The Record of Terrestrial Impact Cratering

Richard Grieve, James Rupert, Janice Smith, Ann Therriault
Continental Geoscience Division, Geological Survey of Canada
Ottawa, Ontario K1A 0Y3, Canada

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 craters 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 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 meteotonic 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.
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 Manager 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 has generated numerous policy-related publications, opinion papers, and speeches in concert with these Washington-based efforts.

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 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.

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 geology 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 Engineering.

Member and former GSA Congressional Science Fellow Craig M. Schifferies, Washington, D.C., has been appointed director of the Board of Directors of Conservation's Maine Geological Survey.

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

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

1996 Birdsall-Dreiss Distinguished Service Award

1995 Annual Meeting

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1996 Annual Meeting Technical Program: for New Orleans NOW AVAILABLE! Go to Meetings and choose the 1996 Annual Meeting. The Technical Program is available in both Macintosh and DOS operating systems formats. You will be able to select one or both for download. This area also includes information about travel 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 the private industry, government research, and academia to the complicated issues of 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 are in water quality and radon concentration. From 1988 to 1991, he was a geologist for AMAX Exploration for two years. Folger received a grant from GSA for an academic year working as a project geologist at the Rocky Flats Plant in Colorado. Prior to that, he was a geochemist 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 offers 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 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 Fellow spends a year (September 1996–August 1997) in the office of an individual member of Congress or a committee for a one-year assignment. Fellows perform 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, possession of a broad range of interests 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 U.SGS are ineligible to apply for this fellowship. For information about other programs, contact AAAS or the Geological Society of America (GSA).

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 RECEPT OF ALL APPLICATION MATERIALS IS FEBRUARY 1, 1996

Membership Need 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. GSA 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 cuts. 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 enhancement 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, geologists can be an integral 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. Amann, Independent Oil Consultant, Houston, Texas
• William L. Fish, 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 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
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. Sheet volume has been one factor, but by no means the only one. The integration of multidisciplinary data on an international basis to address problems 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 document-
A Call to Scientific Communities: Perceptions of Global Data Issues

December 8, 1995

Editor's Note: This article is the result of an inquiry to interested parties on issues in the transborder flow of scientific data. This inquiry was conducted by BITS, the Interagency Software Environment, Library and Information Management Program, which was established by the Office of the National Coordinator for Science and Technology Information under the National Science Foundation. The results of this inquiry, along with other related issues, are included in the report, "International Flow of Scientific Data," which is available from the National Science Foundation.

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) Has the transborder movement of scientific data impacted your organization? (b) What changes do you anticipate over the next 5–10 years, and what are the likely impacts to your activities?

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 Data for Science and Technology
associated with such phenomena as the 1908 Tunguska explosion, the late Pleiocene meteorite debris found over ~300,000 km² of the South Pacific (Kylling, 1968), the Northwest province microtekite 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 presently known shock-morphology features at a particular structure. There is, however, a judgmental component in that the documentation of shock-morphologic effects must be convincing. For some cases for which there have been claims of shock-morphology effects, we have not included the structure. For example, we do not include the Severin structure in the former Czechoslovakia, although there was a report of shock-morphology in quartz (Vašina, 1986). Our own observations and recent transmission electron microscope studies have indicated that this deformation is not shock produced (Cooker et al., 1994). In a few cases of reports of shock-morphology, it is not clear with what degree of confidence they are associated, for example, for Bee Bluff, Texas, sometimes known as Uvalde, there are two separate reports of shock-morphological effects, but it has been suggested that the shocked materials are detrital and not specific to Bee Bluff (Sharpnack 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.

Our listing of the diameters of terrestrial impact structures is a mix of interpretations from topographic, 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 boundary. We list ~170–180 km (Pilkington et al., 1994), but it has been suggested that Chicxulub may be as large as ~300 km (Shibatani et al., 1993). Additional data acquisition, including reflection seismic, planned for the near future should resolve the issue. Data compilations of 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 geometry, 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). The history of its young age, Barringer has a partially preserved exterior ejecta deposit. Most older craters have been eroded and the interior filled with postimpact sediments.

Mesoscopic structures on Earth have diameters of as much as 4 km. Terrestrial impact structures with diameters >4 km generally have a complex form.

Some of this can be ascribed to differ- ences in target rock properties, com- plex craters occurring in sedimentary targets at diameters >2 km. Complex crater forms are characterized by struc- turally complex and faulted rim areas, a flat annular trough, and uplifted topographic 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 phases 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., Grieve and Pesonen, 1992).

Terrestrial complex impact structures also show the second-order effects of 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 cratering ( Pike, 1986). Original morphologic elements can be modified and enhanced 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). In fact, the Chicxulub structure, from which the meteorite responsible for the extinction of dinosaurs (e.g., Moloch, 1989). To this is the documentation of an Mesozoic crater (Therriault et al., 1994).

The lack of definitive evidence for multiring 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 taken from geophysical interpretations.

Spatial distribution

All terrestrial impact structures (Fig. 3) are entirely on land, with the exception of the Chicxulub impact (mixed Chicxulub– Peak Bay, Chicxulub, and Ust-Kara (Table 1). The structure of Ust-Kara has not been described, and so it is not exposed, and Nazareva et al. (1991).
Cratering continued from p. 194

and the present level of knowledge of the ocean floors is insufficient for identification. Ocean-floor sedimentation and subsidence 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 sediments. 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 are 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-Nadajoki, Lummapi, and Suvisvesi (Table 1).

There has been a similar recent upsurge in the identification of impact structures in southern Africa. Few impact structures have been found outside cratonic areas, which are the most favourable sites for the preservation of such structures in the terrestrial geologic environment. A few structures have been heavily tec-

tonized—e.g., Beaverhead and Sudbury (Table 1)—or occur in mountainous areas—e.g., Gardnos and Kata-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 are massive, commonly clast-rich, impact breccias. In a few cases, the original negative topographic expression of the crater is removed all topographic expression, and postshock temperatures to significant increased to ~300 km in diameter (Table 1). Impact age estimates, therefore, are biased toward younger ages to calculate parameters such as cratering rates and impact occurrence. The rate at which this meter. Some postimpact dates, however, are maximum age estimates—e.g., Lockne (Table 1; Grahn and Nokleberg, 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 Charleviox, 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 some cases, craters have been buried, and preserved only, and recently exhumed—e.g., the old, but relatively small Borej, Janisivari, and Sakuvarj structure (Table 1).

Age estimates, therefore, are a mixture of determinations that vary in accuracy and precision. Creationism must be used when using these ages to calculate parameters such as cratering rate estimates and as input to time-series analyses for searches for periods and links to other geologic processes (e.g., Stothers and Rampino, 1990). Shoestring 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 high number of Mesozoic-aged structures (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 a prefilled basin, and the original erosional remnant of the interior of a central uplift.

There has been a similar size-frequency distribution of terrestrial impact structures in Phanerozoic impact provinces (Table 1) and the frequency of terrestrial impact structures at large scales.

---

**TABLE 1. (continued)**

<table>
<thead>
<tr>
<th>Crater name</th>
<th>Location</th>
<th>Diameter (km)</th>
<th>Local</th>
<th>Late</th>
<th>Age (Ma)</th>
<th>Diameter (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lomonosov</td>
<td>South Africa</td>
<td>480 ± 20</td>
<td>13°46</td>
<td>74°20</td>
<td>15 ± 1</td>
<td>2000 ± 5</td>
</tr>
<tr>
<td>Lomonosov</td>
<td>South Africa</td>
<td>480 ± 20</td>
<td>13°46</td>
<td>74°20</td>
<td>15 ± 1</td>
<td>2000 ± 5</td>
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<td>South Africa</td>
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<td>13°46</td>
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<td>15 ± 1</td>
<td>2000 ± 5</td>
</tr>
</tbody>
</table>
diameters is similar to that on other terrestrial impactors (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 geological evidence for the largest terrestrial impact structures can be removed by a depth of 0.5 km. At larger complex structures, the depth diameter ratio is shallower, but the absolute depths are often greater. The uplift of the 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 is similar to that on other terrestrial impactors (Fig. 5).

CRATERING RATE

The most complete record of impact cratering is that of relatively large, geologically young complex impact structures in cratonic areas, such as North America and northern Europe-western Russia, that have been studied intensively. The rate of impact event, or the ratio of the number of impact events per unit time, depends on a number of factors, but is essentially a function of the rate of asteroidal ejection from the asteroid belt. The absolute number of impact events is the subject of ongoing debate with respect to the rate at which asteroids are added to the known sample over the eons of terrestrial evolution.

FIGURE 4

Grieve (1984) concluded that the original morphology of the Kara impact structure currently in our databases, please contact, by E-mail, craterexp.nicm.nic.ca.

ACKNOWLEDGMENTS

We thank M. Pilkington and B. Sharpton for commenting upon an earlier version of the manuscript. The Geological Survey of Canada contribution 15359.

REFERENCES CITED


Cordier, P., Vrána, S., and Doukhan, J. C., 1994, Shock metamorphism in quartz at Sevetin and Barents Sea, 73°48′N, 29°40′E, >135 Ma, 39 km. 12

— 2.7 × 10−15 km2/yr for diameters 20 km and impact structures dated at ≤120 Ma. This rate estimate is comparable to 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 ± 0.9 × 10−15 km2/yr (Shoemaker et al., 1990). The uncertainties attributed to all these estimates are large, a 50%, reflecting concerns about completeness of search and small number of statistics.

The most complete record of impact cratering is that of relatively large, geologically young complex impact structures in cratonic areas, such as North America and northern Europe-western Russia, that have been studied intensively. The rate of impact event, or the ratio of the number of impact events per unit time, depends on a number of factors, but is essentially a function of the rate of asteroidal ejection from the asteroid belt. The absolute number of impact events is the subject of ongoing debate with respect to the rate at which asteroids are added to the known sample over the eons of terrestrial evolution.

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 known and diagnostic of impact (see retrospective by French, 1990). In the terrestrial environment, the shock metamorphism of quartz has been particularly controversial, 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, we will receive information on the various details of particular terrestrial impact structures currently in our databases, please contact, by E-mail, craterexp.nicm.ca.

Figure 5 — A log-log plot of the cumulative number of Phanerozoic-aged impact structures above a particular diameter, binned by increments of 2 km. The power-law distribution down to ~20 km below which the size-frequency distribution falls off, indicating a deficit of smaller impact structures.


Grieve, R. A. F., and Robertson, P. R., 1987, Terrestrial impact structures in the western part of the Ronnel Map of Canada Map 1655A, scale 1:63,000,000.


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 par- tial 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, minori- ties, and persons with disabilities to participate fully in this grants pro- gram. Applicants need not be members of GSA. This program is supported in part by the Geological Society of America Foundation and the National Sci- ence Foundation.

Applications must be on current GSA forms available in geology depart- ments in the United States and Canada, or from the Research Grants Admin- istrator, GSA, P.O. Box 9140, Boulder, CO 80301-9140. Evaluations from two faculty members are required on GSA appraisal forms. The deadline is Febru- ary 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.

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The Gretchen L. Blechschmidt Award supports research by women interested in achieving a Ph.D. in the geological sciences and a career in aca- demic research, especially in the fields of biotatography and/or paleoceanog- raphy, and who have an interest in sequence stratigraphy analysis, particu- larly 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, espe- cially field-based studies dealing with the structural and tectonic develop- ment, and those that include some aspect of geochronology (either paleon- tologic or radiometric) to provide new age control for significant rock units in Alaska.

The Robert K. Fahnestock Memo- rial Award is made annually to the ap- plicant 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 evolu- tion 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 appli- cants for awards by the Engineering Geology, Geophysics (Allan V. G. Carter 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 Min- ing and Minerals Resources Bldg., Uni- versity of Kentucky, Lexington, KY 40506-1107.

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


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

The North-Central Section awards grants to undergraduate students within the geographic boundary of the Section. For further information con- tact the Section secretary, George R.
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 thePlanetary 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 $400 for attendance at the GSA Annual Meeting in New Orleans. Andrew H. Iveser of the University of Georgia received the award for his paper "Late Quaternary Paleoenvironmental Record from Sedi- ments at White Paintings Rock Shelter, Isidro, Sonora, Mexico," presented in the Archaeological Geology Theme Session.

COAL GEOLOGY DIVISION

The Coal Geology Division presented the 1995 Arthur D. McClean Scholarship Award to Penny Alano of University of Kentucky, for her proposal, "Salt Matrix Distribution and Association in the Lower Block and Buffaloville Coals of the Brazi Forma- tion in Daviess County, Indiana: Implica- tions for the Depositional Environ- ment." 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 Estoni- lute, 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 Gra- ham of Northeastern Illinois University for his project "Cadmium Contamina- tion 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 Characterization of the Western U.S. Cordillera Using Combined Waveform Data from Western U.S. Earthquake Networks."

HYDROGEOLOGY DIVISION

Awards for outstanding student research from the Hydrogeology Divi- sion 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;" Al- son Border Seney, 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 Sus- tained Aquifer Sediments and Ground- water;" and Norman G. Van Broekhoven, University of Texas, Austin, for his proposal "Organic Geochemistry and Mecha- nisms of Groundwater Recharge in Lobo Flat and Rhyolite Flat in Trans- Pecos, Texas."

PLANTAR GEOLOGY DIVISION

The Planetary Geology Division presents the Stephen E. Dworkin Best Student Paper Award annually to stu- dents 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 Ench Fosher 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 Head- quarters in Washington, D.C., early in the summer.

QUATERNARY GEOLOGY AND GEOMORPHOLOGY DIVISION

The Quaternary Geology and Geo- morphology Division awarded grants to three students in 1995. The Arthur D. Howard Research Grant was awarded to Sam Light, University of Colorado, for "Amino Acid Paleothermometry: A North/South Transect of the Lake Bonneville Basin, Utah, Simultaneous Last Glacial Maximum." The J. Hoover Mackin Grants went to Michael R. Kaplan, University of Colorado, for his paper "Late Quaternary Ice-Sheet Dynamics in Frobisher Bay, Eastern Canadian Arctic: A Paleo-climatic Signal?"; and Joseph M. Licciardi, Oregon State University, for "Chronology of High-Frequency (10^4 yr) Late-Pleniglacial Climate Change, Western North America."

SEDIMENTARY GEOLOGY DIVISION

The Sedimentary Geology Division presented its 1995 award for an out- standing student research proposal to Linda Elisabeth Sohl, Ph.D. candidate at Columbia University, for her project "The ‘Snowball’ Earth Revisited: A Pale- ometric Tool for Equatorial Glaciation in the Neoproteneozic 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. Conste- nente of the University of Illinois, for his project "Structure and Timing of the Deer Creek Detachment Fault System, Western U.S. Cordillera, Utah;" and Timothy Paulsen, University of Illinois at Urbana-Champaign, for "The Struc- tural 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: Mikel S. Brown, Iowa State Uni- versity; Cynthia Marie Gray; Kent State University; Steven Vanhuyse; University of Wisconsin—Eau Claire; Nicholas D. Loomis; University of Wisconsin—Eau Claire; James J. Luepke; University of Minnesota; Todd A. Myse; University of Wisconsin—Eau Claire; Candace K. Schwantes; University of Wisconsin—River Falls; and Jennifer Tobias; University of Wisconsin—Eau Claire.

SOUTHEASTERN SECTION

The Southeastern Section of GSA presented its annual research awards to the 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; University of Alabama—Tuscaloosa; Louis, for the best oral presentation, for his project "Amino Acid Paleothermometry: A North/South Transect of the Lake Bonneville Basin, Utah, Simultaneous Last Glacial Maximum." The J. Hoover Mackin Grants went to Michael R. Kaplan, University of Colorado, for his paper "Late Quaternary Ice-Sheet Dynamics in Frobisher Bay, Eastern Canadian Arctic: A Paleo-climatic Signal?"; and Joseph M. Licciardi, Oregon State University, for "Chronology of High-Frequency (10^4 yr) Late-Pleniglacial Climate Change, Western North America."

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 undergradu- ate students. The 1995 recipients are Joseph J. Bouchard, University of Con- necticut; K. Aubrey Hottell, Millersville University of Pennsylvania; and Jeanette Oestgaard, Kean College.

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The Cordilleran and Rocky Mountain Sections do not offer grants for student research.
Hallberg, University of Iowa Hygienic Laboratory, 102 Oakdale Campus, HI01 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 21, 1996. The grants will 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. Dworkin 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 award ceremonies 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


This 340-page biography effectively chronicles the life and times of an exceptionally wise and energetic man, who personified a remarkable 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 geologist 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 pro-evolution 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 geophysics 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 put it, “a one-world perspective, combined with a deep belief in America’s 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. Everett
Grand Junction, CO 81509-2906

(see p. 200 and 201 for notes on Mather.)
Washburn Photographs Illuminate Geologic Features

In the summer of 1933 a young Harvard student, inspired by Tarr and Martin'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.
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

Marble cake Moraines, Malaspina Glacier, Alaska (July 19, 1966).

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

“After the Storm”—Snow formations on the East Ridge of the Doldenhorn (11,950 ft), Bernese Overland, Switzerland (July 24, 1960).

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


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


Logan Glacier, Mount Logan (19,500 ft) and King Peak (16,970 ft) (August 6, 1938).
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 Founda- tion 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 month 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-12 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 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 crude oil and gas 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, as well as in the exploitation of coal-bed methane in the San Juan Basin and other areas.

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 announcement.

Pardee Coterie for Planned Givers

The Pardee 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 or significant others will meet 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 inform-al—no bylaws, no officers, no committees. The Joseph T. Pardee Memorial Fund originated through what is perhaps a classic example of planned giv-ing—an estate bequest, a trust, and two charitable remainder unitrusts, transistor- ing several lives. The resulting gift was the second largest ever received by GSA, exceeded only by the R. F. Pen-rose, 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 restaur-ant at 417 Royal Street. The speaker and discussion leader is Dan Ainsworth, 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, char-itable 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. Member-ship in the Pardee Coterie will follow promptly.

GSA Foundation President

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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 AAG meeting to be held during the GSA Annual Meeting in Denver.

CITIZATION 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, and (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.” Their paper was published in Utah Geological Survey Miscellaneous Publication 92-3, Field Guide to Geologic Excursions in Utah and Adjacent Areas of Nevada, Idaho, and Wyoming. The report was a thorough environmental assessment of geologic hazards, with technical detail, introductory explanations for laypersons, and a vivid road log.
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.

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

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.
Help Direct GSA's Future

The Council of the Society encourages you to help direct GSA's future. Please consider running for any of the available offices. Candidate forms are available from the Council at its Spring 1997 meeting for nomination to the respective offices sponsored by AGI on behalf of its member societies. Nominations for 1997 officers and councilors must be received at GSA headquarters no later than April 30, 1996. 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 at the National Academy of Sciences annual meeting during the joint AGU-GSA-GSA meeting. The award recognizes contributions of those individuals who have demonstrated sustained or single contributions of major importance in the public service activities in science and technology, has made an outstanding contribution to the understanding of the Earth through observations made from space.

Vannevar Bush Award

The Vannevar Bush Award is presented annually by the NSF and National Science Foundation Board to an outstanding young researcher in any field of science or engineering supported by NSF. The award is given to a senior statesman of science and technology and complementing the NSF 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.

National Medal of Science

The medal is presented by the President to individuals "deserving of special recognition by reason of their outstanding contributions to their 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 outstanding women and minority scientists who deserve recognition.

CALL FOR NOMINATIONS


Nominations for the national awards described below are being solicited for 1998. Each GSA member who is versed in the area of specialization of the individual or the position recommended (vice president, treasurer, councilor). Nominations for 1997 officers and councilors must be received at GSA headquarters no later than April 30, 1996. The nomination process is coordinated by AGI on behalf of its member societies.
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.

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.

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. Henry, Jr.
1991 .... Dorothy M. Palmer
1992 .... A. R. (Pete) Palmer
1993 .... Michel T. Halbouty
1994 .... F. Michael Wahl
1995 .... John E. Costa
Henry T. Mallins
Arthur G. Sylvester

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

NAME OF CANDIDATE: _______________________________

ADDRESS: _______________________________________

Date of birth: _______________________________

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. __________________________

GSA TODAY, October 1995 205
ROCKY MOUNTAIN SECTION, GSA
48th Annual Meeting
Rapid City, South Dakota
April 18–19, 1996

Preface

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 Southwestern 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.

T

by March 8, 1996. Unregistered and mine tour of the Western Hemisphere's largest gold mine, which is developed to the 8000 ft level, is an Early Proterozoic, structurally complex iron-formation host. Moderately good physical condition required. Limit: 15. Ed Morrison, Homestake Mining Company, 630 E. Summit St., Lead, SD 57754-7100, (605) 384-4831.

Geologic History of the Black Hills

Friday, April 19, 1996. (Evening). Unregistered and mine tour of the Western Hemisphere's largest gold mine, which is developed to the 8000 ft level, is an Early Proterozoic, structurally complex iron-formation host. Moderately good physical condition required. Limit: 15. Ed Morrison, Homestake Mining Company, 630 E. Summit St., Lead, SD 57754-7100, (605) 384-4831.

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Rocky Mountain continued from p. 206

E-mail: nrcarnes@geoscience.org. An origi- nal and 5 copies are required for each abstract. Authors of symposium papers should send their abstracts directly to the appropriate convenor (the first name in the list of symposium organizers above). All other abstracts should be sent to Alvis Lisenbee, Department of Geology and Geologic 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 (Cordilleran 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 stan- dard 35 mm frames. Two projectors and two screens will be available for oral sessions. Authors are strongly encour- aged to bring their own slides. A limited number of carousels will be available. The organizing commitee will try to have a carousel if a request is unavailable for your talk.

POSTER SESSIONS
Poster sessions will be located adja- cent 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 Cordilleran Geologic Maps. The Black Hills and South Dakota, displaying 7.5’ quadrangle maps of the northern Black Hills, a 1:100,000 scale map of the southern 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 AViRS 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 the poster session spon- sored by the Geology Division, Council on Undergraduate Geology. Abstracts must be listed as the first author and have been the major preparer of the poster. Topics are open, but will be reviewed for geographic coverage (Cordilleran region), and originality. Four prizes will be awarded by the convenor of the central committee (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 regis- tration-poster session area. The cost per booth is $50 per 12 ft of space. Addi- tional adjacent booths may be purchased for $50 to expand display space. For further information and booth reser- vations, 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 Geologic Society will sponsor an award for the best student paper in paleontology. A nonstudent can be coauthor, but the author must be both the presenter and (primary) author. To be eligible, the paper must be submitted as a graduate or undergraduate program or have com- pleted 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 Associ- ates of the Geologic Society of America who plan to attend the meeting. Preference for support will be given to pres- enters of papers and posters and to group applications. Students are strongly encouraged to find additional funding. 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: kekolm@mines. colorado.edu. If you are presenting a paper or poster, please include a copy of your registration fee acceptance. Applica- tions must be received by Ken Kolm by Friday, March 15, 1996.

SPECIAL EVENTS
Planned events include a welcoming reception on Friday evening, Wednesday, April 17, 1996. An alumni reunion will be held on Thursday evening, April 18, 1996. Each year, an alumni meeting area reserved should register with Perry Rahn, Department of Geological Engineering, South Dakota School of Mines and Tech- nology, 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 pro- vided. Deadlines for announcements are 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 more scenic drives in the Black Hills and Badlands. The Civic Center is conve- niently located in a pathway near the downtown area, which contains galleries, shops, 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 out- standing exhibits and research collections, and is a major tourist attraction. Orga- nized activities will depend on the num- bers of registered guests.

ACCOMMODATIONS
Blocks of rooms will be reserved at several hotels within a 5-minute walk of the Civic Center. Housing informa- tion 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 Agenda. Abstracts with Programs. Address questions and sugges- tions to Colin Paterson, GSA Meeting Chair, Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-5114, fax 665-394-6703, E-mail: paterson@silver.sdsmt.edu.

Preliminary Announcement and Call for Papers

CORDILLERAN SECTION, GSA 92nd Annual Meeting
Portland, Oregon April 22–24, 1996

T he Department of Geology, Portland State University, Portland, Oregon, will host the 96 meeting of the Cordilleran Section of the Geologic Society of America. The meeting is held jointly with the Pacific Northwest Metals and Min- erals Conference (PNNMC) sponsored by the American Society for Mining, Metallurgy, and Exploration, Inc. (AME), American Welding Society, ASM Inter- national, 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 ablaze with rhododendrons and other flowering trees at the time of the meeting. The weather in late April is pleasant, but rainy weather with inter- mittent “sun breaks” is likely. The aver- age high is 60°F and average low is 41°F. The meeting will be held at the Red Lion Hotel—Lloyd Center, a one-minute walk from the city is easy via Interstates 5 and 4, rail, or air. Interstate 5 and 4 pass through the 400 miles of the Cordilleran. 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 by the convention center.

REGISTRATION
Prgeregistration Deadline: March 15, 1996
Pregistration 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.

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 Coor- dinators Scott Bums, Department of Geology, Portland State University, P.O. Box 751, Portland, OR 97207, (503) 723-3489, fax 503-723-3025, E-mail: scottb@ch1.cx.pdx.edu, or Jeff Markvart, Oregon Department of Geology and Mineral Industries, 1831 South Eastern Ave, P.O. Box 2760, Portland, OR 97208, (503) 978-1941. Field trip info- rmation forms will be available in the Final Announcement in the January 1996 issue of GSA Today.

Presentations


Cordilleran continued on p. 208

GSA TODAY, October 1995 207
THEME I: Regional Seismicity

Geologic Framework of Earthquakes in the Pacific Northwest

Andrew Barth, Department of Geology, Portland State University, P.O. Box 751, Portland, OR 97207, (503) 725-3375, fax 503-725-3025, E-mail: michaель@ch1.ch.pdx.edu.


THEME 2: Infrastructure

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

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

THEME 3: Environmental Concerns

Site Mapping—Geochemical and Geological Dale Avery, Western Oregon University, Newberg, OR 97132, (503) 725-1200 (available after January 1996); Martin Streek, Department of Volcanology and Petrology, Christian-Albrechts-Universität zu Kiel, Germany, E-mail: mstreck@koeln.uni-koeln.de.

Geologic History of Mount Hood Volcano, April 21. Willie Scott Burns, Department of Geology, Portland State University, Dept. of Geosciences, 410 Wilkinson Hall, Corvallis, OR 97331-2538, (503) 725-3025, E-mail: scott@ch1.ch.pdx.edu; and David Michael, Oregon Department of Forestry, Forest Grove, OR 97116, (503) 725-3025, E-mail: michael@ch1.ch.pdx.edu.

THEME 4: Energy

Environmental Compliance. Peter Raer, 88E NE 10th St., Gresham, OR 97030, (503) 661-7995, fax 503-661-7965.

Environmental Noncompliance. Peter Raer, 88E NE 10th St., Gresham, OR 97030, (503) 661-7995, fax 503-661-7965.


Waste Management and Remediation in Manufacturing, Khalid Khan, University of Portland, School of Engineering, 5000 Willamette Blvd., Portland, OR 97203, (503) 283-7276, fax 503-283-3745, E-mail: khkhan@uoregon.edu.

THEME 5: Materials and Technologies


Postmeeting

10. Petrotechnic Elements of Marginal Basin Oceanic Lithosphere: An Example from the Klamath Mountains, Oregon and California, April 22 (evening). Andrew Barth, Portland State University, P. O. Box 751, Portland, OR 97207, (503) 725-1389, fax 503-725-3025, E-mail: scott@ch1.ch.pdx.edu.


12. Executive Summary

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. Details of hotel and area information will be provided in the January 1996 issue of GSA Today.

ACCOMMODATIONS

LEGEND

PSI = poster session; EI = educational insulation; OS = open session; SS = symposium; ED = education day.
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.

GeoHostels

The Geological History of Southwestern Montana
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.

Scenic Geology of Northwestern Colorado and Dinosaur National Monument
Leaders: Gregory Holden, and Kenneth Kolm, Colorado School of Mines

"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.

GeoTrips

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

"The Grand Canyon Trip was a magnificient 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.

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 Rossaly Lopez-Gautier of Altadena, California.

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.

GSA TODY, October 1995 209

Coming in November GSA Today…

GeoVentures 1996
Registration begins January 1.
Call for Papers

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

Abstract Deadline: November 15, 1995

Submit completed abstracts to:
Darrel Schnitzius, Department of Geosciences, Mississippi State University, P.O. Box 9448, Mississippi State, MS 39762, 1-601-323-2904

SOUTHEASTERN SECTION
March 14–15, 1996

GSA Section Meetings — 1996

NORTH-CENTRAL SECTION
March 21–23, 1996

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

NORTHEASTERN SECTION
March 21–23, 1996

SOUTHEASTERN SECTION
March 21–23, 1996

SOUTH-CENTRAL SECTION
April 18–19, 1996
Rapid City Civic Center, Rapid City, South Dakota

Abstract Deadline: January 5, 1996

Submit completed abstracts to:
Arlin L. Lissens, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 511 East St. Joseph St., Rapid City, SD 57701-3995; (605) 394-2463

ROCKY MOUNTAIN SECTION
April 18–19, 1996

Call for Papers

GSA Section Meetings — 1996

SOUTHWESTERN SECTION
March 14–15, 1996

CORDILLERAN SECTION
April 22–24, 1996

SOUTHEASTERN SECTION
March 14–15, 1996

SOUTH-CENTRAL SECTION
April 18–19, 1996

NORTH-CENTRAL SECTION
May 2–3, 1996

GSA Section Meetings — 1996

ROCKY MOUNTAIN SECTION
April 18–19, 1996

NORTHEASTERN SECTION
March 21–23, 1996

Abstract Deadline: December 28, 1995

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

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The 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 complex system whose processes are completely interconnected 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.”

GSA ANNUAL MEETINGS

New Orleans, Louisiana
November 6–9
Ernest N. Morial Convention Center
Hyat 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. Warne, Colorado School of Mines, Dept. of Geology & Geophysical Engineering, Golden, CO 80401 (303) 273-3819, fax 303-273-3859; E-mail: jhumphrey@mines.edu

Field Trip Chairs:
Charles L. Pillmore, (303) 216-1240 and Ren A. Thompson, (303) 216-0929
U.S. Geological Survey, MS 50, P.O. Box 25094 Denver Federal Center, Denver, CO 80225

THEME FOR 1996 ANNUAL MEETING

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

NEW ORLEANS

Call for Continuing Education Course Proposals

Proposals due by December 1, 1995

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 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
October 1995

Opportunities for Students

Graduate Study in Earth-Surface Processes as Complex Systems. An emerging field at the boundary between Earth science and geomorphology, the application of methods of nonlinear dynamics and complex systems to physical processes and patterns in the environment, is the focus of a research program sponsored by the Department of Geography Physics, University of California, San Diego. Spots are available for hydrogeologists and geomorphologists with research interests in beach forms and patterns, waves in the surf zone, and hydrodynamics of coastal zones.

To ensure consideration, applications should be submitted to: Professor Peter R. Hooper, Chair, Search Committee, Department of Geography Physics, University of California, San Diego; La Jolla, California 92039-0225. (858) 535-3929; FAX: (858) 535-1528; Web site: http://geophys.ucsd.edu/complex_systems.html.

Student Opportunities in Hydrogeologic Science at Duke University, Durham, NC. Research projects and teaching assistantships are available to outstanding graduate students interested in Hydrogeologic Science. Eleven faculty participate in the research program and interests include: sediment transport; reactive transport modeling; the flow of granular materials in the transport of sediments; fundamental aspects of the flow of porous media; the set up of flow in confined systems; and the flow of granular materials in the transport of sediments; fundamental aspects of the flow of porous media; and the set up of flow in confined systems. The position is available for up to two years after December 1, 1995, or until the position is filled. Contact: Lawrence L. Malinconico, Jr., Department of Geology and Geophysics, Duke University, Washington, DC 20036-2102 (Andrea Johnson; Tel: (202) 328-4113; E-mail: aej@muhs.edu).

The University of Oklahoma School of Geology and Geophysics solicits its applications and nominations for its current search for an Assistant Professor. The individual holding this chair is expected to: add significantly to the School’s petroleum geology program; attract funding and research support; teach and advise graduate students toward a Ph.D.; develop and maintain an externally-funded research program, collaborate in research projects with other WOU faculty, and make use of external, modern analytical facilities available in the department including EMP, XRF, XRD, XRF, ICP/MS, ICP/MS, ICP/MS, ICP/MS, ICP/MS. The successful candidate will be expected to: teach introductory-level undergraduate geosciences courses and undergraduates graduate geology, geophysics, and petroleum engineering courses; develop and maintain an externally-funded research program, collaborate in research projects with other WOU faculty, and make use of external, modern analytical facilities available in the department including EMP, XRF, XRD, XRF, ICP/MS, ICP/MS, ICP/MS, ICP/MS, ICP/MS. The successful candidate will be expected to: teach introductory-level undergraduate geosciences courses and undergraduates graduate geology, geophysics, and environmental engineering. The successful candidate will be expected to: teach introductory-level undergraduate geosciences courses and undergraduates graduate geology, geophysics, and environmental engineering.

The Chairholder is expected to teach 1-2 courses per year (undergraduate or graduate) and supervise master’s students. The individual must have qualifications of leadership which will bring together academic and industrial stakeholders toward a petroleum effective Institute. The specific field of the Chairholder is open (e.g., stratigraphy, sedimentology, geophysics, geochemistry); however, the individual is expected to: teach introductory-level undergraduate geosciences courses and undergraduates graduate geology, geophysics, and environmental engineering. The successful candidate will be expected to: teach introductory-level undergraduate geosciences courses and undergraduates graduate geology, geophysics, and environmental engineering.

To ensure consideration, applications should be submitted to: Professor P. H. L. Boons, Department of Geology and Geophysics, The University of Oklahoma, 100 East Boyd Street Suite 810, Norman, OK 73019-0628; Telephone: (405) 320-2290; FAX: (405) 320-2290; E-mail: pb@ou.edu. The University of Oklahoma is an EEO/AA employer.

The technician will be expected to: teach introductory-level undergraduate geosciences courses and undergraduates graduate geology, geophysics, and environmental engineering. The successful candidate will be expected to: teach introductory-level undergraduate geosciences courses and undergraduates graduate geology, geophysics, and environmental engineering. The successful candidate will be expected to: teach introductory-level undergraduate geosciences courses and undergraduates graduate geology, geophysics, and environmental engineering. The successful candidate will be expected to: teach introductory-level undergraduate geosciences courses and undergraduates graduate geology, geophysics, and environmental engineering.

The Co-Director will be expected to: teach introductory-level undergraduate geosciences courses and undergraduates graduate geology, geophysics, and environmental engineering.

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