 20 titles.

LETTERS OF SUPPORT

Nominations for any one of these three awards **MUST BE SUPPORTED** by signed letters from five (5) GSA Fellows or Members in addition to the person making the nomination. The letters may be attached to this form or may be sent to the Executive Director separately. Supporting letters must discuss the original research and scientific advances of the candidates. Please also verify all other supporting data.

Name of person making the nomination: _____

Address: _____

Date: _____ Signature: _____

Letters of support will be submitted by:

1. _____
2. _____
3. _____
4. _____
5. _____

RETURN TO: Executive Director
The Geological Society of America
P.O. Box 9140
Boulder, CO 80301
(303) 447-2020

DEADLINE: Completed nomination materials must be received by **February 1, 1996**. To be considered, nomination materials must meet the above criteria. Reprints or articles will not be accepted.

Nominations continued from p. 203

How To Nominate

To ensure thorough consideration by the respective committees, please submit for each candidate a brief biographical sketch, such as used in *American Men and Women of Science* and *Who's Who in America*, a summary of the candidate's scientific contributions to geology that qualify the individual for the award, and a selected bibliography of no more than 20 titles.

A nomination for any one of these three awards **MUST BE SUPPORTED** by signed letters from each of five (5) GSA Fellows or Members in addition to the person making the nomination. The letters may be attached to the nomination form or may be sent to the Execu-

tive Director separately. For Honorary Fellow nominations, please *verify degrees received, publications, positions held, etc.* The names of unsuccessful candidates proposed to the Council by the respective committees will remain for consideration by those committees for three years. **FOR THOSE STILL UNDER CONSIDERATION, IT IS RECOMMENDED THAT AN UPDATED LETTER OF RENOMINATION BE SENT TO THE EXECUTIVE DIRECTOR.**

The deadline for receipt of nominations at the office of the Executive Director is **February 1, 1996.**

Please use the form on page 203 for submitting the name of a candidate for any one of the awards.

Recipients of the awards to date are listed below. ■

About the Honorary Fellow Program

On page 203 you will find a form to be used in nominating candidates for Honorary Fellowship in the Geological Society of America. Each year this honor is bestowed on non-North Americans who live and work outside of North America and have distinguished themselves in geological investigations or in notable service to the Society. Under exceptional circumstances, North Americans have been named Honorary Fellows. This amendment to the bylaws was made in 1969 when the Apollo II astronauts who first walked on the moon were elected.

The program was established by the GSA Council in 1909, and since then, except during a few war years, one or more Honorary Fellows have

been elected annually. Most Honorary Fellows have been elected after many years of outstanding and internationally recognized contributions to the science. At present there are 61 living geologists who have received this honor.

The Council of the Society encourages the membership to submit names of qualified candidates for this honor. In preparing a nomination, it is imperative that the original research and scientific advances of the candidate be stressed. All supporting data, especially degrees received, publications, positions, etc., should also be verified by the nominator. Use the form on page 203 for nominating a candidate for Honorary Fellowship. ■

GSA Medalists and Honorary Fellows

Richard A. F. Penrose, Jr., Medalists

1927 Thomas Chrowder Chamberlin	1950 Morley Evans Wilson	1973 M. King Hubbert
1928 Jakob Johannes Sederholm	1951 Pentti Eskola	1974 William Maurice Ewing
1929 <i>No award given</i>	1952 George Gaylord Simpson	1975 Francis J. Pettijohn
1930 Francois Alfred Antoine Lacroix	1953 Esper S. Larsen, Jr.	1976 Preston Cloud
1931 William Morris Davis	1954 Arthur Francis Buddington	1977 Robert P. Sharp
1932 Edward Oscar Ulrich	1955 Maurice Gignoux	1978 Robert M. Garrels
1933 Waldemar Lindgren	1956 Arthur Holmes	1979 J Harlen Bretz
1934 Charles Schuchert	1957 Bruno Sander	1980 Hollis D. Hedberg
1935 Reginald Aldworth Daly	1958 James Gilluly	1981 John Rodgers
1936 Arthur Philemon Coleman	1959 Adolf Knopf	1982 Aaron C. Waters
1937 <i>No award given</i>	1960 Walter Herman Bucher	1983 G. Arthur Cooper
1938 Andrew Cowper Lawson	1961 Philip Henry Kuenen	1984 Donald E. White
1939 William Berryman Scott	1962 Alfred Sherwood Romer	1985 Rudolf Trümpy
1940 Nelson Horatio Darton	1963 William Walden Rubey	1986 Laurence L. Sloss
1941 Norman Levi Bowen	1964 Donnel Foster Hewett	1987 Marland P. Billings
1942 Charles Kenneth Leith	1965 Philip Burke King	1988 Robert S. Dietz
1943 <i>No award given</i>	1966 Harry H. Hess	1989 Warren Bell Hamilton
1944 Bailey Willis	1967 Herbert Harold Read	1990 Norman D. Newell
1945 Felix Andries Vening-Meinesz	1968 J. Tuzo Wilson	1991 William R. Dickinson
1946 T. Wayland Vaughan	1969 Francis Birch	1992 John Frederick Dewey
1947 Arthur Louis Day	1970 Ralph Alger Bagnold	1993 Alfred G. Fischer
1948 Hans Cloos	1971 Marshall Kay	1994 Luna B. Leopold
1949 Wendell P. Woodring	1972 Wilmot H. Bradley	1995 John C. Crowell

Arthur L. Day Medalists

1948 George W. Morey	1965 Walter H. Munk	1981 Donald L. Turcotte
1949 William Maurice Ewing	1966 Robert M. Garrels	1982 Eugene M. Shoemaker
1950 Francis Birch	1967 O. Frank Tuttle	1983 Harmon Craig
1951 Martin J. Buerger	1968 Frederick J. Vine	1984 Wallace S. Broecker
1952 Sterling Hendricks	1969 Harold C. Urey	1985 Freeman Gilbert
1953 John F. Schairer	1970 Gerald J. Wasserburg	1986 E-an Zen
1954 Marion King Hubbert	1971 Hans P. Eugster	1987 Don L. Anderson
1955 Earl Ingerson	1972 Frank Press	1988 Claude J. Allègre
1956 Alfred O. C. Nier	1973 David T. Griggs	1989 Dan McKenzie
1957 Hugo Benioff	1974 A. E. Ringwood	1990 William S. Fyfe
1958 John Verhoogen	1975 Allan Cox	1991 Ian Carmichael
1959 Sir Edward C. Bullard	1976 Hans Ramberg	1992 Susan Werner Kieffer
1960 Konrad B. Krauskopf	1977 Akiho Miyashiro	1993 Hugh P. Taylor, Jr.
1961 Willard F. Libby	1978 Samuel Epstein	1994 David Walker
1962 Hatten Schuyler Yoder	1979 Walter M. Elsasser	1995 Thomas J. Ahrens
1963 Keith Edward Bullen	1980 Henry G. Thode	
1964 James Burleigh Thompson, Jr.		

Young Scientist Award (Donath Medalists)

1989 Mark Cloos	1992 John Peter Grotzinger	1994 An Yin
1990 Leigh Handy Royden	1993 Michael Gurnis	1995 Ward Earl Sanford
1991 Brian Philip Wernicke		

Honorary Fellows

Edwin "Buzz" Aldrin	William S. Fyfe	Leo Y. Picard	Mircea Sandulescu
Neil Armstrong	Augusto Gansser	Wallace S. Pitcher	Harrison Hagan Schmitt
Jean A. Aubouin	David Headley Green	Jean Piveteau	Eugen Seibold
Krzysztof Ludwik Birkenmajer	Francisco Hervé	Isabella Premoli-Silva	Ali Mehmet Celal Şengör
George Malcolm Brown	Dorothy Hill	Desmond A. Pretorius	Boris Sergeevich Sokolov
S. Warren Carey	Ferenc Horvath	B. P. Radhakrishna	Richard L. Stanton
Maria Bianca Cita	Kenneth J. Hsü	Hans Ramberg	Rashid A. Khan Tahirkheli
Michael Collins	Valdar Jaanusson	Victor A. Ramos	Bernard P. Tissot
William Compston	Emilie Jäger	John G. Ramsay	Livio Trevisan
Douglas Saxon Coombs	Ihsan Ketin	Alfred Rittmann	Rudolf Trümpy
P. G. Cooray	Teiichi Kobayashi	Alexander B. Ronov	Guangzhi Tu
Gabriel Dengo	Hans Laubscher	Rupert W. R. Rutland	Harry B. Whittington
Kingsley C. Dunham	Henno Martin	Kristján Sæmundsson	Alwyn Williams
Stanislaw Dzulynski	Michael W. McElhinny	Rushdi Said	Yang Zun-yi
François Ellenberger	German K. Müller	Hitoshi Sakai	
Hans Füchtbauer	Mervyn Silas Paterson		

Help Direct GSA's Future

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

Nominations for 1997 officers and councilors must be received at GSA headquarters no later than **FEBRUARY 15, 1996.**

Please send nominations and back-up material to Administrative Department, Geological Society of America, P.O. Box 9140, Boulder, CO 80301.

CALL FOR NOMINATIONS

1998 National Awards (Deadline: April 30, 1996)

Nominations for the national awards described below are being solicited for 1998. Each year GSA members have been invited to participate by recommending possible candidates.

Those who wish to make nominations are urged to do so by sending **BACKGROUND INFORMATION** and **VITAE**, and specifying the award for which the candidate is being submitted by **April 30, 1996**, to the GSA External Awards Committee, P.O. Box 9140, Boulder, CO 80301, (303) 447-2020, fax 303-447-1133. The nomination process is coordinated by AGI on behalf of its member societies, and a roster of candidates will be finalized by the AGI Member-Society Council at its Spring 1997 meeting for nomination to the respective offices sponsoring the national awards.

William T. Pecora Award

The Pecora Award, sponsored jointly by NASA and the Department of the Interior, is presented annually in recognition of outstanding contributions of individuals or groups toward the understanding of Earth by means of remote sensing.

The award recognizes contributions of those in the scientific and technical community as well as those involved in the practical application of remote sensing. Consideration will be given to sustained or single contributions of major importance to the art or science of the understanding of Earth through observations made from space.

National Medal of Science

The medal is awarded by the President to individuals "deserving of special recognition by reason of their outstanding contributions to knowledge in the physical, biological, mathematical, engineering, or social and behavioral sciences."

There are now many younger American scientists and engineers who may be reaching a point where their contributions are worthy of recognition. The committee is giving increasing attention to these individuals as well as to those outstanding women and minority scientists who deserve recognition.

Vannevar Bush Award

The Vannevar Bush Award is presented from time to time to a person who, through public service activities in science and technology, has made an outstanding contribution toward the welfare of mankind and the nation.

The award is given to a senior statesman of science and technology and complements the NSF's Alan T. Waterman Award, which is given to a promising young scientist. The two awards are designed to encourage individuals to seek the highest levels of achievement in science, engineering, and service to humanity.

The nomination should be accompanied by a complete biography and a brief citation summarizing the nominee's scientific or technological contributions to our national welfare in promotion of the progress of science.

Alan T. Waterman Award

The Waterman Award is presented annually by the NSF and National Science Board to an outstanding young researcher in any field of science or engineering supported by NSF.

Candidates must be U.S. citizens or permanent residents and must be 35 years of age or younger, *OR* not more than five years beyond receipt of the Ph.D. degree by December 31 of the year in which nominated.

Candidates should have completed sufficient scientific or engineering research to have demonstrated, through personal accomplishments, outstanding capability, and exceptional promise for significant future achievement.

Remember: **BACKGROUND INFORMATION** and **VITAE** of nominated candidates should be sent by **April 30, 1996**, to the GSA External Awards Committee, P.O. Box 9140, Boulder, CO 80301.

Call for Nominations for 1996 Young Scientist Award (Donath Medal)

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

For the year 1996, only those candidates born on or after January 1, 1961, are eligible for consideration. In choosing candidates for the Young Scientist Award, scientific

achievement and age will be the sole criteria. Nominations for the 1996 award must include

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

Nominations for the 1996 Young Scientist Award must be received at GSA headquarters by **February 1, 1996**. Use the form below for submitting the name of a candidate for the Young Scientist Award. ■

Call for Nominations for 1996 GSA Distinguished Service Award

The GSA Distinguished Service Award was established by Council in 1988 to recognize individuals for their exceptional service to the Society. GSA Members, Fellows, Associates, or, in exceptional circumstances, GSA employees may be nominated for consideration. Any GSA member or employee may make a nomination for the award. Awardees will be selected by the Executive Committee, and all selections must be ratified by the Council. Awards may be made annually, or less frequently, at the discretion of Council. This award will be presented during the Annual Meeting of the Society. Letters of nomination and any supporting information should be

addressed to Executive Director, GSA, P.O. Box 9140, Boulder, CO 80301. ■

Deadline for nominations for 1996 is March 1, 1996.

Recipients to date:

1988 Campbell Craddock
Robert D. Hatcher, Jr.
Eldridge M. Moores
William A. Thomas
1990 William B. Heroy, Jr.
1991 Dorothy M. Palmer
1992 A. R. (Pete) Palmer
1993 Michel T. Halbouty
1994 F. Michael Wahl
1995 John E. Costa
Henry T. Mullins
Arthur G. Sylvester

1996 YOUNG SCIENTIST AWARD (DONATH MEDAL)

THE GEOLOGICAL SOCIETY OF AMERICA Nomination for 1996 Young Scientist Award (Donath Medal)

NAME OF CANDIDATE: _____

Date of birth: _____

ADDRESS: _____

For the year 1996, only those candidates born on or after January 1, 1961, are eligible for consideration.

REQUIRED INFORMATION (Please attach)

BIOGRAPHICAL INFORMATION

Provide in a format similar to that found in *American Men and Women of Science, Who's Who in America*.

SUMMARY OF SCIENTIFIC CONTRIBUTIONS TO GEOLOGY

Not more than 200 words.

SELECTED BIBLIOGRAPHY

No more than 10 titles.

LETTERS OF SUPPORT

Nominations for the Donath Medal **MUST BE SUPPORTED** by signed letters from five (5) scientists in addition to the person making the nomination. The letters may be attached to this nomination form or may be sent to the Executive Director separately.

Name of person making the nomination: _____

Address: _____

Date: _____ Signature: _____

Letters of support will be submitted by:

1. _____

2. _____

3. _____

4. _____

5. _____

RETURN TO: Executive Director
The Geological Society of America
P.O. Box 9140
Boulder, CO 80301
(303) 447-2020

DEADLINE: Completed nomination materials must be received by **February 1, 1996**. To be considered, nomination materials must meet the above criteria. Reprints or articles will not be accepted.

ROCKY MOUNTAIN SECTION, GSA 48th Annual Meeting

Rapid City, South Dakota
April 18–19, 1996

The Rocky Mountain Section of the Geological Society of America will meet jointly with the Rocky Mountain Section of the Paleontological Society of America and the Southwest Section of the National Association of Geology Teachers at the Rapid City Civic Center. The host for the meeting is the Department of Geology and Geological Engineering, South Dakota School of Mines and Technology.

SETTING

Rapid City, with a population of 68,000 in and around the city, is the gateway to the Black Hills. The city is located on Mesozoic rocks that dip gently eastward off the Black Hills, a Laramide uplift. Excellent exposures of Mesozoic and Paleozoic rocks are within a few miles of Rapid City. Precambrian metamorphic and igneous rocks are exposed in the central Black Hills. These rocks contain world-famous pegmatites near Mount Rushmore. The northern Black Hills area contains numerous Tertiary igneous intrusive centers, including beautifully exposed examples of laccoliths. Four major gold mines, including the Homestake mine, are currently operating.

The climate during April is typically unpredictable, ranging from temperatures of 60+ (°F) to near freezing. Precipitation is normally rain, although a spring snowstorm is inevitable in April.

Travel to Rapid City by either car or plane. The Rapid City airport has non-stop flights to Denver and Salt Lake City, and connections with Minneapolis via Sioux Falls.

CALL FOR PAPERS

Technical papers are invited for presentation in conventional theme sessions, symposia, and poster sessions. Papers dealing with all aspects of the Rocky Mountain region as well as those of general geological interest will be considered for presentation and discussion. Technical sessions will allow 15 minutes for presentation and 5 minutes for questions and discussion. Session chairs and speakers are asked to adhere stringently to these time limits.

REGISTRATION

Preregistration deadline:

March 8, 1996 (no exceptions)

Preregistration by mail will be handled by the Geological Society of America Meetings Department, P.O. Box 9140, Boulder, CO 80301-9140. For lower registration fees and to assist the local committee in planning, please preregister. Registration details and forms will appear in the January issue of *GSA Today*. On-site registration will begin on April 17, 1996.

GSA is committed to making every event at the 1996 Rocky Mountain Section Meeting accessible to all people interested in attending. If you have special requirements, such as an interpreter or wheelchair accessibility, there will be space to indicate this on the registration form, or you can call Perry Rahn, (605) 394-2464. If possible please let us know by March 8, 1996.

FIELD TRIPS

Both premeeting and postmeeting field trips are planned. For details, contact the respective field trip leaders. General questions should be addressed to Jack Redden, Field Trip Coordinator, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St.,

Rapid City, SD 57701, (605) 394-5113, fax 605-394-6703.

Premeeting

1. Late Neogene Tectonism in the Great Plains: Reality or Geofantasy? 2–3 days, April 15–17, 1996. Visits to the shallow folds and faults in the Little Badlands, North Dakota, and the spectacular slump-type structures of the northern Slim Buttes, South Dakota, where the displaced White River Group is overlain angularly by the Arikaree. An optional third day (see field trip #2) would examine faults and clastic dikes in Badlands National Park, South Dakota. Allan Ashworth, Department of Geosciences, North Dakota State University, Fargo, ND 58105, (701) 231-7919, fax 701-231-7149, and George Shurr, Department of Earth Sciences, St. Cloud State University, St. Cloud, MN 56301, (612) 255-2009, fax 612-255-4262.

2. Neogene Stratigraphy and Sedimentation. Wednesday, April 17, 1996. Visits to classic sections in Badlands National Park, with additional emphasis on structural features. (This field trip can be used as an extension to field trip #1.) Rachel Benton, Badlands National Park, P.O. Box 6, Interior, SD 57750, (605) 433-5361, fax 605-433-5404, E-mail: rachel_benton@nps.gov, and Jim Martin.

3. Black Hills Hydrology. Wednesday, April 17, 1996. Examination of general Black Hills geology, recharging streams, springs in Precambrian and Paleozoic rocks, and a brief look at hydrogeology of an abandoned mine in the southern Black Hills. Limit: 24. Perry Rahn, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-2464, fax 605-394-6703, and Tim Hayes and Arden Davis.

4. Major Unconformities of the Black Hills. Wednesday, April 17, 1996. Visits to well-exposed Middle Proterozoic, Precambrian-Cambrian, Ordovician–Upper Devonian, Mississippian-Pennsylvanian, and Tertiary unconformities in the northern and east-central Black Hills. Jack Redden, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-5113, fax 605-394-6703, and Mark Fahrenbach.

5. Reclamation at Northern Black Hills Gold Mines. Wednesday, April 17, 1996. Reclamation activities that include mitigation of acid-generating sulfide waste rock will be the primary focus at LAC Mineral's Richmond Hill gold mine. The tour will also visit Wharf Resource's gold mine, where concurrent and final reclamation activities at an active mine can be witnessed. Tom Durkin, Office of Minerals and Mining, South Dakota Department of Environment and Natural Resources, Joe Foss Building, 523 E. Capitol Ave., Pierre, SD 57501-3181, (605) 773-4201.

Postmeeting

6. Homestake Iron-Formation-Hosted Gold Deposit. Friday, April 19, 1996 (evening). Underground mine tour of the Western Hemisphere's largest gold mine, which is developed to the 8000 ft level in an Early Proterozoic, structurally complex iron-formation host. Moderately good physical condition required. Limit: 15. Ed Morrow, Homestake Mining Company, 630 E. Summit St., Lead, SD 57754-1700, (605) 584-4843.

7. Geologic Hazards of the Black Hills. Saturday, April 20, 1996. Visits to landslides, swelling soils, flood plains, and gypsum solution features in the Rapid City, Lead, and Spearfish areas. Limit: 24. Perry Rahn, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-2464, fax 605-394-6703, and Arden Davis and Paul Gries.

8. Marine Cretaceous Paleontology and Stratigraphy. Saturday and Sunday, April 20 and 21, 1996. Visits to key sections and fossil localities that support present interpretations of the Cretaceous section. James Martin, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-2427, fax 605-394-6703, and Gorden Bell.

9. Tectonic and Plutonic Development and Associated Metamorphism in the Southern Black Hills. Saturday and Sunday, April 20 and 21, 1996. Visits to key structural, metamorphic, and igneous outcrops illustrating the complex Proterozoic history and metamorphism and metasomatism associated with the 1.7 Ga S-type Harney Peak granite. Jack Redden, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-5113, fax 605-394-6703, and Edward Duke.

10. Paleozoic Stratigraphy of the Black Hills. Sunday, April 21, 1996. This trip will visit outcrops of Cambrian through Permian rocks in the northern Black Hills (South Dakota and Wyoming). Emphasis will be on the Cambrian and Devonian of the Lead-Deadwood area, and the Pennsylvanian of the Sand Creek area (Wyoming). James Fox, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-2468, fax 605-394-6703.

11. Tertiary Igneous Systems and Related Au-Ag Mineralization of the Northern Black Hills. Saturday and Sunday, April 20 and 21, 1996. Visit natural and open-pit mine exposures of the Laramide igneous province to examine petrologic, structural, and gold-ore relations, and the character of dikes, stocks, sills, and laccoliths. James Kirchner, Department of Geography-Geology, Campus Box 4400, Illinois State University, Normal, IL 61790, (309) 438-7649, fax 309-438-5310. Internet: jgkirch@ilstu.edu, and Alvis Lisenbee and Colin Paterson.

SYMPOSIA

General sessions will include structural geology and tectonics, economic geology, igneous and metamorphic petrology, stratigraphy and sedimentation, paleontology, hydrogeology, engineering geology, geomorphology, geophysics, and general geology.

The following symposia will include both invited papers and selected volunteered papers. Prospective authors are encouraged to contact the respective conveners. General questions should be addressed to Alvis Lisenbee, Department of Geology and Geological Engineering, South Dakota School of Mines and Tech-

nology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-2463, fax 605-394-6703.

1. Precambrian Geology of the North-Central United States. Jack Redden, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-5113, fax 605-394-6703.

2. Applications of Geographic Information Systems and Computers in Geology. Maribeth Price, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-2492, fax 605-394-6703. Internet: price@gis.sdsmt.edu.

3. Late Cretaceous Marine Paleontology and Biostratigraphy. James Martin and Gorden L. Bell, Jr., Museum of Geology, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-2427, fax 605-394-6703; Internet: jmartin@msmailgw.sdsmt.edu.

4. Tertiary Alkalic Igneous Rocks of the Northern Rockies. James Kirchner, Department of Geography-Geology, Campus Box 4400, Illinois State University, Normal, IL 61790, (309) 438-7649, fax 309-438-5310. Internet: jgkirch@ilstu.edu.

5. Hydrology of Karst Aquifers. Perry Rahn and Arden Davis, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-2461, fax 605-394-6703.

6. Contaminant Hydrogeology of the Northern Rocky Mountain Region. Cathleen Webb, Department of Chemistry and Chemical Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-1239, fax 605-394-1232, Internet: cwebb@silver.sdsmt.edu, and Tim Hayes, U.S. Geological Survey, 1608 Mountain View Rd., Rapid City, SD 57702, (605) 394-1780 ext. 215, fax 605-394-5373.

7. Northern Great Plains and Rocky Mountain Cenozoic Depositional Systems, Stratigraphy, and Paleontology. Rachel Benton, Badlands National Park, P. O. Box 6, Interior, SD 57750, (605) 433-5361, fax 605-433-5404, E-mail: rachel_benton@nps.gov.

8. Metallogeny of Gold in the Northern Rockies. Colin Paterson, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-5114, fax 605-394-6703, E-mail: paterson@silver.sdsmt.edu.

9. Perspectives on the Western Interior Cretaceous Seaway. Richard Hammond, South Dakota Geological Survey, University Science Center, Vermillion, SD 57069; Karen Porter, Montana Bureau of Mines, Montana College of Mineral Science and Technology, Butte, MT 59701. Send abstracts to George Shurr, Department of Earth Sciences, St. Cloud State University, St. Cloud, MN 56301, (612) 255-2009, fax 612-255-4262.

10. Geoscience Education in Native American Communities. Steven Semken, Navajo Drylands Environments Laboratory, Navajo Community College, P.O. Box 580, Shiprock, Navajo Nation, NM 87420-0580.

ABSTRACTS

Abstracts are limited to 250 words and must be submitted camera ready on official 1996 GSA Abstract forms, available from the Abstracts Coordinator, Geological Society of America, P.O. Box 9140, Boulder, CO 80301, (303) 447-2020,

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E-mail: ncarlson@geosociety.org. An original and 5 copies are required for each abstract. Authors of symposium papers should send their abstracts directly to the appropriate convener (the first name in the list of symposium organizers above). All other abstracts should be sent to Alvis Lisenbee, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701. Abstracts will be reviewed for informative content and format, appropriate geographic coverage (Rocky Mountain region), and originality. To simplify scheduling and provide for a diversity of views, only one volunteered paper may be presented by each individual, although a person may also be a coauthor of additional papers.

ABSTRACT DEADLINE: Friday, January 5, 1996

PROJECTION EQUIPMENT

All slides must be 2" x 2" and fit standard 35 mm carousel trays. Two projectors and two screens will be available for oral sessions. Authors are strongly encouraged to bring their own preloaded carousels. A limited number of carousels will be available. The organizing committee will not be responsible if a carousel is unavailable for your talk.

POSTER SESSIONS

Poster sessions will be located adjacent to the exhibit and registration area. If you wish to present a poster, indicate your preference on your abstract form.

There will be a special poster session on Geologic Maps of the Black Hills and South Dakota, displaying 7.5' quadrangle maps of the northern Black Hills, 1:100,000 scale map of the central Black Hills, a 1:250,000 scale 1' x 2' quadrangles of South Dakota, and the new 1:500,000 scale South Dakota State Geological Map. New AVIRIS remotely-sensed data will also be displayed. Inquiries regarding posters should be directed to Lynn Hedges, South Dakota Department of Environment and Natural Resources, 2050 W. Main St., Suite 1, Rapid City, SD 57702, (605) 394-2229.

Undergraduate students are invited to participate in a poster session sponsored by the Geology Division, Council on Undergraduate Research. Student(s) must be listed as the first author and have been the major preparer of the poster. Topics may vary over a broad spectrum (e.g., see GSA Abstract form), but must be the result of their own participation in an undergraduate research program.

EXHIBITS

Exhibits are planned for the registration-poster session area. The cost per booth is \$50 per 12 x 10 ft space. Additional adjacent booths may be purchased for \$50 each to expand display space. For further information and booth reservation, contact Lynn Hedges or Foster Sawyer, South Dakota Department of Environment and Natural Resources, 2050 W. Main St., Suite 1, Rapid City, SD 57702, (605) 394-2229.

STUDENT PRESENTATIONS

The Museum of Geology at the South Dakota School of Mines and Technology will provide a \$50 award for the best paper by an undergraduate, and \$25 for second-best paper.

The Paleontological Society will sponsor an award for the best student paper in paleontology. A nonstudent can be coauthor, but the student must be both the presenter and senior (primary) author. To be eligible, the speaker must be currently enrolled in a graduate or undergraduate program or have completed such a program no longer than

one month prior to the meeting. The award will be a one-year subscription to *Paleobiology*.

STUDENT TRAVEL SUPPORT

The Rocky Mountain Section has funds available to support Student Associates of the Geological Society of America who plan to attend the meeting. Preference for support will be given to presenters of papers and posters and to group applications. Students are strongly encouraged to apply for these grants. Send a letter of application which identifies all student travelers in the group, GSA Student Associate member numbers, and a summary of costs to Rocky Mountain Section Secretary Ken Kolm, Division of Environmental Science and Engineering Department, Colorado School of Mines, Golden, CO 80401, (303) 273-3932, fax 303-273-3413, Internet: kkolm@mines.colorado.edu. If you are presenting a paper or poster, please include a copy of your notification of acceptance. Applications must be received by Ken Kolm by Friday, March 15, 1996.

SPECIAL EVENTS

Planned events include a welcoming reception in the evening on Wednesday, April 17, 1996. An alumni reception will be held on Thursday evening, April 18, 1996. Those schools wishing to have an alumni meeting area reserved should register with Perry Rahn, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-2464, fax 605-394-6703. A banner with your school name over the reserved area will be provided. Deadline for reservations is April 1, 1996. The annual business and luncheon meeting of the Geological Society of America Rocky Mountain Section will be held at 12 noon on Friday, April 19, 1996.

GUEST PROGRAM

Spring will be budding (we hope) in the Rapid City and Black Hills area. Mount Rushmore and Custer State Park are well-known attractions, and there are many scenic drives in the Black Hills and Badlands. The Civic Center is conveniently located in a parkway near the downtown area, which boasts galleries, shops, hotels, and other attractions. The depot for the Rapid Ride bus system is a two-minute walk from the Civic Center; there are routes to the Rushmore Mall and other parts of Rapid City. The Museum of Geology at the South Dakota School of Mines and Technology has outstanding exhibits and research collections, and is a major tourist attraction. Organized activities will depend on the numbers of preregistered guests.

ACCOMMODATIONS

Blocks of rooms will be reserved at several hotels within a 5-minute walk of the Civic Center. Housing information and a list of room blocks and locations will be provided in the final announcement.

DETAILED INFORMATION

More detailed information regarding registration, accommodations, activities, and the program will be provided in the final announcement in the January issue of *GSA Today*, and as part of the Rocky Mountain Section *Abstracts with Programs*. Address questions and suggestions to Colin Paterson, GSA Meeting Chair, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-5114, fax 605-394-6703, E-mail: paterson@silver.sdsmt.edu. ■

Preliminary Announcement and Call for Papers

CORDILLERAN SECTION, GSA 92nd Annual Meeting

Portland, Oregon

April 22-24, 1996

The Department of Geology, Portland State University, Portland, Oregon, will host the 1996 meeting of the Cordilleran Section of the Geological Society of America. The meeting is held jointly with the Pacific Northwest Metals and Minerals Conference (PNMMC) sponsored by local sections of the Society for Mining, Metallurgy, and Exploration, Inc. (AIME), American Welding Society, ASM International, and Association of Engineering Geologists.

SETTING

Portland, Oregon, is located at the northern end of the Willamette Valley between the Cascade Range to the east and the Coast Range to the west. The City of Roses will be abloom with rhododendrons and azaleas at the time of the meeting. The weather in late April is pleasant, but rainy weather with intermittent "sun breaks" is likely. The average high is 60 °F and average low is 41 °F. The meeting will be held at the Red Lion Hotel—Lloyd Center. Access to the city is easy via Interstates 5 and 84, rail, or air. Interstates 5 and 84 pass within 0.8 miles of the hotel. Portland International Airport is 15 minutes from the hotel and is serviced by hotel shuttle van. Access from the Amtrak station to the Red Lion Hotel—Lloyd Center includes a short bus ride to the light rail system, which passes next to the hotel.

REGISTRATION

**Preregistration Deadline:
March 15, 1996**

Preregistration by mail will be handled by the Geological Society of America Meetings Department, P.O. Box 9140, Boulder, CO 80301-9140. On-site registration will be held in the Ballroom Foyer of the Red Lion Hotel—Lloyd Center.

Please take advantage of the lower registration fees and **register by March 15, 1996.**

GSA is committed to making every event at the 1996 Cordilleran Section Meeting accessible to all people interested in attending. If you have special requirements, such as an interpreter or wheelchair accessibility, there will be space to indicate this on the registration form, or you can call Michael Cummings, (503) 725-3022. If possible, please let us know by March 1, 1996.

Abstracts may be purchased with your GSA membership or on site in the registration area.

CALL FOR PAPERS

Papers are invited for presentation in oral technical sessions, symposia, theme sessions, and poster sessions for all sessions sponsored by participating societies. Papers dealing with all aspects of the Cordilleran region, as well as those of general geological interest, will be considered for presentation and discussion. Technical sessions will allow 12 minutes for presentation and 3 minutes for discussion. Symposia may allow equivalent or longer times for presentation, at the option of the conveners and symposium coordinator.

**ABSTRACTS DEADLINE:
December 28, 1995**

An original and five copies are required for each abstract. Authors of symposium papers should send their abstracts directly to the appropriate convener (see lists above). Other abstracts

should be sent directly to Richard Thoms, Department of Geology, Portland State University, P.O. Box 751, Portland, OR 97207, (503) 725-3379, fax 503-725-3025, E-mail: dick@ch1.ch.pdx.edu.

Abstracts will be reviewed for information content and format, appropriate geographic coverage (Cordilleran region), and originality. Only one volunteered paper may be presented by each individual, although a person may also coauthor papers presented by others and may present additional papers invited for symposia.

ABSTRACT FORMS

Abstracts are limited to about 250 words and must be submitted camera-ready on official 1996 GSA abstract forms, available from the Abstracts Coordinator, Geological Society of America, P.O. Box 9140, Boulder, CO 80301, (303) 447-8850, or E-mail: ncarlson@geosociety.org.

FIELD TRIPS

For details of the premeeting and postmeeting field trips, contact the field trip leaders listed. General questions should be addressed to Field Trip Coordinators Scott Burns, Department of Geology, Portland State University, P.O. Box 751, Portland, OR 97207, (503) 725-3389, fax 503-725-3025, E-mail: scott@ch1.ch.pdx.edu; or Jeff Markstaller, Oregon Steel Mills, P.O. Box 2760, Portland, OR 97208, (503) 978-6168, fax 503-240-5268. Preregistration forms will be available in the Final Announcement in the January 1996 issue of *GSA Today*.

Premeeting

1. Building Stones and Landscaping Boulder Industry of Western Washington, April 20-21. David Knoblach, Marenakos Rock Center, 30250 SE Highpoint Way, Issaquah, WA 98027, (206) 392-3313, fax 206-222-7292.

2. Applied Paleoflood Hydrology in North-Central Oregon, April 20-21. Dan Levisch and Dean Ostenaar, Bureau of Reclamation, Seismotectonic Geology, Mail Code D8331, P.O. Box 25007, Denver Federal Center, Denver, CO 80225-0007, (303) 236-4195, ext. 274.

3. Quaternary Crustal and Subduction Earthquakes on the South Coast of Oregon, April 20-21. Ian Madin, Oregon Department of Geology and Mineral Industries, 1831 First St., Baker City, OR 97814, (503) 523-3133, fax 503-523-5992.

4. Deschutes Basin: A Medial and Distal Record of Cascades Volcanism, April 20-21. Gordon G. Goles, Department of Geological Sciences, University of Oregon, Eugene,

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OR 97403-1272, (503) 346-4589, E-mail: goles@oregon.uoregon.edu.

5. **Columbia River Basalt Intra-canyon Flows in Western Oregon and Washington: Ginkgo, Rosalia, and Pomona**, April 20–21. Marvin Beeson and Terry Tolan, Department of Geology, Portland State University, P.O. Box 751, Portland, OR 97207, (503) 725-3024, fax 503-725-3025, E-mail: marvin@ch1.ch.pdx.edu.

6. **Landslides of the Oregon Coast Range**, April 20. Scott Burns, Department of Geology, Portland State University, P.O. Box 751, Portland, OR 97207, (503) 725-3389, fax 503-725-3025, E-mail: scott@ch1.ch.pdx.edu; and Dave Michael, Oregon Department of Forestry, Forest Grove.

7. **Mount St. Helens: Engineering Geology of Highway 504, Sediment Retention Structure, and the Spirit Lake Tunnel**, April 21. Scott Burns, Department of Geology, Portland State University, P.O. Box 751, Portland, OR 97207, (503) 725-3389, fax 503-725-3025, E-mail: scott@ch1.ch.pdx.edu.

8. **Magmatic and Postemplacement Processes in the Rattlesnake Tuff—Silicic Volcanism of the High Lava Plains, Eastern Oregon**, April 20–21. Anita Grunder, Oregon State University, Dept. of Geosciences, 104 Wilkinson Hall, Corvallis, OR 97333, (503) 737-1249, fax 503-737-1200 (available after January 1996); Martin Streck, Dept. of Volcanology and Petrology, Christian Albrecht University of Kiel, Germany, E-mail: mstreck@geomar.de.

9. **Geologic History of Mount Hood Volcano**, April 21. Willie Scott and Cynthia Gardner, U.S. Geological Survey—Cascades Volcano Observatory, Vancouver, WA 98661, (360) 696-7909, fax 360-696-7866.

Postmeeting

10. **Petrotectonic Elements of Marginal Basin Oceanic Lithosphere: An Example from the Klamath Mountains, Oregon and California**, April 22 (evening)–April 25. Doug Yule and Jason B. Saleeby, California Institute of Technology, Division of Geological and Planetary Sciences 170-25, Pasadena, CA 91125, (818) 395-6590, fax 818-568-0935, E-mail: yule@legs.gps.caltech.edu; Cal Barnes, Texas Tech University, Lubbock; Art Snoke, University of Wyoming, Laramie; Greg Harper, SUNY—Albany, Albany, New York.

11. **Tour of Oregon Steel Mills**, April 24. Susan Graham and Jeff Markstaller, Oregon Steel Mills, P.O. Box 2760, Portland, OR 97208, (503) 978-6168, fax 503-240-5268.

12. **Evidence of the Missoula Floods and Quaternary Geology in the Portland Area**, April 25. Scott Burns, Department of Geology, Portland State University, P.O. Box 751, Portland, OR 97207, (503) 725-3389, fax 503-725-3025, E-mail: scott@ch1.ch.pdx.edu.

TECHNICAL PROGRAM

General questions about the technical program should be addressed to the meeting cochairs, Michael L. Cummings, Department of Geology, Portland State University, Portland, OR 97207, (503) 725-3395, fax 503-725-3025, E-mail: michael@ch1.ch.pdx.edu, or Joe Stafford, Columbia Steel Casting Co., 10425 N. Bloss Ave., Portland, OR 97283, (503)286-0685, ext. 262, fax 503-286-1743. Four themes have been selected to unify the interests of the sponsoring organizations.

THEME 1: Regional Seismicity

Geologic Framework of Earthquakes in the Pacific Northwest. Curt Peterson, Department of Geology, Portland State University, P.O. Box 751, Portland, OR 97207, (503)725-3375, fax 503-725-3025, E-mail: curt@ch1.ch.pdx.edu.

Earthquake and Volcanic Hazards: Site Analysis. Joe Ritchey, Western Field Operations Center, U.S. Bureau of Mines, 360 E. 3rd Ave., Spokane, WA, 99202, (509) 353-2700, fax 509-353-2661.

THEME 2: Infrastructure

Slope Stability: Assessment and Remediation. Sue D'Agnese, Oregon Department of Transportation, Roseburg, OR 97470, (503) 957-3595, fax 503-957-3604.

Infrastructure: Design and Materials. Matthew Kuhn, University of Portland, School of Engineering, 5000 N. Willamette Blvd., Portland, OR 97203-5798, (503) 283-7361, fax 503-283-7345, E-mail: mkuhn@up.edu.

THEME 3: Environmental Concerns

Site Mapping—Geochemical and Geologic. Dale Avery, Western Field Operations Center, U.S. Bureau of Mines, 360 E. 3rd Ave., Spokane, WA 99202, (509) 353-2700, fax 509-353-2661.

Mine Waste Disposal and Cleanup. Norm Day, Recreation Lands and Minerals, P.O. Box 3623, U.S. Forest Service, Portland, OR 97208-3623, (503) 326-6705, fax 503-326-7554.

Waste Management and Remediation in Manufacturing. Khalid Khan, University of Portland, School of Engineering, 5000 Willamette Blvd., Portland, OR 97203, (503) 283-7276, fax 503-283-7345, E-mail: khan@up.edu.

Environmental Compliance. Peter Baer, 838 NE 10th St., Gresham, OR 97030, (503) 661-7995, fax 503-661-7965.

Environmental Noncompliance. Peter Baer, 838 NE 10th St., Gresham, OR 97030, (503) 661-7995, fax 503-661-7965.

Materials: From Cradle Back to Cradle. Adrian McNutt, Glenbrook Nickel Co., P.O. Box 85, Riddle, OR 97469, (503) 874-3171, fax 503-874-3380.

THEME 4: Energy

Geology and Geothermal Resource Potential of the Cascade Range and Northern Basin and Range Province. Michael L. Cummings, Department of Geology, Portland State University, P.O. Box 751, Portland, OR 97207, (503) 725-3395, fax 503-725-3025, E-mail: michael@ch1.ch.pdx.edu; and David McClain, CE Exploration Co., Portland.

Energy: Materials and Technologies. Mark Siddall, Teledyne Wah Chang, P.O. Box 460, Albany, OR 97321, (503) 926-4211, ext. 6110, fax 503-967-6987.

SYMPOSIA

The following symposia will include both invited papers and selected volunteered papers. Prospective authors are encouraged to contact the respective conveners.

1. **Mesozoic and Early Tertiary Evolution of Southern California, Arizona, and Nevada.** Andrew Barth, Department of Geology, Indiana University, 723 West Michigan St., Indianapolis, IN 46202, (317)-274-1243.

2. **Subduction Zone and Intraplate Earthquakes in the Pacific Northwest: Preparing for the Future** (Tuesday evening). Joe Stafford, Columbia Steel Casting Co., 10425 N. Bloss Ave., Portland, OR

97283, (503)286-0685 ext. 262, fax 503-286-1743.

3. **Geoscience Input in Water Resources Decision Making: Case Studies from Portland, Oregon.** Lorna Stickel, Regional Water Supply Project Manager, Portland Water Bureau, 1120 SW 5th Ave., Room 601, Portland, OR 97204, (503) 823-7502, fax 503-823-6133.

THEME SESSIONS

1. **Geologic Evolution of the Oregon Plateau** (oral and poster session). William Hart, Department of Geology, Miami University, Oxford, OH 45056, (513) 529-3217, fax 513-529-1542, E-mail: wkhart@miamv1.muohio.edu.

2. **Ground-water Hydrology and Geology** (oral and poster session). Marshall Gannett, U.S. Geological Survey, Water Resources Division, 10615 SE Cherry Blossom Dr., Portland, OR 97216-3159, (503) 251-3233, E-mail: mgannett@usgs.gov; and Kenneth E. Lite, Oregon Water Resources Department, 158 12th St. NE, Salem, OR 97310-0210, (503) 378-8455, E-mail: liteke@wrds.state.or.us.

3. **Operating Mines in the Western Cordillera.** Brian Ballou, Glenbrook Nickel Co., P.O. Box 85, Riddle, OR 97469, (503) 874-3171, fax 503-874-3380.

4. **Mine Failure Analysis.** Peter Chamberlain, U.S. Bureau of Mines, Twin Cities Research Center, 5629 Minnehaha Ave., South, Minneapolis, MN 55417-3099, (612) 725-4722, fax 612-725-4526.

5. **Underground Mining Procedures.** Lani Boldt, Spokane Research Center, U.S. Bureau of Mines, 315 E. Montgomery, Spokane, WA 99207, (509) 353-2700, fax 509-353-2661.

6. **Computer Software: What's New in Research and Education?** (poster and hands-on session). Ken Cruikshank, Department of Geology, Portland State University, P.O. Box 751, Portland, OR 97207, (503) 725-3383, fax 503-725-3025, E-mail: ken@ch1.ch.pdx.edu.

7. **Educating Today for Tomorrow's World.** Barbara Kirk, Chemeketa Community College, P.O. Box 14007, Salem, OR 97309, (503) 399-5247, fax 503-399-5214, E-mail: kirkfarb@teleport.com.

POSTER SESSIONS

Poster sessions will be located adjacent to the exhibit area. If you wish to take advantage of this highly effective means of communication, please indicate your preference for a poster session on the GSA abstract form.

COMPUTER CENTER

A computer work area where attendees can examine new software for educational and research purposes will be available in the Exhibit Area. Each day software will be changed to allow examination of different applications. The computer center is coordinated with Theme and Poster Session 6 (see above). For more information, contact Ken Cruikshank, Department of Geology, Portland State University, P.O. Box 751, Portland, OR 97207, (503) 725-3383, fax 503-725-3025, E-mail: ken@ch1.ch.pdx.edu.

PROJECTION EQUIPMENT

All slides must be 2" × 2" and fit standard 35 mm carousel trays. A projector and screen will be available for all oral sessions. Please bring loaded carousel trays, if possible. A speaker ready room will be available. An overhead projector will be available upon request.

EARTH SCIENCE EDUCATION PROGRAMS

Several special programs designed for teachers (K–12) and other interested professionals are scheduled during the meeting. Field studies specifically designed to be useful to teachers will be offered April 20–21. For information on any of the earth science education programs, contact Craig Rankine, EMCON, 15055 SW Sequoia Parkway, Suite 40, Portland, OR 97224-7712, (503) 624-7200, fax 503-620-7658; Mike Park, Stack Metallurgical Services, 6340 N. Basin, Portland, OR 97217, (503) 285-7703, fax 503-286-5681; or Elaine Cullen, U.S. Bureau of Mines, 315 E. Montgomery, Spokane, WA 99207, (509) 484-1610, fax 509-640-8070.

An education emphasis is scheduled during technical sessions on Tuesday, April 23. Theme and poster sessions will investigate educational opportunities for the earth science community.

The public is invited to participate in a special symposium Tuesday evening that examines regional seismicity, building codes and design, emergency management, and economic impacts related to potential subduction zone and intraplate earthquakes in the Pacific Northwest.

EXHIBITS

Exhibits will be located adjacent to the poster sessions and the computer work area. The cost of exhibit space is \$300 for commercial exhibitors and \$150 for educational and nonprofit institutions. For further information and space reservations, contact John Kelley, Advanced Surfaces and Processes, 85 N 26th Ave., Bldg. 2, Cornelius, OR 97119, (503) 640-4072, fax 503-640-8070; or Chuck Daellenbach, U.S. Bureau of Mines, 1450 Queen Ave. SW, Albany, OR 97321-2198, (503) 967-5807, fax 503-967-5936, E-mail: daellenb@alrc.usbm.gov.

STUDENT SUPPORT

The GSA Cordilleran Section has funds available for grants to support GSA Student Associates of the section who are presenting papers at the meeting. Apply to Cordilleran Section Secretary Bruce A. Blackerby, Department of Geology, California State University, Fresno, CA 93740, (209) 278-2955 (direct) or 278-3086. Applications should include certification that the student is presenting a paper and is a GSA Student Associate of the Cordilleran Section. *All letters must be received by January 15, 1996.*

ACCOMMODATIONS

A block of rooms at the Red Lion Hotel—Lloyd Center, the site of the meeting, has been reserved for attendees at a special reduced rate of \$115. Additional housing is available within walking distance of the Red Lion Hotel—Lloyd Center. Specific information will be provided in the January 1996 issue of *GSA Today*.

DETAILED INFORMATION

Information concerning registration, accommodations, field trips, symposia and theme sessions, and other activities will appear in the January issue of *GSA Today* and will be updated regularly on the World Wide Web Home Page for the Department of Geology, Portland State University (<http://131.252.71.35/>, or via <http://www.pdx.edu/>). Requests for additional information or suggestions should be sent to General Chair Michael Cummings, Department of Geology, Portland State University, P.O. Box 751, Portland, OR 97207, (503) 725-3395, fax 503-725-3025, E-mail: michael@ch1.ch.pdx.edu. ■

1995 GEOVENTURES

The GSA GeoVentures Program offered four programs in 1995 unrelated to the annual or section meetings. The total of 104 participants, ranging in age from 26 to 80, represented a vast range of interests and backgrounds.

This educational program serves professionals who enjoy their geology and the company of other geologists in a field setting. GeoVentures are a special benefit created for members, but are open to guests and friends also.

GeoVentures is the overall name for adult educational and adventure experiences of two kinds: GeoHostels and GeoTrips. Both are known for superior scientific leadership. Fees for both are low to moderate (relative to the destination, length, time of year, and number of participants). GeoHostels are usually five-day, campus-based programs. GeoTrips are anywhere from one to three weeks in length, and the itinerary includes multiple destinations.

GEOHOSTELS

The Geological History of Southwestern Montana

28 participants. June 17–22, 1995.

Leader: Robert Thomas, Western Montana College

"Rob is a natural! The group was great," wrote Irene and Al Boland of Rock Hill, South Carolina.

"I've come to view the GeoHostels as offering remarkable insights to the geology of the American West. I hadn't been in that area (Montana) for 30 years, and Rob Thomas brought me up to date with the new geological interpretations," wrote Jim Carl of Potsdam, New York.



Dillon gang. Edna Collis

Scenic Geology of Northwestern Colorado and Dinosaur National Monument

32 participants. June 24–29, 1995.

Leaders: Gregory Holden, and Kenneth Kolm, Colorado School of Mines



Cruisin' down the river ... Split Mountain. Amy Ross

"I had a fantastic time! It was one of the funnest things I've ever done," wrote Sandy Krempasky of Fredericksburg, Virginia.

"This was my third GeoHostel. I have thoroughly enjoyed all of them and hope to enjoy more," wrote Tom Robertson of Los Gatos, California.



Steamboat Springs-Vernal gang. Ken Kolm

GEOTRIPS

Geology of the Grand Canyon—Lee's Ferry to Pierce Ferry

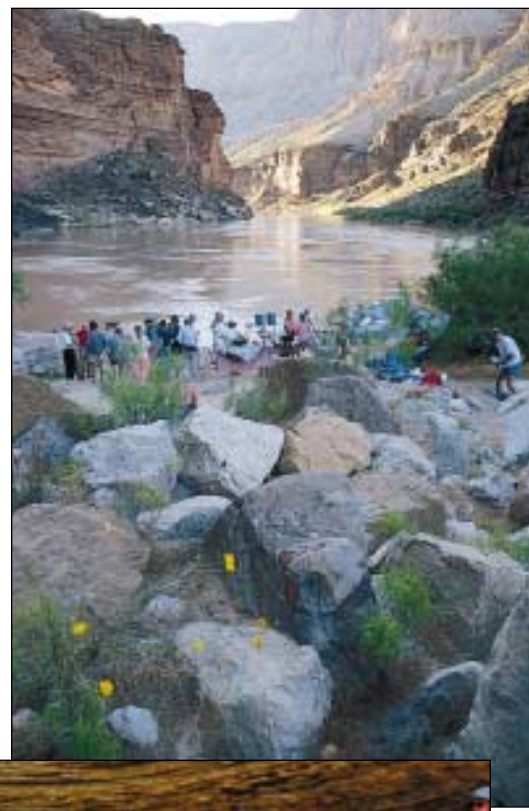
31 participants,

April 21–28, 1995.

Leaders: Stanley Beus, Northern Arizona University, Flagstaff, and Ivo Lucchitta, U.S. Geological Survey, Flagstaff, Arizona.

"The Grand Canyon Trip was a magnificent experience," wrote Pierre Sauve of Quebec, Canada.

"World Class outcrops, knowledgeable and interesting leaders, spectacular stops and campsites, well-organized—all get an A+," wrote Weldon Frost, Longboat Key, Florida.



Morning in the canyon. Ivo Lucchitta



Redwall Cavern—Taking a break with Ivo. Sue Tanges

Iceland: Fire and Ice

13 participants, July 16–30, 1995

Leaders: Haraldur Sigurdsson, Graduate School of Oceanography, University of Rhode Island, Narragansett, Rhode Island and Haukur Johannesson, Natural History Institute, Reykjavik, Iceland.

"Congratulations to GSA on having presented such a well organized and informative trip. An outstanding experience and one that I will remember for a long time," wrote Armando Ricci, Jr. of Natchez, Mississippi.

"Our leaders made the trip both geologically interesting and thoroughly enjoyable. Good discussions and lots of fun!," wrote Unni Rowell of Bloomington, Indiana.

"There are many other places in Iceland I would like to go to, but I think we had the best possible itinerary for a two-week trip," wrote Rosaly Lopes-Gautier of Altadena, California.



Gullfoss waterfall, 90 km (55 mi) east of Reykjavik. Bob Grant

Coming in November GSA Today...

GEOVENTURES 1996

Registration begins January 1.

GSA SECTION MEETINGS — 1996

Call for Papers

SOUTH-CENTRAL SECTION

March 11–12, 1996
University of Texas, Austin, Texas

Abstract Deadline:
November 20, 1995

Submit completed abstracts to:
William F. Mullican, Bureau of Economic
Geology, University of Texas, University
Station Box X, Austin, TX 78712,
(512) 471-1534, mullicanb@
begv.beg.utexas.edu

SOUTHEASTERN SECTION

March 14–15, 1996
Ramada Plaza Hotel, Jackson, Mississippi

Abstract Deadline:
November 15, 1995

Submit completed abstracts to:
Darrel Schmitz, Department of Geo-
sciences, Mississippi State University, P.O.
Box 5448, Mississippi State, MS 39762,
(601) 325-2904

NORTHEASTERN SECTION

March 21–23, 1996
Hyatt Regency, Buffalo, New York

Abstract Deadline:
November 20, 1995

Submit completed abstracts to:
Charles E. Mitchell, Department of Geol-
ogy, SUNY at Buffalo, 876 Natural Science
and Mathematics Complex, Buffalo, NY
14260-3050, (716) 645-6800, glgchuck@
ubvms.cc.buffalo.edu

ROCKY MOUNTAIN SECTION

April 18–19, 1996
Rapid City Civic Center,
Rapid City, South Dakota

Abstract Deadline:
January 5, 1996

Submit completed abstracts to:
Alvis L. Lisenbee, Department of Geology
and Geological Engineering, South Dakota
School of Mines and Technology, 501 East
St. Joseph St., Rapid City, SD 57701-3995,
(605) 394-2463

CORDILLERAN SECTION

April 22–24, 1996
Red Lion Hotel at Lloyd Center,
Portland, Oregon

Abstract Deadline:
December 28, 1995

Submit completed abstracts to:
Richard Thoms, Department of Geology,
Portland State University, P.O. Box 751,
Portland, OR 97207-0751, (503) 725-3379

NORTH-CENTRAL SECTION

May 2–3, 1996
Iowa State University, Ames, Iowa

Abstract Deadline:
January 17, 1996

Submit completed abstracts to:
Kenneth E. Windom, Department of Geo-
logical and Atmospheric Sciences, Iowa
State University, 253 Science I Building,
Ames, IA 50011-3210, (515) 294-2430,
kewindom@iastate.edu

GSA ANNUAL MEETINGS

1995

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



1996

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

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

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

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



THEME FOR 1996 ANNUAL MEETING

The scientific theme for the 1996 Annual Meeting is "Earth System Summit." As with past themes, this one has several meanings. In particular, we wish to emphasize that Earth is a complete system whose processes are complexly interrelated at a variety of scales. Second, the theme emphasizes that we are all inhabitants of this complex system; our actions can have significant impact—or be impacted by—its dynamic behavior. Theme sessions and symposia will be offered on aspects of multidisciplinary integrated studies of the Earth System, with special emphasis on the Rocky Mountain, High Plains, and Western Interior regions. We are, therefore, soliciting symposia and theme topics and field-trip proposals that will integrate a variety of disciplines around a broad topic. We envision a coupling of symposia-theme sessions and field trips, in which pre- or postmeeting field trips complement technical sessions presented during the meeting. Examples of such synergy might be "The Yellowstone Volcanic System," "The Rio Grande Rift System," or "The San Luis Valley Hydrologic System."

1996 ABSTRACT FORM REQUEST

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

Please send ___ copies of the 1996 GSA abstract form. I understand that the same form may be used for all 1996 GSA meetings.

Name _____

Address _____

City _____ State _____ ZIP _____

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	3526	16,500
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	(1) Sales through dealers and carriers, street vendors, and counter sales (not mailed)	0
	(2) Paid or Requested Mail Subscriptions, (Including advertisers)	15,182
	proof copies and exchange copies)	14,097
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This information taken from PS Form 3526, signed September 20, 1995 by the Publisher, Donald M. Davidson, Jr., and filed with the United States Postal Service in Boulder, Colorado.

CALL FOR CONTINUING EDUCATION COURSE PROPOSALS

PROPOSALS DUE BY DECEMBER 1

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

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

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

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

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

CLASSIFIED ADVERTISING

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

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Situations Wanted

PH.D. IN GEOLOGY with postdoc experience and good publication record is looking for research/teaching position. Research interests include geochronology (its applications to various geological problems), morphotectonics, regional geology of Gondwana, Tethyan orogenies and Asia. Please reply to GSA Box 1060, GSA, P.O. Box 9140, Boulder, CO 80301-9140.

Upcoming Penrose Conferences

October 1995

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

October 14-20,
The Argentine Pre-cordillera: A Laurentian Terrane?, San Juan, Argentina. Information: Ian W. D. Dalziel, Institute for Geophysics, University of Texas at Austin, 8701 N. Mopac Expy., Austin, TX 78759-8397, (512) 471-0341, fax 512-471-8844, E-mail: ian@utig.utexas.edu.

April 1996

April 16-21,
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.

Positions Open

ENVIRONMENTAL GEOSCIENTIST

The Programs in Geosciences at The University of Texas at Dallas have an opening for a tenure-track, faculty position in the field of Environmental Geosciences. The successful candidate will complement our existing strengths in high resolution geophysics and geochemistry and will lead an expanding research effort in environmental geosciences. Applications are invited from hydrogeologists with strength in environmental geophysics or low temperature geochemistry. Teaching responsibilities will include graduate and undergraduate courses in hydrogeology, courses in the area of specialization, and supervision of graduate students. We expect to fill this position at the assistant professor level, but rank and salary are negotiable. The successful applicant will be expected to begin his/her duties at the beginning of the fall semester, 1996.

Formerly the Southwest Center of Advanced Studies, The University of Texas at Dallas was established in 1969. UTD has an international reputation for its research. The Programs in Geosciences currently have 14 faculty, 3 technical support staff, 5 research scientists, 4 post-docs, and a full complement of analytical equipment and computers. There are approximately 78 graduate and 50 undergraduate students enrolled in a full range of degree programs including BA, BS, MS, and Ph.D.

Applicants must possess a Ph.D. at the time of appointment. All applicants should send a resume and a concise statement describing their areas of teaching and research interests. They should also provide the names, addresses, and telephone and FAX numbers of at least three references who can attest to their teaching and research capabilities. Review of applications will begin on January 15, 1996, and continue until position is filled. Applications should be forwarded to the Chair, Search #2022, The University of Texas at Dallas, P.O. Box 830688, Richardson, TX 75083-0688. The University of Texas at Dallas is an equal opportunity/affirmative action employer and encourages applications from women and members of minority groups.

INDIANA UNIVERSITY, BLOOMINGTON

The Department of Geological Sciences at Indiana University, Bloomington, invites applications for a tenure-track assistant professorship in geobiology starting August, 1996. Research areas of particular interest include biodiversity, global change, paleoceanography, paleoclimatology, and evolutionary history. Candidates should have demonstrable potential as an effective teacher and as a research scientist capable of developing an externally funded research program.

Applicants should submit a vita, summary of interests in research and teaching, and names and

addresses (including phone, fax, and e mail) of three referees by 15 October to the Geobiology Search Committee, Department of Geological Sciences, Indiana University, Bloomington, IN 47405-1403; (812) 855-5581; fax: 812-855-7899; email: dodd@indiana.edu.

Indiana University is an equal-opportunity, affirmative-action employer. Women and minorities are encouraged to apply.

THE WIENER LABORATORY OF THE AMERICA SCHOOL OF CLASSICAL STUDIES AT ATHENS, GREECE, DIRECTOR

Applications are invited for the position of Director of the Wiener Laboratory of the American School of Classical Studies at Athens, Greece. Applicants should have an area of expertise in one of the primary areas of the Lab's research programs (gearchaeology, human skeletal analysis, zooarchaeology) with an established publication record and demonstrated administrative and fund raising abilities. A strong background in natural science, experience in collaborating with archaeological and Classical scholars, and a commitment to Aegean archaeology is desired. Under the supervision of the Director of the School, the Director of the lab is responsible for developing and administering the research and workshop programs, collections, and facilities of the Lab as well as maintaining and enlarging established networks with other laboratories and institutions. He/she chairs the local administrative committee and an international science advisory committee. Salary (\$30,000-\$40,000) commensurate with rank and experience; housing allowance; qualified for TIAA/CREF after two years if not previously enrolled. Term 1 July 1996 to 30 June 1999, eligibility for renewal. Deadline for applications is 15 November 1995. Applicants must include a letter concerning his/her views on the future direction of the Wiener Laboratory, a curriculum vitae, and names of three references that may be contacted. Application materials should be sent to the search committee chair: Professor George Rapp, Jr., Director, Archaeometry Laboratory, University of Minnesota, Duluth, MN 55812, USA. Phone (218)726-7629. Fax: 218-726-6979.

IGNEOUS PETROLOGY

The Department of Geology at Washington State University invites applications for a tenure-track position in igneous petrology to be filled at the Assistant or Associate Professor level, beginning August 16, 1996 or January 1, 1997. As the Department positions itself for the 21st century, we will be filling a number of vacancies over the next few years. For the current vacancy a Ph.D. in geology with an emphasis in igneous petrology is required. Special interests in Cordilleran magmatism, isotopic dating, or volcanic hazards will be given preference. Postdoctoral research experience is desirable at the Assistant Professor level and an active externally funded research program with a substantial publication record in refereed journals is expected at the Associate Professor level. The successful candidate will be expected to: teach introductory-level undergraduate geoscience courses and undergraduate/graduate igneous petrology, supervise M.S. and Ph.D. candidates, develop and maintain an externally-funded research program, collaborate in research projects with other WSU faculty, and make use of extensive, modern analytical facilities available in the department including EMP, XRD, XRF, ICP/MS, SIMS.

Applications, indicating the level for which you are applying, and including a statement describing research and teaching interests, resume, and the names and addresses of four referees should be sent to: Professor Peter R. Hooper, Chair, Search Committee, Department of Geology, Washington State University, Pullman, WA 99164-2812, (509) 335-3009, e-mail: prhooper@mail.wsu.edu.

To ensure consideration, applications should be received by January 1, 1996. Washington State University is an equal opportunity educator and employer; women and minorities are encouraged to apply.

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LAFAYETTE COLLEGE

Assistant Professor, tenure-track position beginning Fall 1996 to teach courses in Sedimentology/Stratigraphy, Earth History, Oceanography/Marine Geology, and to participate in Introductory Geology courses. Applicants are invited to describe additional courses that they might teach in an undergraduate geology and environmental geosciences curriculum. A Ph.D. is required and teaching experience is preferred.

Please send a resume, a statement of teaching and research interests, graduate and undergraduate transcripts, and three reference letters to: Dr. Lawrence L. Malinconico, Jr., Department of Geology and Environmental Geosciences, Lafayette College, Easton, PA 18042-1768. Women and minorities are encouraged to apply. We will interview candidates at the Geological Society of America meeting in New Orleans, LA. However, applications will be accepted until December 31, 1995, or until the position is filled. An equal opportunity employer.

Services & Supplies

LEATHER FIELD CASES. Free brochure, SHERER CUSTOM SADDLES, INC., P.O. Box 385, Dept. GN, Franktown, CO 80116.

Opportunities for Students

Graduate Study in Earth-Surface Processes as Complex Systems. An emerging field at the boundary between physics and geomorphology, the application of the methods of nonlinear dynamics and complex systems to physical processes and patterns in the environment, is the focus of a research program at the Institute of Geophysics and Planetary Physics, University of California, San Diego. Specific research topics include the nonlinear dynamics of beach forms and patterns; waves in the surf zone; formation of ripples, dunes, and other landform patterns; ice-induced segregation in frozen ground; and the flow of granular materials in the transport of sediment. Opportunities exist for the use of theory, computer simulation and/or field experimentation to investigate these and other phenomena. Students with a background in physics, geophysics or engineering and an interest in nonlinear dynamics and in testing theory against field data are encouraged to apply. For further information and for an application, contact Brad Werner; Institute of Geophysics and Planetary Physics 0225; University of California, San Diego; La Jolla, California 92093-0225. (619) 534-0583, bwerner@ucsd.edu; http://bagnold.ucsd.edu/complex_systems.html.

Student Opportunities in Hydrologic Science at Duke University. Fellowships, research assistantships and teaching assistantships are available to highly qualified Ph.D. students through the Center for Hydrologic Science. Eleven faculty participate in the Center and Ph.D. degrees for hydrology students are awarded in Civil and Environmental Engineering, Environmental Science, Geology and Mathematics. For further information on graduate study in hydrologic sciences at Duke University contact: Stuart Rojstaczer, Director, Center for Hydrologic Science, Box 90230, 106 Old Chemistry, Duke University, Durham, NC 27708; (919) 681-8160; FAX 919-684-5833; hydro@geo.duke.edu; Web site http://www.geo.duke.edu/hydro.htm.

JOI/USSAC Ocean Drilling Fellowships. JOI/U.S. Science Advisory Committee is seeking doctoral candidates of unusual promise and ability who are enrolled at 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. Proposals and applications should be submitted to the JOI office according to the following schedule: Shorebased Research: 11/15/95 (regardless of DSDP or ODP leg).

For more information and to receive an application contact: JOI/USSAC Ocean Drilling Fellowship Program, Joint Oceanographic Institutions, Inc., 1755 Massachusetts Ave., NW, Suite 800, Washington, DC 20036-2102 (Andrea Johnson; Tel: (202) 232-3900, ext. 213; Internet: ajohnson@brook.edu).

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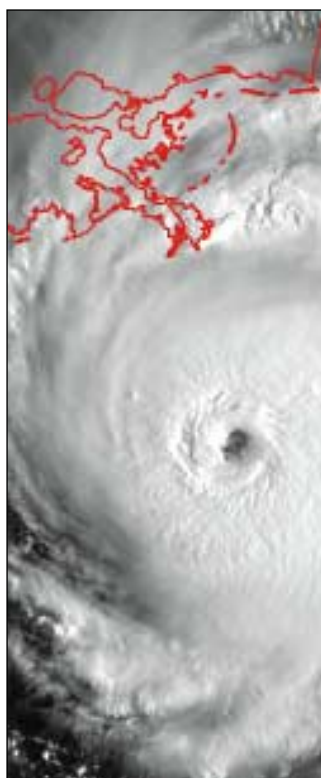
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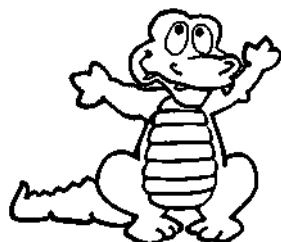
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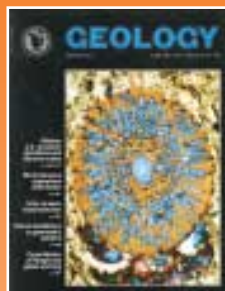
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