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## Regular Canyon Spacing in the Submarine Environment: The Link Between Hydrology and Geomorphology

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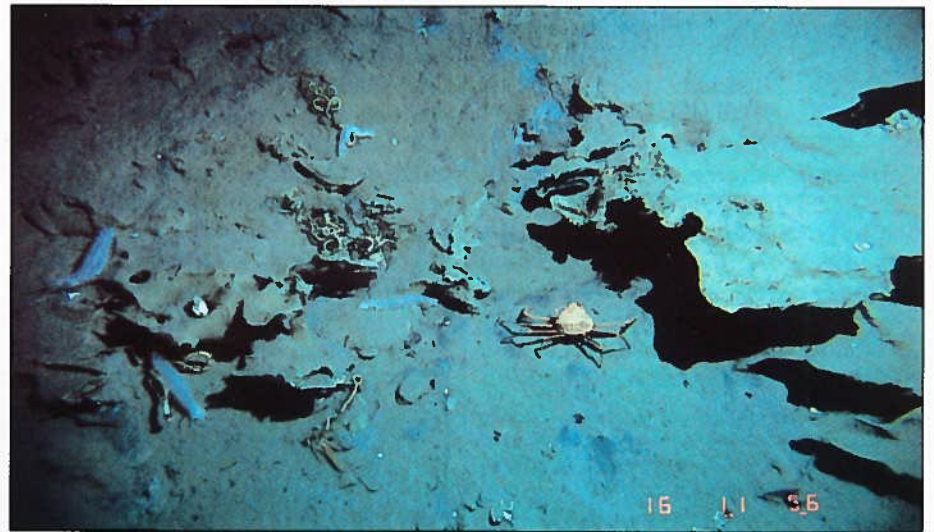
### ABSTRACT

The strikingly regular spacing of headless submarine canyons on both active and passive margins implies self-organizing feedback between hydrologic and geomorphic processes. Canyons formed at the toe of the Cascadia accretionary complex, a submarine fold and thrust belt north of Hispaniola, the western Florida Escarpment, and the continental slope east of Maryland–New Jersey all exhibit steep sidewalls, abrupt headwalls, and linear trends perpendicular to the local slope. These canyons show no evidence of channel erosion as a canyon-forming mechanism. The mean distance between adjacent canyons ranges from  $8.85 \pm 2.63$  km on the western Florida Escarpment to  $335 \pm 200$  m north of Hispaniola. Regular spacing of headless submarine canyons in diverse geologic settings implies an interaction between the conditions necessary for slope failure and the influence a canyon has on the surrounding area. Creation of a canyon dramatically increases the head gradient at its head, thereby facilitating further failure. This increase in head gradient (and convergence of flow lines) affects the regional flow field, leading to a corresponding decrease in head gradient (a divergence of flow lines) in a “shadowed” region surrounding the canyon, which prevents neighboring failures. Closer average canyon spacing could be due to a higher overall slope, higher ambient head gradient, or lower material strength. As canyons grow,

the convergence of flow lines will further increase toward the canyon head, leading to a larger reduction in head gradient surrounding the canyon and a larger overall spacing of actively propagating canyons. The fastest growing canyons can capture the flow of smaller neighboring canyons, thereby terminating their growth. Canyon growth can also stop if the material into which the canyon is propagating becomes strong enough to resist seepage failure.

### INTRODUCTION

Submarine canyons are common features of almost every continental margin. Although some channels formed by downslope erosional processes, the geometry of many canyons suggests that they formed by means of internal rather than external causes. These canyons are similar to headless canyons well documented in the subaerial setting (e.g., Laity and Malin, 1985; Baker et al., 1990) in that they display a distinct geomorphic style with steep headwalls and flat floors. The term “headless” is applied to canyons that are isolated from down-



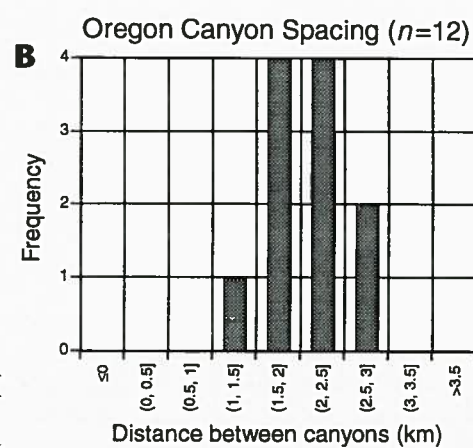
DS/RV *Alvin* photo of a cold seep community (tube worms and carbonate crusts) located within a headless submarine canyon on the toe of the Oregon accretionary complex. The same fluid expulsion that supports the cold seep community may lead to slope failure and canyon formation; in turn, the presence of a canyon affects the regional flow field and therefore the presence and absence of cold seeps.

slope erosive flows and channel-cutting activity. These canyons tend to be straight and oriented downslope, and they branch but do not meander. Many such canyons may originate on the

slope and grow headward (Orange and Breen, 1992; Moore et al., 1990).

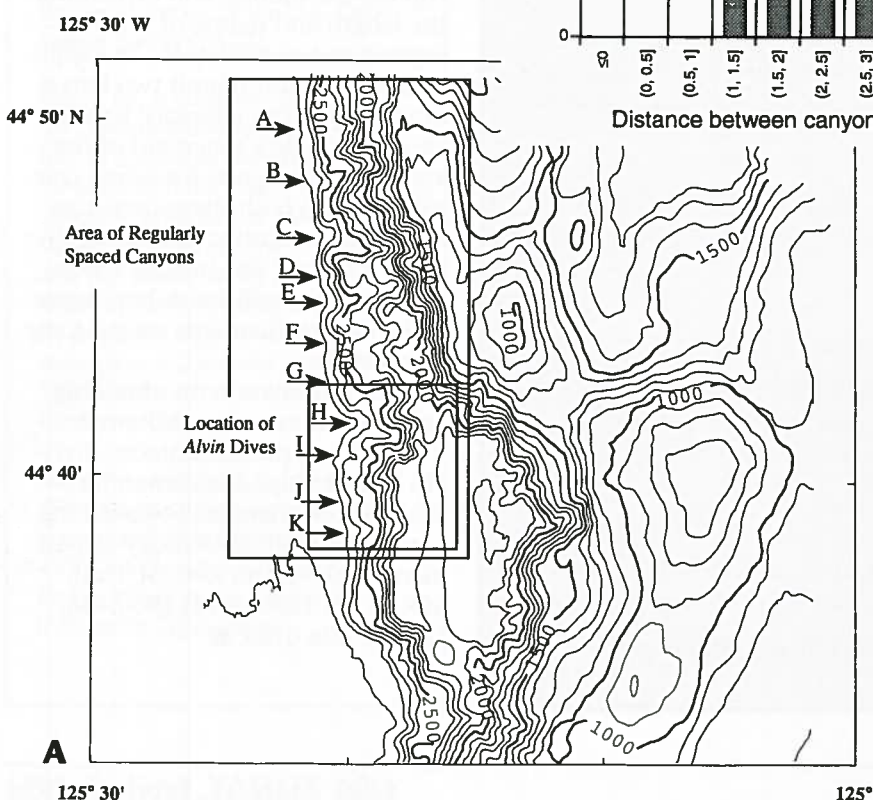
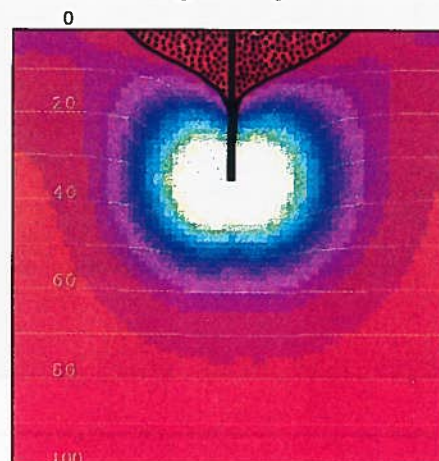
On land, many headless canyons may result from seepage-induced spring sapping, particularly in the spectacular theater-headed valleys of the Colorado Plateau (Laity and Malin, 1985). Headless submarine canyons are present both on passive continental slopes (Florida, U.S. East Coast) and on convergent margins (southern Cascadia [U.S. West Coast], northern Hispaniola). These canyons may have formed by dissolution by fluid flow (Florida; Paull et al., 1990), diagenetic fluid expulsion leading to fracturing and exfoliation (New Jersey; McHugh et al., 1993), or seepage-induced slope failure (Cascadia, Hispaniola; Orange and Breen, 1992). Both dissolution and diagenetic fracturing can lead to slope failure, but they cannot account for nonrandom canyon spacing. We focus here on seepage-induced failure, but the hydrologic approach outlined is equally appropriate for any mechanism that includes a component of fluid flow (e.g., dissolution, diagenetic fracturing) because the presence of a canyon affects the regional flow field.

Seepage-induced slope failure occurs where the fluid head gradient (excess pore pressure) offsets the gravitational and frictional forces of the surface material (Denlinger and Iverson, 1990; Iverson and Major, 1986; Dahlen, 1984); that is, the failure is caused by the excessive pore pressure gradient rather than fluid flow per se. In active margins, excess fluid pressure may result from tectonically induced porosity reduction, loading by sediments or thrust faults, or both (Bray and Karig,



**Figure 1.** A: Composite SeaBeam map of the toe of the Cascadia accretionary complex (offshore Oregon); contours are in metres. Arrows indicate headless submarine canyons isolated from downslope flow. B: Histogram of canyon spacing. C: Flow field and head-gradient field due to a single canyon incised into the seafloor. Contours are equipotentials. The flow is driven from depth toward the constant-head seafloor and canyon incision. The colors reflect the pattern of head gradients; the highest gradients (brightest) are near the canyon tip. The stipple patterns indicate values of head gradients below the originally uniform gradient and indicate the region where seepage-induced failures will be impeded.

**C** Single Canyon



Link continued on p. 36



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## Students Air Ideas about GSA at Presidential Forum in Boston

Robert D. Hatcher, Jr., GSA Past President

An informal discussion was held at the 1993 GSA Annual Meeting in Boston on Tuesday, October 26, between Student Associates of GSA (graduate, undergraduate, and any others) and President Bob Hatcher. The goal of this forum was to discuss the ideas and suggestions of Student Associates on their perceptions of what the Society is and where it is going, improvements that might strengthen the roles of the Society in the 21st century, and especially how students could become more involved in Society affairs. This discussion session in Boston was an innovation, the first such attempt to better understand student perspectives on the Society since the Student Associate category was established in 1971. About 100 students and several members of the GSA Council participated in the exchange of ideas, and other students wrote comments and mailed them to me.

The students made several important points. One was that they (mostly

graduate students) felt that the registration fees at Annual and Section meetings are too high; for example, the student registration fee for the Boston meeting was \$65, whereas the fee for K-12 teachers was \$15. Undergraduates from the Northeastern Section were able to preregister for the meeting for only \$10. Several of these undergraduates indicated their appreciation and stated that they hoped this policy would be continued (and broadened to include all undergraduates) at future GSA Annual Meetings.

The suggestion was made that perhaps a student division of GSA might be formed, but upon further discussion all agreed that this might only create a separate organization within GSA without students becoming involved in the mainstream of the Society. Discussion focused on greater involvement in committees, where possible, and being able to vote in Society elections. I had earlier raised the question of greater involvement of Student Associates in Society affairs at both the October 1992



and May 1993 Council meetings. The issues of Student Associate involvement in committees and student voting were brought before the Council at the meeting on October 27. A motion was made and passed "... that the Council endorse its commitment to finding ways to increase student input into the Council including at the very least the kind of mechanism that Hatcher initiated earlier this year and to explore other alternatives as well." There will be additional discussion of this at the May 1994 Council meeting; if either or both requests were to be passed, the bylaws of the Society would be changed at that time.

Other requests included greater participation in Section affairs, support for field camps, and greater cost subsidies for student participation in field trips and other Society activities. Several of the students requested that another forum on this issue be held at the next and subsequent GSA Annual Meetings. ■

## GSA BULLETIN EDITORS NEEDED

GSA solicits applications and nominations of two persons to serve as Editors of the *Bulletin*. The terms of the current Editors will end December 31, 1994, and the new Editors will begin three-year terms at that time. A phased transition should begin in the fall of 1994.

These are not salaried positions, but GSA pays expenses for secretarial assistance, mail, and telephone at the editor's locations and for travel to GSA headquarters. GSA headquarters staff conducts copy-editing and production activities.

Interested persons should submit a résumé and a brief letter describing relevant qualifications, experience, and objectives. Nominations should include a letter and the nominee's written permission and résumé. Applications and nominations should be sent **BEFORE FEBRUARY 18, 1994** to F. Michael Wahl, Executive Director, Geological Society of America, P.O. Box 9140, Boulder, CO 80301.

### EDITOR DUTIES

1. Ensure that the *Bulletin* remains one of the premier journals in the geological sciences.
2. Select and maintain an appropriate Board of Associate Editors.
3. Maintain expeditious manuscript flow.
4. Make decisions regarding acceptability of submitted manuscripts in concert with recommendations of reviewers and Associate Editors.
5. Advise authors about necessary revisions.
6. Organize the content and select cover design for each issue of the *Bulletin*.
7. Keep the Committee on Publications and the GSA headquarters staff informed about the flow of manuscripts and other *Bulletin* business.
8. Respond promptly to inquiries from authors and prospective authors.

### EDITOR QUALITIES

1. Broad background and active research in the geological sciences with particular emphasis on regional geology (including geomorphology, geophysics, geochemistry).
2. Good organizational skills.
3. Willingness to invest approximately one day per week.
4. Enthusiasm, tenacity, and imagination for future innovations and improvements in the *Bulletin*.
5. Broad knowledge of the geological research activities of scientists both nationally and internationally.
6. Good English language skills.
7. Objectivity.
8. Scientific maturity.
9. Patience, courtesy, tact, and firmness in dealing with authors.

## AWG Foundation Offers Chrysalis Scholarships

The Association for Women Geoscientists Foundation will award at least two Chrysalis Scholarships on March 31, 1994. The \$750 awards will be given to geoscience Masters or Ph.D. candidates to cover expenses associated with finishing their theses. The Chrysalis Scholarship is for candidates who have returned to school after an interruption in their education of one year or longer. The support can be used for anything necessary to assist the candidate in completing her thesis, such as typing, drafting expenses, field work, or child care.

Applications should be made by *March 1, 1994*. The applicant should write a letter stating her background, career goals, and objectives, her involvement in both the geosciences and her community, and how she will use the money, and explaining the length and nature of the interruption to her education. The applicant should also submit two letters of reference. The reference letters should include a statement of the applicant's prospects for future contributions to both the geosciences and her community. Her thesis advisor should also include when the candidate will finish her degree and what requirements are yet to be completed.

For information on obtaining an application or for additional information, please contact: Chrysalis Scholarship, Association for Women Geoscientists Foundation, Macalester College Geology Department, 1600 Grand Ave., St. Paul, MN 55105-1899, (612) 696-6448, fax 612-696-6183. ■



# The GSA Institute for Environmental Education Public Outreach Program for Geology and the Environment



Fred A. Donath, Executive Director—Institute for Environmental Education

In his GSA presidential address (see *GSA Today*, January 1993), E-an Zen admonished, "Geology directly impinges on human welfare and so cannot be an ivory-tower science. Conservation of the environment, discovery and recovery of Earth's resources, avoidance of natural hazards, disposal of wastes, forecasting of global change, decisions on land use, equity for the future—these and other issues need geological knowledge both for technical resolution and for guiding public policy. Public policy needs public support; we ignore the public at our own peril.... [We] need to demonstrate the importance of geology in public affairs, and we must accept our public obligation to be good citizen-geologists."

Communication gaps are a reality today as decision makers struggle with complex scientific issues and represent constituencies with widely disparate levels of scientific literacy. Sensitive and complex environmental issues must be addressed carefully and thoughtfully to avoid polarization, communications breakdown, and lack of resolution. The need for geoscientists to be actively involved in the appropriate transfer of scientific information to the lay public and to decision makers in the environmental arena has never been greater.

The geoscientist's grasp of complex geoenvironmental issues carries a responsibility to raise public awareness of the risks of natural hazards, resource availability and consumption, and the impacts of human activities. In addition to providing technical expertise on the risk of natural hazards to persons and property and on the availability of natural resources, geologists can help the global community and environment by enhancing understanding at the "grass roots" level of the impacts of resource consumption, of the relationships between human activities

and geologic hazards, and of the value of geologic input to engineering designs in challenging geologic environments.

The development of environmental regulations, a fact of life today, is often difficult and sometimes misguided because of conflicts between facts and values, as perceived by those who will be affected by them and as interpreted by those formulating the regulations. Geoscientists routinely use reasoning processes that test data reliability and relevance, probabilities, and causal relations, and these skills can help clear public confusion over verity, risk, and consequences. Thus, the geologist can help the public and decision makers develop rational perspectives in environmental debates by advocating the correct application of relevant geoscience information.

Interestingly, the transition from the Cold War era and the accompanying rapid evolution of U.S. science policy and research presents a unique opportunity for scientists as the mission and goals of federal programs are being redefined. A narrow window of opportunity is open to the geological sciences if they can demonstrate the greatest leadership toward solving the complex issues of today and the future. Many of these issues are environmental in nature, and the input of people who understand earth processes is essential to issue resolution. Equally important is the value of geological reasoning as an intellectual process for the public to understand environmental problems in time and space. Public understanding of the geological approach to inquiry can greatly enhance decision making through an increased ability to set priorities, grasp tradeoffs, evaluate consequences, and, ultimately, resolve disputes.

In consideration of the above-stated public obligation, need, and

opportunity, the GSA Institute for Environmental Education (IEE) has initiated its Public Outreach Program For Geology and the Environment. Objectives of the program include heightening public understanding of geoscience and the geological approach to inquiry, increasing the effectiveness of disseminating geoscience information, and enhancing environmental decision making with relevant geoscience. IEE's approach in developing this program involves: (1) identifying individuals and organizations who can contribute to meeting program objectives; (2) identifying local and regional environmental issues, and potential audiences and individuals who can benefit from the program; and (3) developing symposia, theme sessions, and/or workshops in conjunction with the GSA Section meetings that promote program objectives at the local and regional level.

Activities in conjunction with GSA Section meetings are well under way, with IEE-sponsored symposia being planned for the Cordilleran, South-Central, North-Central, and Rocky Mountain Section meetings during 1994. *Earth Science in the Public Arena: Strengthening Environmental Decisions with the Geological Approach to Inquiry* will be the subject of a symposium being organized by Gary Ernst, Pat Abbott, and Vic Baker for the Cordilleran Section in March. Also that month, the South-Central Section will host a symposium organized by John Breyer, Ken Morgan, and Al Karlin on *GIS Technology for the Environmental Earth Sciences*. In April, a symposium on *Integration of Geosciences, Engineering, and Land-Use Planning Principles to Maximize Environmental Capabilities* will be convened at the North-Central Section meeting by William Davidson and Ken Detlof. In May, Jack Schmidt will convene a symposium for the

Rocky Mountain Section on *Earth Science Contributions to Water Resources Decision Making in the Southwest*.

Events such as these symposia are an excellent means of raising self-awareness about the need to meet our public obligation as geoscientists. But, how might we capitalize on the unique opportunity that lies before us to demonstrate great leadership? For that, we need to have the media, our representatives in government, and decision makers *demand* that geological scientists be involved in addressing important geoenvironmental issues—*because they are the most qualified and the most credible among all scientists to do so!*

To achieve this goal we need the support of the media. We can get the media on our side by *educating them*—by letting them know what geologic aspects need to be considered and what questions need to be asked. Opportunities continually arise for us, as geoscientists, to participate in this educational process. Eventually, IEE seeks to establish regional geoscientist networks for information exchange, and speakers' bureaus and geoscience liaisons to educate the media, the public, and decision makers about the relevance of geoscience to complex environmental problems.

In building its network of individuals and organizations, IEE has already received positive responses to its distributed questionnaires from more than 125 individuals, and it now has strong representation, growing daily, in every GSA Section. If you are interested in participating or would like more information on this new IEE public outreach program on geology and the environment, please mail or fax your name and address to IEE Network, Geological Society of America, P.O. Box 9140, Boulder, CO 80301, fax 303-447-1133. ■

## Gordon Eaton Nominated To Head USGS

President Bill Clinton has selected GSA Fellow Gordon P. Eaton to be the new director of the U.S. Geological Survey (USGS).

Eaton, 64, is currently director of the Lamont-Doherty Earth Observatory of Columbia University. After 16 years with the USGS, Eaton served as president of Iowa State University in Ames, and provost and vice president for academic affairs at Texas A&M University. He has been active in GSA, most recently as a Councilor (1991–1993) and as chair of the Committee on Committees.

Eaton received his B.A. in geology at Wesleyan University (with high honors and high distinction) in 1951, and his M.S. (1953) and Ph.D. (1957) at the California Institute of Technology.

## CALL FOR NOMINATIONS

### 1994 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 1994 award will be presented at the autumn AASG meeting to be held during the GSA Annual Meeting in Seattle. Members of the selection committee are Chairman Frank E. Kottowski, New Mexico Bureau of Mines and Mineral Resources; John P. Kempton, Illinois Geological Survey; and Diane L. Conrad, Vermont Division of Geology and Mineral Resources.

#### CRITERIA FOR NOMINATION

Nominations can be made by anyone, based on the following criteria:

(1) paper must be selected from GSA or state geological survey publications, (2) paper must be selected from those published during the preceding three full calendar years, (3) nomination must include a paragraph stating the pertinence of the paper, (4) **nominations must be sent to Executive Director, GSA, P.O. Box 9140, Boulder, CO 80301.**

**Deadline: March 31, 1994.**

#### 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).

#### 1993 AWARD RECIPIENT NAMED

The 1993 award was presented at the GSA Annual Meeting in Boston to Robert F. Walters, Walters Drilling Company and Adjunct Senior Scientist of the Kansas Geological Survey, for his paper *Gorham Oil Field, Russell County, Kansas*, Bulletin 228 (1991), Kansas Geological Survey. The report describes environmental impacts of the birth, development, and decline of a large oil field, as well as the successful mitigation efforts.



Bruce F. Molnia

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

**ISSUE: Improving Earth Science Education: A Potpourri**

GSA TODAY has previously presented two Forums (July 1991 and April 1992) concerned with improving earth science education. This Forum presents three perspectives from members suggesting additional improvements that can be made.

**PERSPECTIVE 1: Community Colleges Need to Play a More Dynamic Role in Geoscience Education**

Dorothy Stout, Cyprus College, Cypress, CA

To quote geologist Clarence Hall, Dean of Physical Sciences at the University of California, Los Angeles, "We cannot afford to train everyone

as a scientist, ... but there are hardly any students to teach. Science and engineering are the engine of economic progress and without some changes, we are bound to lose the fuel for that engine."

Studies completed by NSF indicate that community colleges teach 40% of matriculating students nationwide. The 1988 NSF-funded Westat Corporation report states, "Professional associations need to recognize the role of the two-year faculty in the area of science, engineering, and mathematics, and seek to enhance their participation as active and valued members. National-level grants and scholarships should be made available to a large number of interested faculty. The collective talent of the nation's two-year faculty, administration and staff has been under-recognized for far too long."

The necessity of understanding geoscience has expanded rapidly in the past decade. Societal, environmental, and economic pressures; geohazards and georesources problems; new careers, and retraining have impacted the geosciences. The urgency for greater comprehension of geoscience-related problems, better quality geoscience teaching, and more practitioners is critical. The multifaceted role of the community college accommodates many needs in today's educational climate, which includes an increasingly diverse student population, with severe budgetary cutbacks, yet a projected need for more science majors. The two-year institutions' geoscience departments fulfill a number of roles, including (1) preparation of students for a variety of educational options, (2) improvement of the quality of geoscience education, and (3) production of more geoscience majors (California community colleges produce more than 50% of the geoscience majors that attend state universities in California).

Current budget considerations are forcing more four-year students to seek lower division courses at two-year institutions in California. In the past, four-year institutions' lower division course offerings supported the dwindling student numbers in upper division classes. Over time, this reduced enrollment has led to fewer community colleges offering the typically lower division courses, such as historical geology, mineralogy, petrology, and other major courses. Class-size quotas at community colleges are set for courses, resulting in the elimination of prerequisites for these major courses, hence weakening the courses.

The large number of introductory geoscience course sections, low student/teacher ratios, commitment to lower division courses at the community college level, and enhanced faculty-student interaction possible at community colleges are all advantages in creating an initial interest in the geosciences. Updating and enhancing of two-year faculty and increasing the lower division load of transferable courses would increase the time students have to develop an interest in the geosciences. The transfer of sufficiently rigorous lower division community-college geology courses needs to be encouraged.

A Needs Assessment administered to two-year institutions nationwide (65 community colleges), representing a total of 20,000+ geoscience students, indicated that students, by and large, are not being exposed to, much less trained in the use of, modern tools of data collection, analysis, and modeling. This also indicates that geoscience professionals are not aware of the vast information available through electronic media.

Today we must promote the use of existing technological capabilities in order to allow student, teacher, citizen, researcher, applied scientist, policy maker, to share ideas and hypotheses. Today's innovative communication avenues allow for rapid exploration within the discipline of geoscience, but they also allow for interaction and integration of all sciences in the efficient operation of the engine.

Four-year institutions need to increase communications and foster a stronger relationship with community colleges by partnering, sharing in research developments, improving the knowledge in the workplace, cosponsoring field trips, and other means that enhance the potential of more qualified and better prepared students.

We all must share in improving the workplace. As geologist Frank Press, former president of the National Academy of Sciences, stated, "The higher expectations of the decade will present geoscience teachers with challenges that most present courses are unable to meet, and offer them opportunities to be in the vanguard of education reform."

**PERSPECTIVE 2: A Federal, University, Junior High School, and Industry Partnership: A Field Project at Lowes Island Wetland, Virginia**

Eleanora I. Robbins, U.S. Geological Survey, Reston, VA; Nina J. Priestly, Wright State University, Dayton, OH; Sue W. Pfeiffer, Herndon Intermediate School, Herndon, VA; and Ernest V. Anderson, Greenhorne and O'Mara, Greenbelt, MD

We successfully put together an informal partnership between a government agency, a university, a junior high school, and industry to answer a scientific question and to provide an exciting field experience to interest students in scientific careers. USGS geologist Eleanora Robbins, working on a project dealing with modern and ancient wetlands of the Great Lakes, was asked whether stumps of an ancient forest found under 87 ft of water in Lake Michigan could have grown in a wetland rather than an upland forest. Scientifically, this question is difficult to answer because the root systems of wetland trees have not been studied systematically. The data are not available because they are not needed in modern wetland delineation studies. Wetland delineations rest on (1) species identification, primarily of the understory plants, (2) soil character, and (3) analysis of site hydrology. Because no remains of understory plants are present under Lake Michigan, no definitive cores were taken of the sediments, and the paleohydrology could not be determined, a modern setting would have to be studied to provide an analog before deciding if the ancient forest was that of an upland or wetland setting.

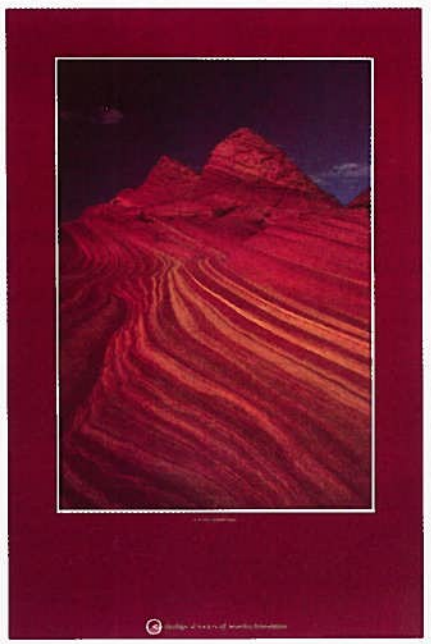
A site was sought where wetland and upland tree species root systems could be compared. Ernest Anderson, Greenhorne and O'Mara, was about to work on a site along the Potomac River near Herndon, Virginia, called Lowes Island. This site was to be stripped to construct two golf courses. Trees were to be removed by grubbing, a technique by which trees are pulled and pushed over by a front-end loader and their roots exposed. The site was perfect for the study because some of the same species of trees were growing in both upland and wetland conditions.

Nina Priestly, a graduate student at Wright State University, was hired for the study under a National Association of Geology Teachers (NAGT) internship program.


Because measuring tree girth and root insertion angles requires three sets of hands—two to pull a tape measure around a tree and one to record information, additional field assistants were needed. However, there was no money in the budget for additional personnel.

Robbins had previously shared the results of other research with Sue Pfeiffer's five 7th-grade science classes at Herndon Intermediate School. Afterwards, Pfeiffer had the 12-year-old students practice their writing skills by sending thank-you letters.

*continued on p. 33*



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Several of the letters said, "If you ever need help with your research, remember me."

Robbins contacted Pfeiffer, and together they developed a plan to find student volunteers to work during the summer. Letters were sent home to parents inviting students to participate in the USGS "Volunteer for Science Program." Interested children were asked to write a 250-word essay explaining their availability, their special qualifications, and how this experience might help their career goals.

The essay would be their first opportunity to learn grant writing skills. The essay was to be handwritten, so it would not be edited by parents. Parents were asked to write a letter in support, discussing why this project would be a wonderful opportunity for their child. Pfeiffer discussed the project in each class, provided a handout for interested students, and wrote the due date on the blackboard.

Of 135 students contacted, six responded. Most of the respondents said that they loved the outdoors and that they either wanted to be scientists or wanted the opportunity to join a real science project to test their career choice. Initially, one student, Aaron Taylor, and an alternate were chosen. Aaron stated that he had been a Boy Scout for three years, loved the outdoors, and was not afraid of wild animals. His mother wrote that he understood that this project was real and had defined goals and deadlines to be met, and she agreed to have him ready on time every morning. The alternate, Elizabeth Leaderman, submitted an extremely well written essay discussing why she wanted to be a scientist. A third student, Stephen Lineberry, chosen later when another set of hands was needed, also stated that he wanted to be a scientist. The three students were signed up as Volunteers, which qualified them for liability coverage.

The students were picked up every morning, and they donned hard hats as they drove through the construction site. In the woods, ticks and poison ivy were a constant problem; mosquitoes were present but not common. The field team measured more than 100 trees in upland and wetland conditions. The layout of the field site changed constantly as trees were felled and dirt was moved to sculpt the golf course. In the end, the project accumulated voluminous data.

We discovered that 12-year-olds cannot work a full eight-hour day. However, 8-hour days of field work are difficult in the Washington, D.C. area for anyone, because summer temperatures hover above 90°F. Breaks were very important for the entire field party. In retrospect, a better project design would have limited field work to mornings only. However, the ever-changing configuration of the field site required that data be collected whenever the front-end loader was otherwise occupied.

The tasks that now lie ahead all revolve around writing and analyzing the data to determine if the observed differences in tree morphology are statistically valid. Pfeiffer is writing a paper for a National Science Teachers Association journal. The 7th graders learned about successful grant-proposal writing and about working as a team under field conditions. They will be asked to write a paper on their thoughts and observations.

The wetlands business community is very excited about this completed project. No accidents occurred, respect

for rules and one another was maintained, and the developer gained something positive from the otherwise difficult task of felling the 200-year-old trees on the site. Anderson was committed to this project because the advancement of solid technical knowledge related to wetlands will ultimately lead to more exact wetland delineation and wetland function evaluation techniques. This knowledge will assist the development community by eliminating some of the uncertainty now associated with decisions related to land allocation and land use.

The adult scientists involved in this project are quite excited about their part in developing and successfully completing an exercise that had the added dimension of turning students on to real science. We hope that when they become scientists in charge of projects, they will be able to improve upon our design.

### PERSPECTIVE 3: Educational and Public Outreach Opportunities for the Professional Geologist

Myrna M. Killey,  
Illinois State Geological Survey, Champaign

Professional geologists are becoming increasingly aware of the need for becoming more involved in educational and public outreach activities, but may have few ideas on how to go about it. Except for the occasional talk by a parent-geologist to school children, many willing geologists remain puzzled about how to participate in such activities. Teaching and public outreach opportunities abound for earth scientists if both geologists and educators take the initiative.

My purpose is to briefly describe these activities in order to provide both educators and geologists with ideas for exploring the variety of ways geologists can make outreach contributions. Educators can help initiate contacts with geologists through professional societies and state agencies.

A review of my own educational and public outreach activities during the past year shows an interesting variety, ranging from giving classroom talks and judging at science fairs, through conducting a hands-on career workshop for middle-school girls interested in science, leading a field trip for local officials involved in landfill screening, and conducting a GSA field trip for minority students, to leading a "rock walk" along a National Scenic River for a local environmental group. Many of these activities came about through incidental contacts. Activities like these represent just a few examples of the opportunities available to professional geologists.

#### Student Activities

The educational activity that most readily comes to mind is *speaking to school classes*, a function usually performed by a geologist-parent with a child in that classroom. It is probably the most common interaction professional geologists have with students of all ages. Professional geologists can also contact former professors, former fellow students who now teach, and educators in local or nearby colleges, and volunteer to give talks to their classes. Students benefit from hearing how professionals work in the real world and learning what a career in geology really involves.

Judging projects at *science fairs* is an excellent way to establish one-on-

Forum continued on p. 34

## PUBLICATIONS NEWS FROM GSA

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SPE284, 352 p., paperback, indexed,  
ISBN 0-8137-2284-5, \$75.00

#### BIOSTRATIGRAPHY OF JAMAICA

edited by Raymond M. Wright and Edward  
Robinson, 1994

Although Jamaican biostratigraphy has been studied for more than 150 years, in the past two decades intensified field work there has significantly advanced our understanding of this important Caribbean island. This volume includes primarily descriptive articles, very clearly presented. It provides a taxonomic and photographic key to the Jamaica marker fossils, making it a useful reference work for academia, research, and industry, and as a supplemental textbook as well. It also is an invaluable source book on the Cretaceous and Paleogene biostratigraphy of a low-latitude country.

MWR182, 504 p., hardbound, indexed, 0-8137-1182-7,  
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### other publications of interest ...

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by I. Baljinyam and others, 1993

MWR181, 66 p., indexed, ISBN 0-8137-1181-9, \$37.50

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one contacts between earth science professionals and elementary and secondary school students who have shown an awakening interest in the geosciences. By their demeanor, attitude, and expertise, geologists can have a strong influence not only on the students' ideas for developing their projects further, but also on the students' self-image of their potential for pursuing a career in the geosciences. The fairs generally offer the opportunity for short individual chats with students after formal presentations, and these few minutes can be of immense importance in students' impressions of geology. Even if the student's project is not selected for advancement to regional or state competitions, the geologist may still influence not only the student's possible career choice but also his or her impressions of science and its place in society.

I recently presented a *workshop* on geology at Sangamon State University in Springfield, the site of one of Illinois's yearly workshops on "Expanding Your Horizons in Math and Science," a nationwide conference for middle-school girls. Billed as "a fun-filled conference for 7th and 8th grade girls," the workshop offers participants three hands-on sessions from a choice of more than 25 possibilities, presented by women professionals in chemistry, medicine, statistics, geology, astronomy, architecture, accountancy, medical photography, land surveying, physics, botany, psychology, electronics, biology, and other sciences. Each session is limited to ten participants.

I thought the best way to acquaint the students with the geologic materials of their area was by having them work with samples of common glacial materials. Each student received four samples: loess, two tills that differed by color and texture, and sand and gravel outwash. First, I described the material and asked the participants to

choose which of the four samples it was. This gave them the opportunity to examine the look and feel of samples to identify them. Simple geologic columns containing the four material types were distributed, and I explained how a geologist might find these materials in the same sequence in an outcrop or a drillhole, and how she might then construct a geologic map of a region using this information.

We then applied our knowledge by considering a scenario in which we, as geologists, were approached by officials of a major city in central Illinois who were anticipating an expanding city population in the next 20 years and needed help with finding a water supply and siting a landfill. All the students were interested, and several demonstrated real enthusiasm with geologic materials and how they relate to real life. Whether or not any of the girls are inspired to think of a career in geology, all of them will retain some memory of the geologic materials they handled and will be better informed

voters and decision makers when issues such as water resources and landfill siting face them as adults. This workshop offered an excellent way for women geoscience professionals to make a contribution in the educational arena. The format could also be adapted to students of both sexes and several grade levels.

At its annual meetings, GSA conducts a day-long geology *field trip* arranged by local geologists for middle-school science students and their teachers. Minority and women geologists from all over the country go on the field trip with the students, explaining the geology, answering questions, and discussing their careers as members of minority groups in the profession. The professionals participating in this trip willingly sacrifice attending the day's technical sessions to share their enthusiasm about their profession directly with the students.

### Activities for the General Public

One way to make our professional expertise known to political decision-makers is to take them on *field trips in relation to specific projects*. We successfully did this in Champaign County, Illinois, with a field trip for elected officials and staff of the Intergovernmental Solid Waste Disposal Association (ISWDA). The ISWDA had funded geologic map preparation to examine the county's thick glacial deposits for areas capable of supporting a landfill. We provided ISWDA members the opportunity to recognize and characterize materials such as till and outwash in order to understand the geologic maps.

The most effective stop on the half-day field trip was at an exposure of two tills. A handful of each till and simple instructions on how to feel differences in matrix grain size provided a far more memorable example of the earth materials considered as potential containers for waste than reading a description of the same materials. An oblique joint in the exposure had been exploited by tree root growth and provided an excellent illustration of a pathway for movement of ground water, or leachate, through the till. At the last stop, we laid out sample sets typical of the quality of samples geologists work with to illustrate the data upon which the project's maps are based. The board members came away from the experience with very positive comments (including "Why didn't we do this sooner?").

*Leaders of Boy Scout troops* in the Champaign-Urbana area meet monthly and usually invite a speaker. I spoke on the geology of east-central Illinois, including collecting areas for rock, mineral, and fossil specimens for Scouts' work toward earning merit badges in geology. One presentation like that can have wide influence, because the geologist will have reached not only a dozen or so Scout leaders, but their present and future Scouts and others as well. A call to your local Boy Scout and Girl Scout council offices to volunteer your services as a speaker or instructor may result in your being welcomed with open arms.

In east-central Illinois, a day-long celebration of the designation of the Middle Fork of the Vermilion River as Illinois's first National Scenic River highlighted numerous nature-related activities, including a walking field trip along the riverbank. I led the *rock walk*, which was attended by 30 to 40 people of all ages and occupations,

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including educators and students. Discussion during the walk was not limited to the geology of the area, but ranged widely over a variety of geological and environmental issues. An engineer remarked that he found particularly helpful a discussion on the processes of glacial deposition. A self-styled philosopher asked why geology was important. The answer included a discussion on environmental applications of geologic knowledge such as water and mineral resource exploration, land-use planning, ground-water protection, landfill screening, and similar activities. Others wanted to talk about the process of landfill screening and siting, which led to a discussion on the importance of basic geologic mapping. An informal, nontechnical approach to the geology of an area became a valuable way to reach people who wanted to learn more not only about the particular piece of the world they live in but about geology's place in their lives.

Geologists who travel to areas that contain geologically interesting phenomena can offer slides and give interesting travelogues that contain enough geology to intrigue listeners into asking for more information. These talks can be offered to community-service organizations and social or church groups with which the geologist, family members, or friends are associated. An effective way for a geologist to reach many people is to list your area of expertise and your recent activities with a speakers bureau for civic or professional groups.

Additional Ideas: Local television and radio stations may offer exciting opportunities and challenges to geologists interested in expanding their contacts with educators, students, and the general public. Most cable companies are required to provide "public access" channels that can offer opportunities either for appearing as a guest on an existing program or devising your own TV show. Your local cable television company can provide more information. Another worthwhile activity requiring considerably more preparation time is for geologists to offer classroom and/or field courses in some aspect of the geosciences for K-12 teachers in local school systems. An individual geologist, or group of geologists working together, could reach many more people through the students subsequently taught by teachers taking such courses. A nearby community college may be able to assist you in organizing such a course within their formalized program. They may even be looking for instructors for geology courses. Many local park districts, nature preserves, and other agencies offer classes for adults and children. A class on the local geology could be another way to reach out to the public.

If professional geologists were to increase participation in outreach efforts such as those listed above by even one or two additional activities per year, the sphere of increased understanding of the earth sciences could expand enormously. The potential benefits of such interactions would be greatly increased if educators were to help initiate ideas and contacts. Most people enjoy sharing their enthusiasms. When geologists and educators can convey their sense of excitement about the field of earth science, we will have increased others' understanding about the vital role of geology in today's world. ■

**Reminder**

**CALL FOR NOMINATIONS**

Materials and supporting information for nominations for the Distinguished Service Award may be sent to GSA Executive Director, Geological Society of America, P.O. Box 9140, Boulder, CO 80301. For more detailed information about the nomination procedures, refer to the October 1993 issue of *GSA Today*, or call headquarters at (303) 447-2020, extension 136.

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The GSA Distinguished Service Award was established by Council in 1988 to recognize individuals for their exceptional service to the Society. GSA Members, Fellows, Student 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 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. Deadline for nominations for 1994 is **MARCH 1, 1994**.

**National Research Council Announces Associateship Programs**

The National Research Council announces the 1994 Resident, Cooperative, and Postdoctoral Research Associateship Programs to be conducted on behalf of federal agencies or research institutions whose 140 participating research laboratories are located throughout the United States. The programs provide opportunities for Ph.D. scientists and engineers of unusual promise and ability to perform research on problems largely of their own choosing, yet compatible with the research interests of the sponsoring laboratory. Initiated in 1954, the Associateship Programs have contributed to the career development of more than 7000 scientists ranging from recent Ph.D. recipients to distinguished senior scientists.

Approximately 350 new full-time associateships will be awarded on a competitive basis in 1994 for research in chemistry; earth and atmospheric sciences; engineering and applied sciences; biological, health, and behavioral sciences and biotechnology; mathematics; space and planetary sciences; and physics. Most of the programs are open to both U.S. and non-U.S. nationals, and to both recent Ph.D. degree recipients and senior investigators.

Awards are made for one or two years, renewable to a maximum of three years; senior applicants who have

held the doctorate at least five years may request a shorter period. Annual stipends for recent Ph.D.s for the 1994 program year range from \$30,000 to \$45,000 depending upon the sponsoring laboratory, and will be appropriately higher for senior associates.

Financial support is provided for allowable relocation expenses and for limited professional travel during duration of the award. The host laboratory provides the Associate with programmatic assistance including facilities, support services, necessary equipment, and travel necessary for the conduct of the approved research program.

Applications submitted directly to the National Research Council are accepted on a continuous basis throughout the year. Those postmarked no later than April 15 will be reviewed in June; if postmarked by August 15, applications will be reviewed in October. Initial awards will be announced in July and November, followed by awards to alternate candidates later.

Information on specific research opportunities and participating federal laboratories, as well as application materials, may be obtained from: Associateship Programs (TJ 2094/D2), National Research Council, 2101 Constitution Avenue, N.W., Washington, DC 20418, fax 202-334-2759. **Deadlines for application: April 15 and August 15, 1994.** ■

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1985); on passive margins high fluid pressures can result from diagenetic transformations (McHugh et al., 1993), density-driven flow (Paull et al., 1990), rapid sedimentation (Fertl, 1976), or aquifer-driven flow (Magara, 1987; Robb, 1990). Fluid flow leading to cement dissolution and a decrease in the material strength may also cause internally driven slope failure.

In the four areas described here, headless submarine canyons are regularly spaced and self-organized; i.e., canyon spacing arises from feedback between hydrologic and geomorphic systems. In this paper we examine the regularity of canyon spacing and discuss how differences in permeability, head gradient, slope, and material strength may control the observed variations in regular spacing.

### HEADLESS SUBMARINE CANYONS—EXAMPLES

#### Southern Cascadia

Upper Miocene to Pliocene oceanic crust is currently subducting beneath coastal Washington and Oregon (DeMets et al., 1990). The thick section of incoming sediment provides an abundant source of fluids during accretion (Kulm, von Huene, et al., 1973). At the toe of the Cascadia accretionary complex off central Oregon, numerous headless submarine canyons are present seaward of anticlinal ridge crests (Fig. 1A; Orange and Breen, 1992). The average slope of the frontal ridge is 14°. In order to identify canyons for our spacing study, we selected features that illustrated an inflection in a single contour and that repeated this inflection in

adjacent contours. Some canyons (e.g., B and F in Fig. 1) display large, linear cuts, with straight sidewalls and an abrupt headwall; others (e.g., C and H) illustrate a branching morphology midway up the canyon. Canyon sizes also vary, ranging from large (several kilometres long; e.g., C and H) to relatively minor (G and J). Most canyons are >500 m deep. Submarine vents within two canyons (H and K; Fig. 1A; Moore et al., 1990), indicate local active seepage and fluid-pressure gradients that are higher than hydrostatic.

The distance between adjacent canyons in this region ranges from 1.5 to 3.5 km (Fig. 1B), with a mean and standard deviation of 2.0 ± 0.7 km.

#### Northern Hispaniola Margin

Dewatering associated with folding and thrusting of Hispaniola Basin sedimentary deposits has also resulted in the development of regularly spaced headless canyons, although with a much smaller average spacing. Compression along the Caribbean–North American plate boundary in northern Hispaniola has caused uplift and compression onshore (Mann et al., 1984) and the development of a seaward-vergent fold and thrust belt between the Hispaniola Basin and the shelf (Austin, 1983; Dillon et al., 1987; Breen et al., 1991). Hispaniola Basin sediments (Mullins et al., 1992) may be an excellent source of water, because they are thrust-loaded and compacted.

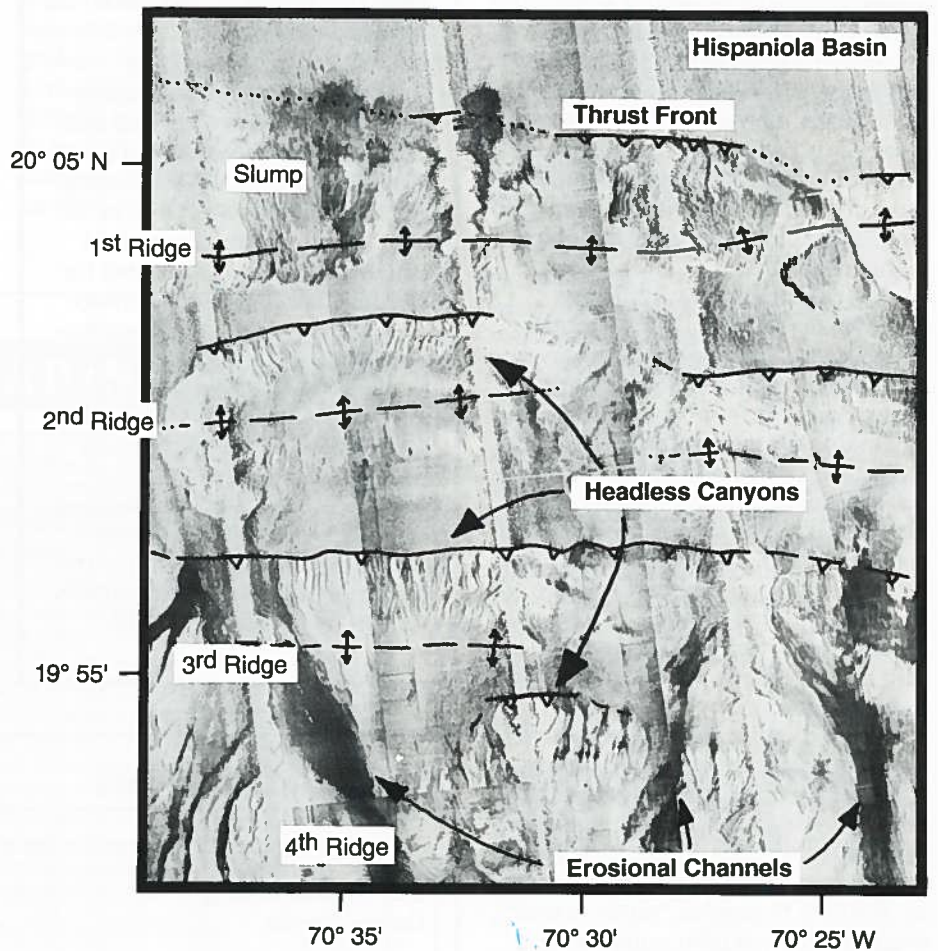
Canyons and slope failures are widespread in this fold and thrust belt (Orange and Breen, 1992). Small headless canyons (Fig. 2) are present on the seaward flanks of seaward-vergent folds spaced about 6–7 km apart. Headless canyons are narrow (several tens of

metres wide), straight, only rarely branching features originating abruptly at the base of the slope and terminating on the slopes beneath anticlinal ridge crests. Canyons are generally 1–2 km long; a few are as long as 3–4 km. Headless canyons thus differ in form and probably origin from larger, sinuous, highly reflective canyons that result from downslope erosive flow.

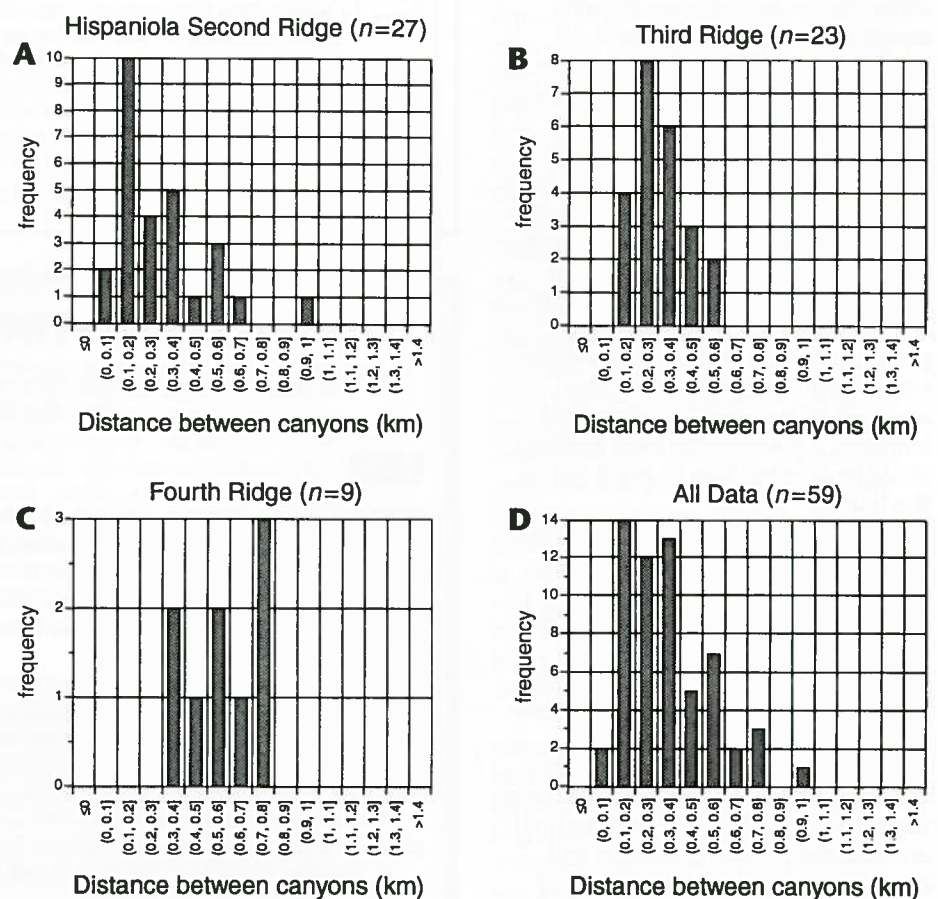
The regular spacing of headless canyons increases with landward distance from the toe of the thrust belt (Fig. 3). The variation in canyon spacing is independent of slope, as all ridges have mean slopes of 12° to 13°. On the second ridge, canyon spacing ranges from 100 to 900 m, with a non-

Gaussian distribution about a mean of 280 m (±200 m; Fig. 3A). Canyons on the third ridge range from 150 to 600 m apart, with a nearly Gaussian distribution about a mean of 300 m (±220 m; Fig. 3B). On the fourth ridge, which is the beginning of the continental rise, headless canyons are spaced 580 ± 160 m apart, with a distribution skewed to larger spacing (Fig. 3C). All Hispaniola canyons taken together show a spacing with mean and standard deviation of 335 ± 200 m (Fig. 3D), approximately six times smaller than the Cascadia canyons.

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**Figure 2.** SeaMARC II side-scan survey of a fold and thrust belt north of Hispaniola (see Orange and Breen, 1992, Fig. 11). Areas of higher reflectivity are dark and include large, sinuous, erosional channels that traverse the slope. Four seaward-vergent thrust faults and associated anticlinal ridges are shown. On the first ridge slope failure occurs by massive regional landsliding (e.g., area labeled "Slump"), whereas on the second, third, and fourth ridges the slope is cut by numerous headless canyons that are linear and rarely branch.



**Figure 3.** Histograms of distances between headless canyons shown in Fig. 2. A: The slope is 11.5° to 16.1°. B: The slope is 10° to 14°. C: The slope is 10° to 16°. D: The mean spacing between canyons increases landward of the toe, although there is no evidence of slope dependence in this data set.

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### Florida Escarpment

Headless canyons on the Florida Escarpment (Paull et al., 1990) show a much wider spacing than those of either Cascadia or Hispaniola. The Florida Escarpment, located west of Florida in the Gulf of Mexico, is a passive-margin carbonate platform. Thus, depositional or tectonic loading and resultant porosity reduction cannot have produced the fluids. Paull et al. (1990) inferred instead a density-driven circulation cell composed of platform brines mixing with fresh and sea water as the source of fluid discharge and slope failure at the base of the Florida Escarpment.

Between lat 27° and 24°30'N, the Florida Escarpment displays 14 headless canyons, all trending east-northeast nearly perpendicular to the regional slope. Our analysis of Paull et al.'s data (1990, Figs. 1 and 2) indicates a canyon spacing ranging from 6 to 15 km, with a mean and standard deviation of 8.85 ± 2.63 km (Fig. 4).

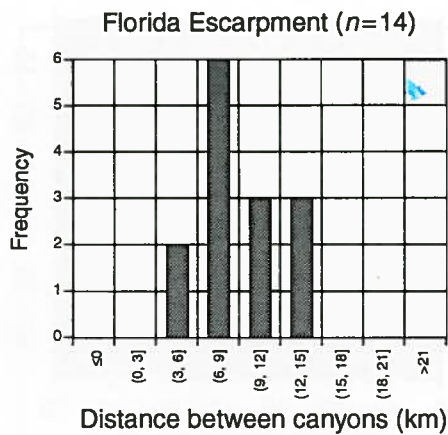
Paull et al. (1990) suggested that a regional joint pattern exposed on land may have caused the increased flow and consequent cement corrosion. Although this joint set may control the orientation of the canyons subperpendicular to the local slope, we believe that jointing alone cannot be responsible for the wide canyon spacing, which is many times greater than the average joint spacing. We argue that while the propagation mechanism for individual canyons may well be as described by Paull et al. (1990), the canyon spacing arises from the hydrologic feedback leading to self-organization.

### Atlantic Margin of North America

Regularly spaced headless canyons off North America between Georges Bank and Delaware are present within gently seaward dipping chalky Eocene sedimentary rocks and silty Miocene claystones (Twichell and Roberts, 1982; Robb, 1984, 1990; McHugh et al., 1993). Seismic profiling and wells (Hathaway et al., 1979; Grow et al., 1979; Poag, 1985) show that these strata are continuous beneath the continental shelf and extend under the coastal plain. The conditions necessary for ground-water sapping on the slope are most favorable during sea-level lowstands (Robb, 1990).

Headless canyons are incised into the continental slope, but in general do not reach the shelf. On the lower continental slope, canyons are narrow and have straight courses, flat bottoms, and steep sidewalls and headwalls (Robb, 1984). Canyons that reach the shelf break display a modified, sinuous morphology that is distinct from the headless canyons. Although active seeps have not been observed, Robb (1984) speculated that pits in submarine chalk outcrops and fissures along joints may be the result of fluid-induced dissolution. McHugh et al. (1993) presented compelling evidence that diagenetic transformations of opal A to opal CT led to fluid expulsion and resultant hydrofracturing. Exfoliation along these fractures may have led to canyon formation (McHugh et al., 1993) but cannot have caused the regular canyon spacing.

Twichell and Roberts (1982) divided the area of the Atlantic coast between 38° and 39°N into three zones, on the basis of the mean slope and the range in canyon spacing. All zones contain regularly spaced headless submarine canyons except in a 3- to 7-km-wide area directly adjacent to larger shelf-cutting canyons. In analyzing



**Figure 4.** Spacing of the canyons located on the western Florida Escarpment (determined from Paull et al., 1990, Figs. 1 and 2). Canyon spacing is 8.85 ± 2.63 km, an order of magnitude larger than the Hispaniola features.

canyon-spacing statistics we have ignored these larger, sinuous canyons. In the southern area, between Baltimore and Wilmington canyons, spacing ranges from 2 to 10 km on a slope of 3°–5° (Twichell and Roberts, 1982, Fig. 5), with a mean and standard deviation of spacing of 2.7 ± 0.6 km (Fig. 5A). In the central area, spacing between Wilmington and Lindenkohl canyons ranges from 1.5 to 4 km on a slope of 6° (Twichell and Roberts, 1982), with a mean and standard deviation of 2.2 ± 1.6 km (Fig. 5B). In the northern area, spacing between Lindenkohl and Mey canyons ranges from 2 to 10 km on a mean slope of 3°–5° (Twichell and Roberts, 1982), with a mean and standard deviation of 4.5 ± 2.1 km (Fig. 5C). Thus, the spacings in the southern and central areas are indistinguishable from each other, and the northern area canyons have a higher mean spacing.

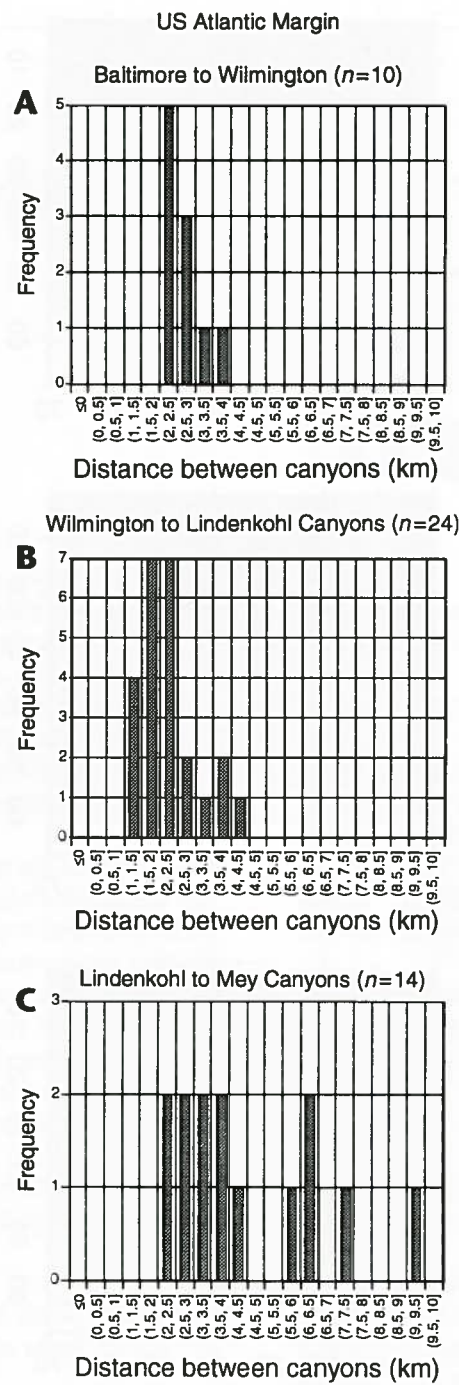
### DISCUSSION

The presence of regularly spaced headless canyons in the diverse environments discussed above—carbonate-platform shelf edge, a clastic passive margin, and two convergent margins—suggests that these canyons are related by a common process. In each region the canyons have a geometry created by hydrologic forcing and seepage-induced spring sapping, where the increase of head gradient at the canyon head drives failure. For Hispaniola and Oregon, rapid tectonic compaction of accreting sediments may increase the hydrologic forcing and lead to failure, whereas in Florida and the Atlantic margin, fluid flow may lead to cement dissolution (a weakening of the matrix material) and decrease the resistance to failure. Such canyons may interact during their growth so that the presence of one canyon can influence the probability of failure elsewhere on the slope.

### Interaction of Submarine Canyons

Localized failure implies that there are areas where the head gradient attains the critical value for slope failure. Regular canyon spacing requires feedback mechanisms that affect the probability of repeated failure not only in the same locality, but also along the adjacent slope. That is, the presence of one canyon must affect the hydrologic conditions in neighboring canyons.

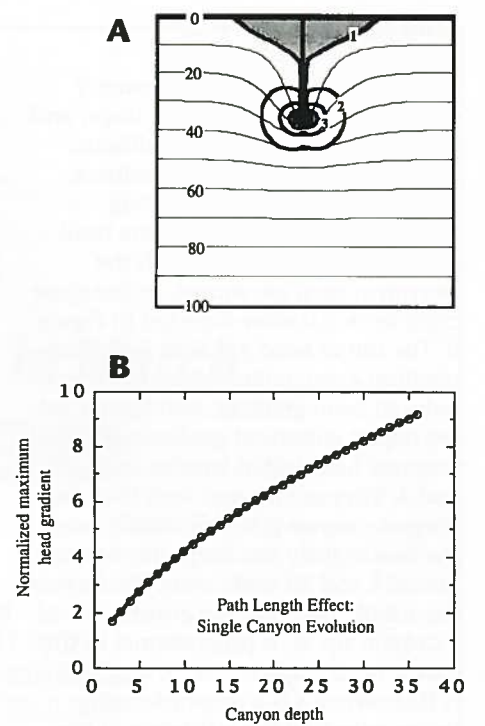
We can model the interaction between canyons by examining the effect of an existing canyon on the flow field, as has been modeled for the subaerial case graphically by



**Figure 5.** Spacing between canyons on the continental shelf off New Jersey, between Baltimore and Mey canyons (determined from Twichell and Roberts, 1982, Fig. 5). A: The spacing is 2.7 ± 0.6 km on a slope of 3°–5°. B: The spacing is 2.2 ± 1.6 km on a slope of 6°. C: The spacing is 4.5 ± 2.1 km on a slope of 3°–5°.

Dunne (1980, 1990), experimentally by Howard (1988) and Kochel et al. (1988), and numerically by Howard (1988). The boundary conditions for the submarine case, however, are different from the subaerial. In the submarine case the surface slope is a constant head boundary, whereas in the subaerial case the surface head gradient is unconstrained in both direction and magnitude. This additional constraint in the submarine case makes the modeling more straightforward by eliminating a degree of freedom.

Any indentation in a constant head boundary leads to an increase in the head gradient and a convergence of flow within the indentation (Fig. 6; Dunne, 1980, 1990). Figure 6 presents results of a simple model illustrating the response of an initially uniform gradient in the fluid head field to the incision of a single canyon. Because the model space is two-dimensional, this model only crudely represents the real geometry, which would involve incision of a triangular wedge into a uniform slope to which planes of equal head would be initially parallel. The model space therefore corresponds to a section through the canyon, taken normal to the regional slope and normal to the trend of the canyon. The steady-state head field shown is calculated by finite difference on a square grid following algorithms presented in Freeze



**Figure 6.** Effect of a single canyon on the flow field. A: Cross-sectional view through a region, taken normal to the sea bottom, and normal to the trend of the canyon. Light contours are equipotentials at steady state, the flow being driven by a head gradient from 100 at the base to 0 along the top boundary, including the surface of the canyon. Heavy lines contour the magnitude of the head gradient,  $|\nabla H|$ , normalized against the original uniform gradient. Values >1 represent enhanced head gradient and increased seepage forces; values <1 reflect divergence of the flow lines and reduction of seepage forces. Seepage forces are highest at the canyon tip. B: Maximum head gradient as a function of increasing canyon depth. The increasing effect of deeper incision into the flow field is here solely due to the decreased path length between the uniform source at depth and the equipotential surface of the seafloor and canyon axis.

and Cherry (1979). The hydraulic conductivity is isotropic. Boundary conditions imposed include a hydraulic head of 100 (units are arbitrary) on the basal boundary, zero flux on the sides, and zero head on both the top and the entire length of the incision representing the canyon. The lines of equal head are warped significantly by the presence of the incision, focusing fluid flow toward the canyon tip. Also shown is the associated head gradient field,  $|\nabla H|$ , demonstrating the extreme enhancement of the head gradients near the tip of the topographic incision. It is important to note that whereas the tip shows enhanced gradients, a zone along the depth of the canyon and along the top boundary for some distance displays significant reduction in head gradient, as implied by the divergence of lines of equal head near the canyon.

Figure 6B shows the relative enhancement of the maximum head gradient with increasing incision depth, owing to the reduction in path length. This relation illustrates the nature of the feedback that will lead to the enhanced probability of failure as a canyon etches into the ground-water flow field.

The decrease in head gradient on the flanks of the canyon reduces the probability that another canyon can grow close by, because the conditions necessary to initiate failure will be more difficult to achieve. The average spacing of canyons will be controlled by the tradeoff between the decline in head gradient along strike due to one canyon and the enhancement of head gradient at the next canyon head. The parameters affecting the sphere of influence of a canyon include the



physical dimensions and geometry of the canyons, the regional slope, and the regional hydrologic conditions.

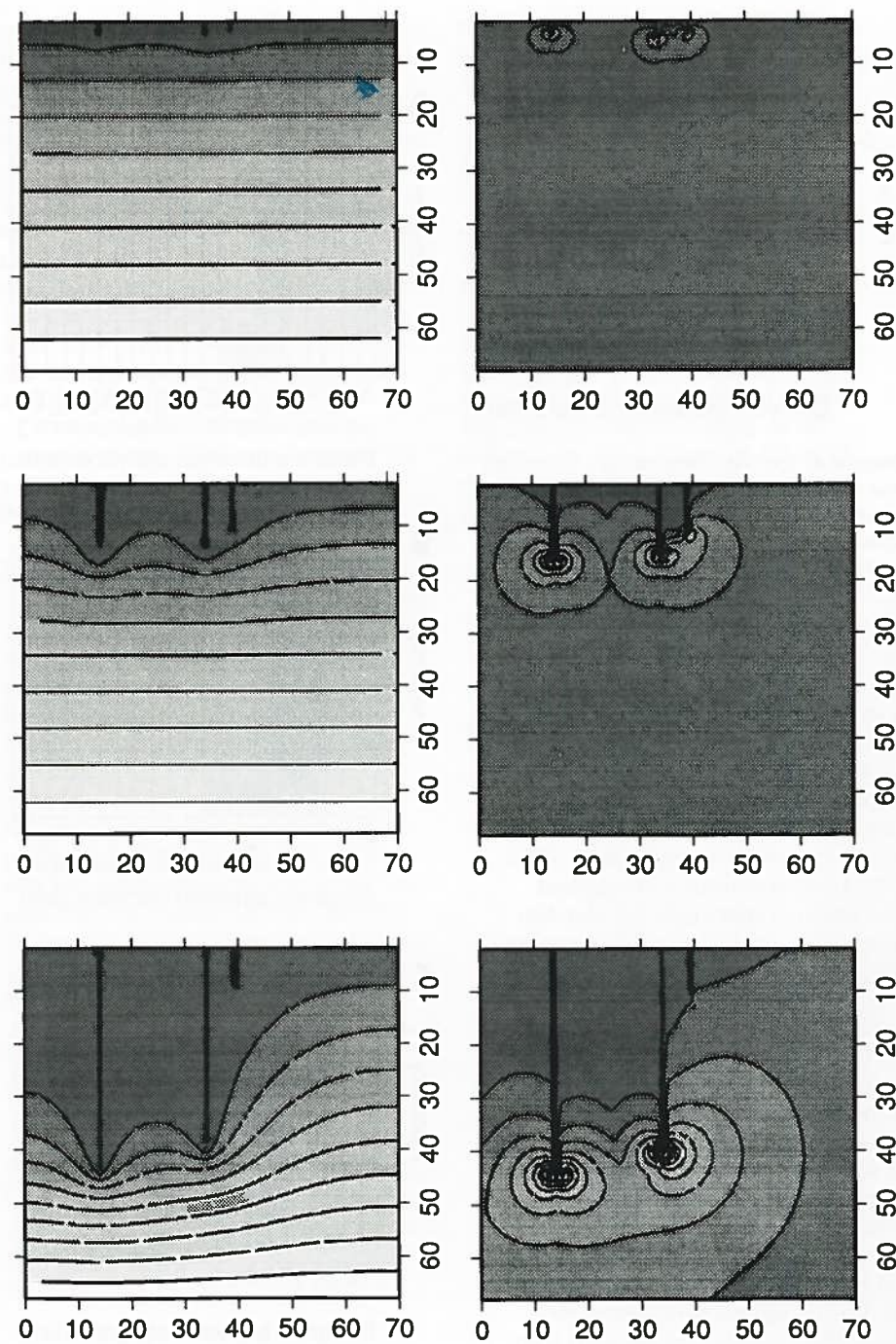
We now illustrate the feedback that can lead to canyon spacing (Fig. 7). Three snapshots of the head gradient field associated with the canyon system are shown, in the same cross-sectional view depicted in Figure 6. The initial head gradient is shaded medium gray; darker values represent reduced head gradient, and lighter values depict enhanced gradients. Three canyons have initial lengths of 5, 4, and 4. They are located such that the deepest canyon is in the middle, and the two slightly less deep canyons are placed 5 and 20 units away. We impose the simple rule that the growth rate of a canyon tip,  $U$ , is proportional to the excess head gradient; i.e.,  $U = \alpha(|\nabla H| - |\nabla H|_c)$ , where  $\alpha$  is a proportionality factor reflecting the efficiency of the canyon-cutting process,  $|\nabla H|$  is the mean head gradient at the canyon tip, and  $|\nabla H|_c$  is the critical head gradient necessary to cause failure. This simple hypothesis links the probability and frequency of failure with excess head gradient. At time 2 the canyons have all grown; while the initially deepest canyon is outpacing its nearest neighbor, the other neighbor is keeping up. The near neighbor has fallen more and more deeply into the head-gradient shadow of the larger canyon, and it shuts off after time 2. Later in time, the two surviving canyons continue to be active, while the small canyon remains shut off. The steady-state spacing between active canyons in the mature setting is thus greater than the initial spacing, as early canyons that are triggered by mass-wasting processes may be shut down by the faster growth of nearby larger canyons.

The higher the ambient head gradient, the smaller the eventual canyon spacing will be. If the original head gradient was high (or the slope close to failure), then a new failure (with its own increase in head gradient associated with it) can offset the drawdown of an adjacent canyon at closer intervals. Any mechanism that places the regional slope closer to overall failure (higher regional slope, weaker material), can be viewed in the same way and will lead to closer overall canyon spacing.

Seepage-induced slope failure results from an increase in head gradient. Recall that head gradient is related to fluid discharge and permeability via Darcy's law. Thus, for a given constant fluid discharge, a lower permeability will lead to higher head gradient and higher seepage force, thereby placing a slope closer to failure and leading to closer canyon spacing. Similarly, if permeability is held constant and the fluid discharge increases, then the overall head gradient will increase, leading to a closer spacing of canyons.

Applying this analysis to the New Jersey margin, the decrease in canyon spacing adjacent to the large down-slope canyons suggests that the latter dominate the flow field, thereby hindering canyon growth near them (see Twichell and Roberts, 1982, Fig. 2). Some differences in the sizes of the Cascadia canyons (Fig. 1A) may result from canyon competition, where the lateral impingement of recharge zones leads to the "capture" of one canyon's flow by another.

The growth of small canyons may have been arrested by theft of recharge zones. In the end-member case, the larger canyon could eventually capture all of the flow going into the smaller canyon, and as the sidewalls approach,



**Figure 7.** Simulation illustrating the effects of canyon growth on the flow field, leading to preferred canyon spacing. A: Equipotential fields are shown at initial and two subsequent times. B: Contours of head gradients at initial and two subsequent times. Rules in the simulation are discussed in the text. Of the three initial canyons, two continue to grow, but the third (the closest neighbor to the initially longest canyon) becomes dormant at roughly time 2. Canyons will interact in such a way as to evolve toward some final spacing over time. Canyons will continue to grow until either the head gradient decreases below a critical value or the material that the canyon encounters becomes strong enough to withstand the seepage-induced forces.

erosional collapse may result in a much wider canyon. This new, large canyon might then show two headwalls, such as the branching morphology observed off Hispaniola (fourth ridge, Fig. 2) and Cascadia (Fig. 1A). As Dunne (1980) has illustrated, a branching morphology can result if a region along the canyon sidewall becomes unstable and fails. This failure creates a second region of focused flow and increased head gradient, and thus continued failure. Our calculations show that this process is most likely to happen at or near the heads of the canyons.

This competition for regional flow is analogous to the mechanics of crystal growth and the evolution of salt diapirs, where the presence of one crystal or diapir affects the growth of its neighbors (e.g., Christian, 1981; Seni and Jackson, 1983). Within the past decade, the geomorphic community has also become aware of examples of self-organization in the natural landscape at many scales (Hallet, 1990). Examples calling upon the feedbacks between adjacent features, and/or between a solid substrate and a fluid include eolian ripples (e.g., Anderson, 1990; Forrest and Haff, 1992) and other bedforms, beach cusps (Werner and Fink, 1993), and sorted stripes (Werner and Hallet, 1993) and patterned ground (Hallet, 1990) in the periglacial environment. Headless submarine

canyons may be the largest geomorphic example of self-organization so far described.

#### Relevance to Hazards and Subaerial Canyons

Submarine slope failures are a serious hazard to ocean platforms as well as cables and other structures. We suggest that any investigation of sites for the placement of submarine assets take into account the submarine geomorphology. Any slope that contains geomorphic features suggestive of internally driven failure could represent a region with high probability of future failure due to the positive feedback mechanisms mentioned above. In addition to being hazardous to submarine installations, such failures could also trigger tsunamis.

Headless canyons also occur on land, and the above approach may be appropriate for the analysis of regular canyon spacing in the subaerial environment. The necessary hydrologic analysis, however, is more complex, owing to the unknown geometry of the head gradient with respect to the topography.

We note that in some important cases subaerial topography originates as topography established in the submarine world. This is especially true in accretionary settings where uplift caused by telescoping of the prism may

lead to eventual emergence. Headless submarine canyons could then set the initial conditions for operation of subaerial geomorphic processes. Given the large amplitude of the submarine headless canyons, they would undoubtedly become the largest of the subaerial channels whose spacing would have been set by processes quite distinct from those that serve to incise these channels subaerially. The same processes of seepage-induced failure may remain active in the subaerial environment, although overland channelized flow will predominate in all but the most arid regimes. Thus, submarine canyons may provide insight into the desired initial conditions of large-scale landscape models.

#### CONCLUSIONS

The regular spacing of headless submarine canyons on both active and passive margins leads to the question, Are convergent margins really all that different from passive margins in terms of fluid flow? The sources of fluid within active margins (tectonic compaction, dehydration reactions, and exotically derived fluids from depth) may be volumetrically similar to fluids within passive margins, which may be driven by sedimentary compaction, dehydration reactions, subaerial aquifers, and brine circulation. The methods of fluid expulsion are similar for both active and passive margins, and the overall slopes may also be similar. Both environments display diffusive fluid flow and diapirism, as well as focused fluid flow due to fracture permeability and stratigraphic conduits. In addition, the distinctive biological communities surrounding the surface manifestations of focused venting are found in both settings. In both environments, headless submarine canyons form by the feedback between fluid-flow and slope-failure processes. This feedback leads to a self-organized morphology where the competition between initial slope failures results in the regular spacing of mature canyon systems.

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#### REFERENCES CITED

- Anderson, R. S., 1990, Eolian ripples as examples of self-organization in geomorphological systems: *Earth-Science Reviews*, v. 29, p. 77-96.
- Austin, J. A., 1983, Overthrusting in a deep-water carbonate terrane, in Bally, A. W., ed., *Seismic expression of structural styles: American Association of Petroleum Geologists Studies in Geology*, v. 15, p. 3.4.2-167-3.4.2-172.
- Baker, V. R., Kochel, R. C., Laity, J. E., and Howard, A. D., 1990, Spring sapping and valley network development, in Higgins, C. G., and Coates, D. R., eds., *Groundwater geomorphology: Geological Society of America Special Paper 252*, p. 235-265.
- Bray, C. J., and Karig, D. E., 1985, Porosity of sediments in accretionary prisms and some implications for dewatering processes: *Journal of Geophysical Research*, v. 90, p. 768-778.

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Breen, N. A., Orange, D. L., Mullins, H. T., and Dolan, J., 1991, Accretion in the Eastern Hispaniola basin: Eos (Transactions, American Geophysical Union), v. 71, p. 460.

Christian, J. W., 1981, The theory of transformations in metals and alloys, Part I: Equilibrium and general kinetic theory, (second edition): Oxford, United Kingdom, Pergamon Press, 586 p.

Dahlen, F. A., 1984, Noncohesive critical coulomb wedges: An exact solution, *Journal of Geophysical Research*, v. 89, p. 10,125-10,133.

DeMets, C., Gordon, R. G., Argus, D. F., and Stein, S., 1990, Current plate motions: *Geophysical Journal International*, v. 101, p. 425-478.

Denlinger, R. P., and Iverson, R. M., 1990, A general condition of limiting equilibrium for infinite submarine slopes: *Marine Geotechnology*, v. 9, p. 299-312.

Dillon, W. P., Edgar, N. T., Scanlon, K. M., and Klitgord, K. D., 1987, *Geology of the Caribbean: Oceanus*, v. 30, p. 42-52.

Dunne, T., 1980, Formation and controls of channel networks: *Progress in Physical Geography*, v. 4, p. 211-239.

Dunne, T., 1990, Hydrology, mechanics, and geomorphic implications of erosion by subsurface flow, in Higgins, C. G., and Coates, D. R., eds., *Groundwater geomorphology: Geological Society of America Special Paper 252*, p. 1-28.

Fertl, W. H., 1976, Abnormal formation pressures: Implications to exploration, drilling, and production of oil and gas resources: Amsterdam, Elsevier, 382 p.

Forrest, S. B. and Haff, P. K., 1992, Mechanics of wind ripple stratigraphy: *Science*, v. 255, p. 1240-1243.

Freeze, R. A., and Cherry, J. A., 1979, *Groundwater*: Englewood Cliffs, New Jersey, Prentice-Hall, 604 p.

Grow, J. A., Mattick, R. E., and Schlee, J. S., 1979, Multichannel seismic depth sections and interval velocities over outer continental shelf and upper continental slope between Cape Hatteras and Cape Cod: *American Association of Petroleum Geologists Memoir 29*, p. 65-83.

Hallet, B., 1990, Spatial self-organization in geomorphology: From periodic bedforms in patterned ground to scale-invariant topography: *Earth-Science Reviews*, v. 29, p. 57-76.

Hathaway, J. C., et al., 1979, U.S. Geological Survey core drilling on the Atlantic shelf: *Science*, v. 206, p. 515-527.

Howard, A. D., 1988, Groundwater sapping experiments and modeling, in Howard, A. D., et al., eds., *Sapping features of the Colorado Plateau—A comparative planetary geology field guide: Washington, D.C., NASA*, p. 71-84.

Iverson, R. M., and Major, J. J., 1986, Groundwater seepage vectors and the potential for hillslope failure and debris flow mobilization: *Water Resources Research*, v. 22, p. 1543-1548.

Kochel, R. C., Simmons, D. W., and Piper, J. F., 1988, Groundwater sapping experiments in weakly consolidated layered sediments: A qualitative summary, in Howard, A. D., et al., eds., *Sapping features of the Colorado Plateau—A comparative planetary geology field guide: Washington, D.C., NASA*, p. 84-93.

Kulm, L. D., von Huene, R., et al., 1973, Initial reports of the Deep Sea Drilling Project, Volume 18: Washington, D.C., U.S. Government Printing Office, 1077 p.

Laity, J. E., and Malin, M. C., 1985, Sapping processes and the development of theater-headed valley networks on the Colorado Plateau: *Geological Society of America Bulletin*, v. 96, p. 203-217.

Magara, K., 1987, Fluid flow due to sediment loading—An application to the Arabian Gulf region, in Goff, J. C., and Williams, B. P. J., eds., *Fluid flow in sedimentary basins and aquifers: Oxford, United Kingdom, Blackwell*, p. 19-28.

Mann, P., Burke, K., and Matumoto, T., 1993, Neotectonics of Hispaniola: Plate motion, sedimentation, and seismicity at a restraining bend: *Earth and Planetary Science Letters*, v. 70, p. 311-324.

McHugh, C. M., Ryan, W. B. F., and Schreiber, B. C., 1993, The role of diagenesis in exfoliation for submarine canyons: *American Association of Petroleum Geologists Bulletin*, v. 77, p. 145-172.

Moore, J. C., Orange, D., and Kulm, L. D., 1990, Interrelationship of fluid venting and structural evolution: ALVIN observations from the frontal accretionary prism, Oregon: *Journal of Geophysical Research*, v. 95, p. 8795-8808.

Mullins, H. T., and nine others, 1992, Carbonate platforms along the southeast Bahamas-Hispaniola collision zone: *Marine Geology*, v. 105, p. 169-209.

Orange, D. L., and Breen, N. A., 1992, The effects of fluid escape on accretionary wedges, II: Seepage force, slope failure, headless submarine canyons and vents: *Journal of Geophysical Research*, v. 97, p. 9277-9295.

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Paull, C. K., Spiess, F. N., Curry, J. R., and Twichell, D. C., 1990, Origin of Florida Canyon and the role of spring sapping on the formation of submarine box canyons: *Geological Society of America Bulletin*, v. 102, p. 502-515.

Poag, C. W., 1985, Depositional history and stratigraphic reference section for central Baltimore Canyon Trough, in Poag, C. W., ed., *Geologic evolution of the United States Atlantic margin: New York, Van Nostrand Reinhold*, p. 217-264.

Robb, J. M., 1984, Spring sapping on the lower continental slope, offshore New Jersey: *Geology*, v. 12, p. 278-282.

Robb, J. M., 1990, Groundwater processes in the submarine environment, in Higgins, C. G., and Coates, D. R., eds., *Groundwater geomorphology: Geological Society of America Special Paper 252*, p. 267-281.

Seni, S. J., and Jackson, M. P. A., 1983, Evolution of salt structures, East Texas diapir province, Part I: Sedimentary record of halokinesis: *American Association of Petroleum Geologists Bulletin*, v. 67, p. 1219-1244.

Twichell, D. C., and Roberts, D. G., 1982, Morphology, distribution, and development of submarine canyons on the United States Atlantic continental slope between Hudson and Baltimore Canyons: *Geology*, v. 10, p. 408-412.

Werner, B. T., and Fink, T. M., 1993, Beach cusps as self-organized patterns: *Science*, v. 260, p. 968-971.

Werner, B. T., and Hallet, B., 1993, Numerical simulation of self-organized stone stripes: *Nature*, v. 361, p. 142-145.

*Manuscript received March 20, 1993; revision received July 12, 1993; accepted July 26, 1993* ■

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Robert L. Fuchs

### Institutional Gifts Support GSA Programs

The Foundation has received \$38,000 in gifts from three institutions, for support of Research Grants, SAGE, and IEE. One of the gifts will be for the Foundation's endowment. The other two are program funds for use by GSA during 1994.

#### Coal Geology Scholarships

The Rocky Mountain Coal Symposium established a fund in 1983 for scholarships for students of coal geology in the western part of the United States and Canada. Since inception, the fund has made awards totaling \$8790 to 14 individuals. The GSA Foundation has managed the monies in the RMCS Fund, which has grown from \$10,000 to \$23,000 over the ten-year period.

Late in 1993, the RMCS management committee, consisting of Gary Glass, Joe Hatch, Lew Ladwig, Karl Newman, and Chuck Pillmore, approved the transfer of the RMCS Fund to the GSA Foundation, to be incorporated into the Antoinette Lierman Medlin Scholarship Award Fund for coal geology. With the addition of the RMCS monies, the Medlin Fund will increase to more than \$56,000.

Henceforth, scholarship awards for the study of western coal geology and related topics such as dewatering, coalbed methane, and environmental topics will be handled by GSA's Coal Geology Division, which has been responsible for awards under the Medlin Fund. Students interested in applying for a grant should first contact June Forstrom, GSA Research Grants Administrator. The 1994 deadline is February 15, and the Coal Geology Division Scholarship Committee will decide upon awardees by April 1, 1994.

#### SAGE Benefits from Grant

An unrestricted grant of \$10,000 has been received from a private foundation in support of the SAGE program. Ed Geary, GSA's Coordinator

for Educational Programs, said that the funds have come at a most opportune time in the expanding SAGE program. The National Earth Science Teachers Association has agreed to merge its partnering efforts with Partners for Excellence. A pilot program that will provide training and support for partners, InSTEP, is being developed in conjunction with Colorado teachers. Other SAGE projects include a program to train park rangers, interpreters, and local K-12 teachers in the geology of selected national parks, a directory of earth science resources, slide sets for K-12 educators, and a blueprint for professional program development, to name a few.

#### Contribution Earmarked for IEE

The Institute for Environmental Education program is the beneficiary of a \$5000 grant from the Frank A. Campini Foundation of California. The Campini Foundation was formed from the estate of the late Frank A. Campini, former owner of the San Francisco investment firm Pflueger & Baerwald. The foundation's fields of interest include the environment, arts and culture, and medical research, primarily AIDS and cancer.

In addition to general support of the IEE program, the Campini Foundation will be a sponsor of the IEE symposium "Earth Science in the Public Arena: Strengthening Decisions with the Geological Approach to Critical Inquiry." This is one of the scheduled symposia at the Cordilleran Section meeting in San Bernardino, March 21-23, 1994, and will be chaired by W. Gary Ernst of Stanford University. IEE Executive Director Fred A. Donath noted the appropriateness of this support from a California philanthropic organization, a state in which environmental problems and solutions are of great and continuing concern to the public. ■

### Gift from Former GSA Councilor

Don U. Deere and his wife Carmen have made a generous gift to GSA's Second Century Fund for Earth-Education-Environment. The Deeres are residents of Gainesville, Florida, where Don maintains the base for his international consulting business as well as an adjunct professorship at the University of Florida.

Don Deere studied mining engineering at Iowa State, and after receiving a B.S. degree he studied geology at the University of Colorado, leading to his M.S. degree. He subsequently received a Ph.D. in civil engineering from the University of Illinois and became a member of the faculty at that institution in 1955, a post he held until 1972, when he and Carmen moved to Gainesville.

Because of his varied education and university background, with degrees in mining engineering, geology, and civil engineering, Don Deere has enjoyed a similarly varied professional career in geology and engineering. In his early years he worked in mining engineering for Phelps Dodge and the Potash Company of America. While an associate professor in civil engineering at the University of Puerto Rico (Mayagüez), he was a partner in the Foundation Engineering Company of Puerto Rico. His ties with the University of Florida are to both the civil engineering and geology departments. He was appointed to a term as chairman of the Nuclear Waste Technical Review Board by President Ronald Reagan.

Don Deere maintains an active international geotechnical consulting practice in his areas of special expertise—engineering geology and applied rock mechanics. His work on large hydroelectric projects, tunnels, and landslide stabilization takes him to many parts of the globe—New Zealand, Chile, and northeastern Canada, to name a few recent destinations.

Don Deere has received numerous honors and awards during his career—



Don and Carmen Deere

the Honorary Member Award from AEG, the Rock Mechanics Award from SME, and the Distinguished Practice Award from GSA's Engineering Geology Division. He was elected to both the National Academy of Engineering and the National Academy of Science. He has been active in GSA, as a member and Councilor of the Engineering Geology Division, as a GSA Councilor, and as a member of Audit Committee. He currently serves the Foundation as an Honorary Chair of the Second Century Fund Committee.

Commenting on their gift, Don Deere said, "My fifty-year career in teaching and consulting has always been based on the principle that studying and understanding site geology is the essential precursor to any meaningful planning, analysis, and design of an engineering project. Because of the importance of geology to me, to civil engineering, and to the community at large, Carmen and I are pleased to make a gift to GSA's endowment in support of the programs that benefit geologists and geology." ■

### GeoRef Adds New Programs and Features

The American Geological Institute's GeoRef database offers five new programs and features in 1994: abstracts; more frequent updates; and enhanced coverage, document delivery service, and end-user searching.

"The addition of full text abstracts for more than 7000 items in 1994 is just a first step toward our goal of abstracts for the entire database," said Marcus E. Milling, AGI Executive Director. "The cooperation of the publishers of the 'core journals' in geology has given us a start," Milling added. These publishers include Elsevier, the Geological Society of America, and the American Association of Petroleum Geologists.

GeoRef users are benefiting from updates of the database twice each month; previously, a monthly update of the database was standard. This important step results from the new

production system GeoRef installed in 1993.

GeoRef has upgraded the AGI Document Delivery Service to satisfy a substantial increase in demand for documents from GeoRef searches. AGI is actively supporting the use of GeoRef by geoscientists. The user-friendly systems of DIALOG, ORBIT, STN, and OCLC have been endorsed by GeoRef, and the GeoRef CD-ROM is now searchable on SilverPlatter's WinSPIRS, a Windows version of their software.

The GeoRef database contains over 1.8 million references to geoscience journal articles, books, maps, conference papers, reports, and theses. It covers the geology of North America from 1785 to the present and the geology of the rest of the world from 1933 to the present. ■



## Have you thought about *Recycling* your Research Grant?

GSA's student research grants program has had a profound impact on geology throughout its 61-year history. \$4.8 million has been awarded to 5,280 geologists for projects around the world.

Success begets demand — over 500 applicants for fewer than 200 grants. The program needs additional financial support, and alumni may wish to think about the *career effect of their grants* and provide one of today's students a similar opportunity.

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The Geological Society of America

## Congressional Science Fellowship 1994-1995

The Geological Society of America is accepting applications for the 1994-1995 Congressional Science Fellowship. The Fellow selected will spend a year (September 1994- August 1995) in the office of an individual member of Congress or a congressional committee for the purpose of contributing scientific and technical expertise to public policy issues and gaining firsthand experience with the legislative process. The American Association for the Advancement of Science conducts an orientation program to assist the Fellow seeking a congressional staff position in which he or she can work on major legislative issues.

### Criteria

The program is open to highly qualified postdoctoral to mid-career earth scientists. Candidates should have exceptional competence in some area of the earth sciences, cognizance of a broad range of matters outside the Fellow's particular area, and a strong interest in working on a range of public policy problems.

### Award

The GSA Congressional Science Fellowship carries with it a \$38,000 stipend, and limited health insurance, relocation, and travel allowances. The fellowship is funded by GSA and by a grant from the U.S. Geological Survey. (Employees of the USGS are ineligible to apply for this fellowship. For information about other programs, contact AAAS or the Geological Society of America.)

### To Apply

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



**DEADLINE FOR RECEIPT OF ALL APPLICATION MATERIALS IS FEBRUARY 15, 1994**



# NORTH-CENTRAL SECTION, GSA 27th Annual Meeting Kalamazoo, Michigan April 28-29, 1994



The North-Central Section of the Geological Society of America will meet in the Fetzer Center and Rood Hall on the campus of Western Michigan University in Kalamazoo, Michigan. The meeting will be hosted by the Department of Geology, College of Arts and Sciences, WMU. Societies that will meet in conjunction with North-Central GSA include the East-Central Section of the National Association of Geology Teachers, the Great Lakes Section of SEPM (Society for Sedimentary Geology), the Pander Society, the North-Central Section of the Paleontological Society, and the Geology Division of the Council on Undergraduate Research.

## LOCATION

Kalamazoo, Michigan, is midway between Chicago, Illinois, and Detroit, Michigan, on I-94. Lake Michigan, along with the wine- and fruit-producing belt of Michigan, is only 30 miles west of the city, providing numerous opportunities for recreation and sight-seeing. The weather in late April is generally pleasant and warm, although showers are common.

The meeting will be held on the campus of Western Michigan University, with easy access to restaurants and lodging. In addition to nearby motels, rooms in university dorms will be available at lower cost.

## REGISTRATION

### Preregistration Deadline: April 5, 1994

Preregistration by mail will be handled by the Office of Conferences and Institutes, Western Michigan University, Kalamazoo, MI 49008; (616) 387-4174, fax 616-387-4189. Registration fees are listed below.

Please take advantage of the lower registration fees and register by April 5. Advance registration is strongly recommended for all field trips and many of the special activities because of participant limits.

Full payment MUST accompany registration (purchase orders are NOT accepted). Charge cards are accepted as indicated on the preregistration form. Your confirmation letter from Western Michigan University will be your receipt; no other receipt will be sent.

Return the completed registration form with full payment to: 1994 GSA Meeting, Office of Conferences and Institutes, Western Michigan University, Kalamazoo, MI 49008, or fax 616-387-4189. Register one professional or student per form. Copy the form for your records. Preregistration forms received after the April 5 deadline will be charged at the on-site rate. Badges must be worn for access to ALL activities.

Guest registration is required to attend guest activities. To obtain the guest rate, all guests must be accompanied by a registered professional or a registered student.

Current student ID is required to obtain student rates. Students not carrying a current student ID when they arrive to pick up registration materials will be required to pay the professional fee.

**Cancellations, Changes, and Refunds** All requests for registration additions, changes, and cancellations must be made in writing and received by the Office of Conferences and Institutes at Western Michigan University by April 12, 1994. Faxes will be accepted. Advance registrations will be refunded for all such cancellations. NO REFUNDS WILL BE MADE ON CANCELLATION NOTICES RECEIVED AFTER APRIL 12, 1994. Refunds will be mailed after the meeting. Refunds for fees paid by credit card will be credited according to the card number on the preregistration form. NO refunds will be given for on-site registration and ticket sales.

## ON-SITE REGISTRATION SCHEDULE

Wednesday, April 27, Rood Hall Lobby  
5:00 p.m.-9:00 p.m.  
Thursday, April 28, Fetzer Center  
7:30 a.m.-5:00 p.m.  
Friday, April 29, Fetzer Center  
7:30 a.m.-12:00 noon

## STUDENT PAPERS AND TRAVEL ASSISTANCE

The North-Central Section of GSA will award \$75 for each of the eight best papers whose principal author and presenter is a graduate or undergraduate student. Abstracts submitted for these awards should be clearly indicated. In addition, awards for travel assistance will be made to students who are members of the GSA North-Central Section as of January 1994. To receive a travel grant, the student must present at the meeting a paper (oral or poster) of which he or she is the author or co-author. Applications for travel assistance awards may be obtained by writing the General Chair, Alan E. Kehew, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5495. Applications must be received by **February 15, 1994**.

## SPECIAL EVENTS

The **Welcoming Reception** will be held on the evening of Wednesday, April 27, 1994, in the lobby of Rood Hall from 6:00 to 9:00 p.m. The **Annual Banquet** will be held on Thursday evening, April 28th, at the Holiday Inn—West, preceded by a social hour beginning at 6:00 p.m. The banquet address will be given by William S. Fyfe of the University of Western Ontario. The title of his talk is "Wanted—New Technologies for the 21st Century: The Role of Geosciences." Cost: \$25.

A **Joint Luncheon** of the Great Lakes Section of SEPM, the North-Central Section of the Paleontological Society, and the Pander Society will be on Thursday, April 28, in Fetzer Center. Cost: \$15. The National Association of Geology Teachers and the GSA North-Central Education Committee will have a **Shareathon and sack lunch** on Friday, April 29, in Rood Hall. Cost: \$5.

The **North-Central GSA Management Board Breakfast and Business Meeting** will be on Thursday, April 28, 1994, at 7:00 a.m. at the Fetzer Center.

The **North-Central GSA Campus Representatives** will hold a breakfast on Friday, April 29, in the Fetzer Center at 7:00 a.m.

## SPOUSE and GUEST ACTIVITIES

The coordinator for Spouse and Guest activities is Linda Harrison. Questions regarding the trips described below can be addressed to her at (616) 345-2406.

**Culture, Crafts and Food in Northern Indiana Amish Country.** Step back in time and immerse yourself in the Amish farm country of northern Indiana. We'll visit Menno-Hof, a Mennonite-Amish visitors center, to learn their origins, beliefs, practices, and customs. Amish builders erected Menno-Hof's barn. Along with Mennonite craftspeople, they created a multimedia experience you'll find fascinating and memorable.

We'll have an old-fashioned Amish lunch with baked chicken, assorted vegetables, salads, and dessert. No, it's not low-calorie, but you're on holiday.

Shopping in Shipshewana, you will find quilts, crafts, bread, pies, dried flowers and herbs, fine art, and a quaint drug store. Or you may just want to sit on a porch and watch the horse-drawn buggies roll by.

Admission to the visitors center and lunch are included. Thursday, April 28, 1994, 8:30 a.m. to 5:00 p.m. Cost: \$30. Participants will board vans in the Rood Hall parking lot.

**Michigan Wineries: Tour, Luncheon, and Champagne Tasting.** We'll visit Paw Paw, the heart of southwestern Michigan's wine country. St. Julian Winery, Michigan's oldest and largest winery, offers us a tour of its wine cellars and a tasting of Michigan's premium wines. St. Julian has attracted national attention and won numerous gold medals for its Chardonnay and dessert wines, including Solera cream sherry.

Just next door, Warner Champagne Cellars and Bistro will host us for a scrumptious buffet lunch and champagne tasting. Friday, April 29, 1994, 9:00 a.m. to 2:00 p.m. Cost: \$20. Participants will board vans in the Rood Hall parking lot.

## ACCOMMODATIONS

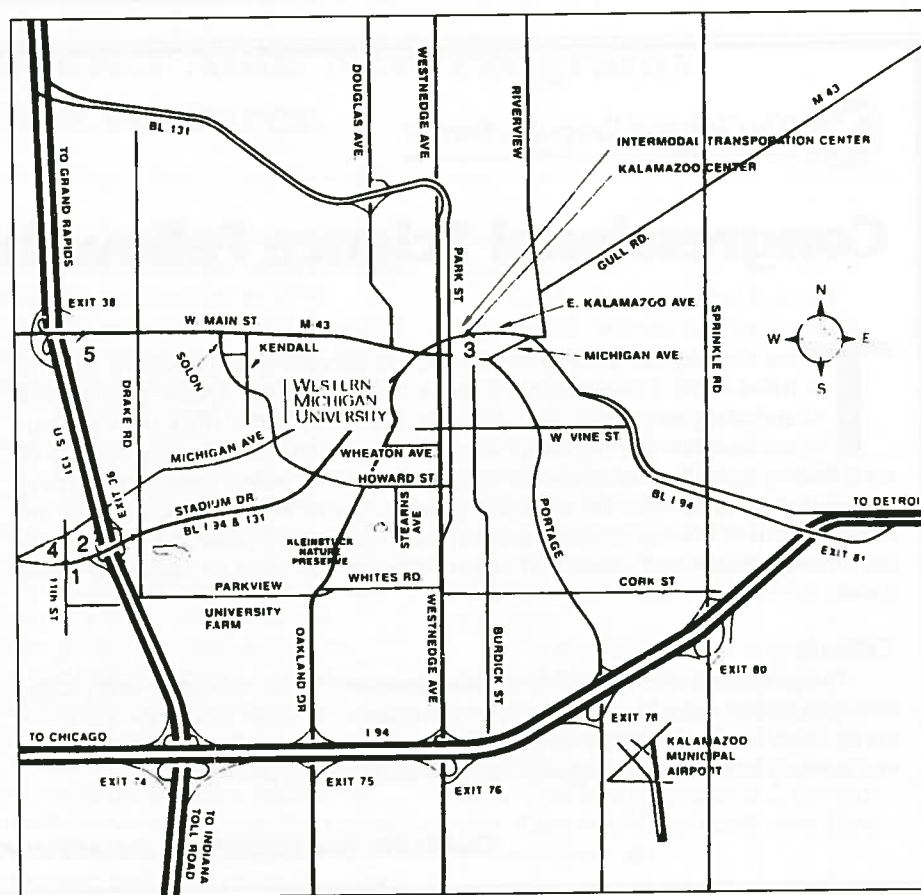
A block of rooms has been reserved for attendees at several area hotels and motels (numbers correspond to numbers on map).

1. **Holiday Inn—West:** 2747 South 11th Street, (616) 375-6000, \$62.
2. **Budgetel Inn:** 2203 South 11th Street, (616) 372-7999, \$41.95.
3. **Radisson Plaza Hotel:** 100 W. Michigan Avenue, (616) 343-3333, \$70.
4. **Red Roof Inn—West:** 5425 W. Michigan Avenue, (616) 375-7400, \$29.99-\$35.99.
5. **Super 8 Motel:** 618 Maple Hill Drive, (616) 345-0146, \$32.29-\$51.19.

A tax of 8% is added to all rates. To make reservations, telephone the hotel directly and indicate that you are attending the 1994 GSA meeting. Please call early, because many of the special rates are on a space-available basis only and are guaranteed only up to four weeks before the meeting.

North-Central continued on p. 43

## KALAMAZOO AREA



## REGISTRATION FEES

	Advance (by 4/5/94)		On-site	
	Full	One day	Full	One day
Professional Member	\$45	\$25	\$55	\$30
Professional Nonmember	\$50	\$30	\$60	\$35
Student Member	\$15	\$10	\$25	\$15
Student Nonmember	\$20	\$15	\$30	\$20
Guest	\$10	NA	\$10	NA



Housing is also available in a residence hall on the campus of Western Michigan University, at rates from \$13 to \$16. Please call (616) 387-4750 for reservations.

**MEALS**

A wide variety of restaurants, both on and off campus, offer meal service. The Bronco Mall, which has several fast food restaurants, is located in the Bernhard Center, in the middle of the campus.

**TRANSPORTATION**

Western Michigan University is easily reached via I-94, which passes just south of the city. Air, rail, and bus service to Kalamazoo is also available. Cab service is available from the airport and the train/bus station to the hotels. Some hotels provide shuttle service to and from the airport.

Free parking will be available at the Fetzer Center (lot 72F) on a space-available basis. Overflow parking space is available in lots 72R and 72W, located next to the Fetzer Center.

Shuttle service from the hotels (with the exception of the Super 8 Motel) to the Fetzer Center on the Western Michigan University campus begins Thursday morning and continues until the end of the meeting on Friday. Schedule information will be posted in the hotels and at the meeting.

**TECHNICAL PROGRAM**

Any questions about the technical program can be directed to Ronald B. Chase, Department of Geology, Western Michigan University, Kalamazoo, MI 49008; (616) 387-5500; fax 616-387-5513.

**SYMPOSIA**

The following symposia have been organized. Authors are encouraged to contact the individual symposium organizers for information.

- 1. Devonian History of Central Euramerica (Central and Eastern North America).** William B. Harrison III, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5488, fax 616-387-5513; James E. Day, Dept. of Geography-Geology, Illinois State University, Normal, IL 61761, (309) 438-7649.
- 2. Great Lakes Coastal Processes.** David A. Barnes, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5493; David W. Folger, U.S. Geological Survey, Woods Hole, MA 02543, (508) 457-2234.
- 3. The Biological Basis of Taphonomic Patterns.** Paleontological Society Symposium. Danita Brandt, Dept. of Geological Sciences, Michigan State University, East Lansing, MI 48824, (517) 355-4626.
- 4. Controls on the Development of Ground-Water Contaminant Plumes.** Duane Hampton, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5496.
- 5. MEARTH (Math in Earth Sciences).** Marian Smith, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-3756.
- 6. Aquifer Systems of the Great Lakes Region.** Great Lakes Section, SEPM, Annual Symposium David B. Westjohn, U.S. Geological Survey, Water Resources Division, 6520 Mercantile Way, Suite 5, Lansing, MI 48911, (517) 377-1608; Paul Catacosinos, Dept. of Geology, Delta College, University Center, MI 48710, (517) 686-9252.

**Preregistration Form**

**GSA North-Central Section**  
Kalamazoo, Michigan • April 28-29, 1994

Preregistration deadline is April 5, 1994.

*Please print clearly • THIS AREA IS FOR YOUR BADGE*

Name as it should appear on your badge (last name first) \_\_\_\_\_

Employer/University Affiliation \_\_\_\_\_

City \_\_\_\_\_ State or Country \_\_\_\_\_

( ) \_\_\_\_\_ Business Phone

( ) \_\_\_\_\_ fax

( ) \_\_\_\_\_ Home Phone

Mailing Address (use two lines if necessary) \_\_\_\_\_

Please indicate if you will need services to accommodate a motor or sensory impairment  Yes

City \_\_\_\_\_ State \_\_\_\_\_ ZIP Code \_\_\_\_\_ Country (if other than USA) \_\_\_\_\_

Circle member affiliation (to qualify for registration member discount): (A) GSA (B) NAGT (C) Pander Soc. (D) NCS Paleo Soc. (E) SEPM

*GUEST INFORMATION • Please print clearly • This area is for badge*

Name as it should appear on your guest's badge \_\_\_\_\_ City/State or Country \_\_\_\_\_

**PREREGISTRATION**

	Qty	Amount
Professional Member	\$45 <input type="checkbox"/> 1	\$ _____
Professional Nonmember	\$50 <input type="checkbox"/> 1	\$ _____
Student Member	\$15 <input type="checkbox"/> 1	\$ _____
Student Nonmember	\$20 <input type="checkbox"/> 1	\$ _____
Teacher (K-12)	\$10 <input type="checkbox"/> 1	\$ _____
Spouse or Guest	\$10 <input type="checkbox"/>	\$ _____
Abstracts with Programs (reserved, pick up at registration table)	\$10 <input type="checkbox"/>	\$ _____

**GUEST ACTIVITIES**

Culture, Crafts, and Food in Northern Indiana Amish Country	April 28	\$ 30	\$ _____
Michigan Wineries: Tour, Luncheon, and Champagne Tasting	April 29	\$ 20	\$ _____

**SPECIAL EVENTS**

Annual Banquet	April 28	\$ 25	\$ _____
Combined Paleo Society, Pander Society, and Great Lakes SEPM Luncheon	April 28	\$ 15	\$ _____
GSA North-Central Section Management Board Breakfast	April 28	FREE	\$ _____
NAGT and GSA North-Central Section Education Committee Shareathon	April 29	\$ 5	\$ _____
GSA Campus Representatives Breakfast	April 29	FREE	\$ _____

**SHORT COURSES**

1. Devonian Stratigraphy and Lithofacies of the Michigan Basin	April 30	\$ 45	\$ _____
2. Environmental Geophysics	April 30	\$ 50	\$ _____
3. Hydrocarbon Monitoring and Recovery	April 30	\$ 50	\$ _____
4. Building Ground-Water Flow Models	April 29	\$ 200	\$ _____
5. Environmental Hydrogeology	April 26-27	(register through SEPM)	\$ _____

**FIELD TRIPS**

**Premeeting**

1. Hydrogeology of Kalamazoo and Cass Counties, Michigan	April 27	\$ 45	1	\$ _____
2. Geology of Kentland Structural Anomaly, Northwestern Indiana	April 27	\$ 60	1	\$ _____

**Postmeeting**

3. Great Lakes Coastal Geology and Coastal Engineering, Southeastern Lake Michigan	April 30-May 1			
Double room		\$ 125	1	\$ _____
Single room		\$ 145	1	\$ _____
Flyover		Add \$ 100	1	\$ _____
4. Glacial Geology of the Grand Valley, Michigan	April 30	\$ 50	1	\$ _____
5. Classic Silurian Reefs of the Chicago Area	April 30	\$ 55	1	\$ _____

**TOTAL FEES** ..... \$ \_\_\_\_\_

Remit in U.S. funds payable to: **Western Michigan University**  
(All preregistrations must be prepaid. Purchase Orders not accepted.)  
Payment by (check one):  Check  VISA  MasterCard  Discover

Card Number \_\_\_\_\_ Expires \_\_\_\_\_

Signature \_\_\_\_\_

**Office Use Only** 23-364053

CK/MO# \_\_\_\_\_ Date \_\_\_\_\_

CC \_\_\_\_\_ Cash \_\_\_\_\_

Amt \$ \_\_\_\_\_ Recpt \_\_\_\_\_

Issued by \_\_\_\_\_

**MAIL TO:** 1994 GSA North-Central Section Meeting, Office of Conferences and Institutes, Western Michigan University, Kalamazoo, MI 49008. Or fax to 616-387-4189.

- 7. Integration of Geosciences, Engineering and Land Use Planning Principles to Maximize Environmental Capabilities.** William Davidson, BLDI, 2 Fountain Place, NE, Suite 350, Grand Rapids, MI 49503, (616) 459-3737; Ken Detlof, Wilkins and Wheaton Environmental Services, Inc., 169 Portage Road, Kalamazoo, MI 49008, (616) 345-1158. Cosponsored by the GSA Institute for Environmental Education.
- 8. Geophysical and Tectonic Studies of the Eastern Arm of the Mid-Centimeter Rift.** William A. Smith, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5497, E-mail: smith@gw.wmich.edu; Ernest C. Hauser, Institute for the Study of the Continents, Snee Hall, Cornell University, Ithaca, NY 14853-1504, (607) 265-4316, E-mail: hauser@geology.cornell.edu.
- 9. Geology and Hydrogeology of Glacial Outwash Systems.** Gordon Fraser, Indiana Geological Survey, 611 N. Walnut Grove, Indiana Uni-

- versity, Bloomington, IN 47405, and W. Thomas Straw, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5485.
- 10. Aquifer Restoration and Remedial Action.** Paul Daniels, BLDI, 2 Fountain Place, NE, Suite 350, Grand Rapids, MI 49503, (616) 459-3737.
  - 11. Geophysical Applications to Environmental Problems.** William A. Smith and Estella Atekwana, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5497, E-mail smith@gw.wmich.edu.
  - 12. Structural Geology and Tectonics of the Precambrian Lake Superior Region.** William J. Gregg, Dept. of Geological Engineering, Geology and Geophysics, Michigan Technological University, Houghton, MI 49931-1295, (906) 487-2795; Stephen D. Stahl, Dept. of Geology, Central Michigan University, Mount Pleasant, MI 48859, (517) 774-3179.
  - 13. The National Park System and Informal Geology Education in the Great Lakes States.** Robert

Corbett, Dept. of Geography-Geology, Illinois State University, Normal, IL 61761, (309) 438-7649; Barbara Manner, Dept. of Physics and School of Education, Duquesne University, Pittsburgh, PA 15282, (412) 396-5482.

**SHORT COURSES**

- 1. Devonian Stratigraphy and Lithofacies of the Michigan Basin: A Core Workshop.** William B. Harrison III, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5488. Cores from the major Devonian stratigraphic units in the Michigan Basin will be displayed with interpretive lithofacies and stratigraphic data. The Michigan Devonian section is a complete representation of the lower Kaskaskia megasequence. Shelf and restricted carbonates along with basin-centered evaporites compose the section. Saturday, April 30, 9:00 a.m., Michigan Basin Core Research Laboratory. Cost: \$45.

North-Central continued on p. 44



## 2. Environmental Geophysics.

William A. Sauck, William A. Smith, and Estella Atekwana, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-4991. About one hour will be spent in the classroom reviewing the methods and techniques used in shallow applications of geophysics to environmental problems. They include seismic, ground-penetrating radar, magnetic, resistivity, and borehole logging methods. The next six hours will be spent at a nearby field site for a demonstration of the equipment and methods and to gather data. A final hour in the computer laboratory will be used to show results of preliminary processing and interpretation. Saturday, April 30, 8:30 a.m. to 5:00 p.m. Cost: \$50, including lunch and transportation.

## 3. Hydrocarbon Monitoring and Recovery.

Duane Hampton, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5496. The principles of separate-phase hydrocarbon movement and accumulation in aquifers will be illustrated. Then we will focus on wells for locating, quantifying, and removing spilled hydrocarbons. We will proceed from laboratory experiments to field tests of methods of spill-volume determination and well design. Related experiments with DNAPLs will also be shown. Papers describing these experiments will be distributed to participants. Saturday, April 30, 9:00 a.m., Rood Hall. Cost: \$50.

## 4. Building Ground-Water Flow Models.

Richard N. Passero, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5502. The G.E.M. Regional Center at Western Michigan University, under a grant from the W. K. Kellogg Foundation, has developed several "sand tank" models for demonstrating and teaching principles of ground-water flow and contaminant transport. The models range from those replicating local geology in 60-gallon aquariums to 5-gallon models used in introductory geology labs. In this workshop, each participant will receive a classroom model valued at \$190, learn how to operate the model, and be introduced to student lab exercises for the model. The larger models will also be described. Friday, April 29, 3:00 p.m. Cost \$200.

## 5. Environmental Hydrogeology.

Eric Eslinger, Alpha Earth, Inc., 10 Sussex Road, Glenmont, NY 12077, (518) 439-8447. Sponsored by SEPM and the Great Lakes Section of SEPM. This is a two-day course in hydrogeology with an emphasis on contaminant fate and transport in soils and ground water and aquifer remediation. It will be offered on April 26 and 27. Computer applications in hydrogeology will be intro-

duced and used in the course. Basic preparation for the course is a four-year degree in geology or a related science. Cost of the course is \$360 for SEPM members and \$410 for nonmembers and on-site registration. Conference participants interested in this course should contact SEPM directly to register: SEPM, P.O. Box 4756, Tulsa, OK 74159-0756, (918) 743-9765.

## PROJECTION EQUIPMENT

Two standard 35 mm carousel projectors for 2" x 2" slides and one overhead projector for transparencies will be provided in each meeting room. Please bring your own loaded carousel trays identified with speaker's name, session, and speaker number. A speaker ready room equipped with projectors will be available for review and practice.

## POSTER SESSIONS

We strongly encourage student and professional members to take advantage of this highly effective means of communication. Please indicate Poster Session on the GSA Abstract Form. Each poster booth will provide three 4' x 4' boards arranged at table height. Poster sessions will be located in the same vicinity as the exhibits and will be available for viewing for one-half day.

The Geology Division of the Council on Undergraduate Research will sponsor a poster session on research by undergraduate students, in any discipline of geology.

## FIELD TRIPS

Both premeeting and postmeeting field trips are planned. Trips are technical in nature and can be physically demanding. Please check with the trip leader if you have any questions. General questions should be addressed to Field Trip Coordinator John Grace, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5494.

All trips will begin and end at the Fetzer Center at Western Michigan University, unless otherwise specified. Trip costs for one-day trips will include transportation, field guide, lunch, and soft drinks.

Preregistration for field trips is recommended because of logistical limitations. Participants will be accepted on a first-come, first-served basis. All field trip participants must also register for at least one day of the meeting. Trip members should be prepared for inclement weather and muddy walking conditions.

If a trip must be canceled due to logistical reasons, a full refund will be issued after the meeting.

## Premeeting

### 1. Hydrogeology of Kalamazoo and Cass Counties, Michigan.

Richard N. Passero and W. Thomas Straw, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5485. This trip will emphasize recent research on the general hydrogeology and industrial and agricultural contamination of ground water within the Kalamazoo morainal complex. The Schoolcraft outwash plain and the Prairie Ronde alluvial fan bordering the moraine are included in the trip. One day, Wednesday, April 27. Cost: \$45.

### 2. Geology of the Kentland Structural Anomaly, Northwestern Indiana.

Shanaka L. de Silva, Dept. of Geology and Geography, Indiana State University, Terre Haute, IN 47809, (812) 237-2269. The Kentland anomaly, or dome, has received much attention from geologists over many years. This remarkable piece of geologic real estate is exposed in the quarry of the Newton County Stone Company, in Kentland, Indiana. Much of the knowledge of the geology of the quarry is a result of the lifelong efforts of Ray Gutschick, who has shown that Kentland offers the rare opportunity to see structural detail seldom freshly exposed laterally and vertically on this scale. The Newton County Stone Company recognizes the scientific value of this site; however, while the quarrying process exposes a great deal of new geology, several classic exposures are also being destroyed. This may be a rare opportunity to see this structure before many of its vital features are removed.

Stratigraphic units from the Early Ordovician Shakopee Dolomite to Early Silurian Salamonie Dolomite, which elsewhere are nearly horizontal, are a chaotic jumble of steeply dipping and pervasively faulted strata in this quarry. Furthermore, these strata have been uplifted some 1500-1800 ft through Silurian to Mississippian cover rocks which, although absent from the quarry, are found in the subsurface within a mile or so of the quarry. Such structurally disturbed and uplifted strata are a common feature of central uplifts associated with impact craters around the world. This fact, coupled with the macroscopic evidence of shatter cones and breccia dikes and the microscopic evidence of shocked quartz and veins of melt in the St. Peters Sandstone, has led to many suggestions that the Kentland anomaly is in fact a fossil impact site. This is challenged by others who believe that the structure is cryptovolcanic in origin. This field trip will allow interested individuals to examine the evidence for themselves and debate these ideas in the field. Wednesday, April 27, 8:00 a.m. Cost: \$60.

## Postmeeting

### 3. Great Lakes Coastal Geology and Coastal Engineering, Southeastern Lake Michigan.

Larry Parson, Army Corps of Engineers, WES—Vicksburg, Mississippi; Charles Thompson and Ronald Ericson, Army Corps of Engineers, Detroit District, Detroit, Michigan; Charlie Johnson, Army Corps of Engineers, North Central Division; David A. Barnes, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5493.

St. Joseph, Michigan, on the southeastern shore of Lake Michigan, is located at the mouth of the St. Joseph River over an ancient, predominantly sand-filled river valley. It is the location of an ongoing beach-nourishment project initiated in 1976 to mitigate the adverse erosional effects of the federal

navigation structure. The coastline on either side of the St. Joseph jetty consists of a relatively thin veneer of sand and gravel overlying cohesive glacial till or bedrock.

This two-day field trip will visit a reach of shoreline from about two miles north of St. Joseph-Benton Harbor in the vicinity of Rocky Gap Park, to about 10 miles south, near Grand Mere State Park. This reach comprises at least three principal geomorphological shore types on Lake Michigan (low and high till bluffs, sand dunes). Examples of nearly every type of engineered coastal structures used in the Great Lakes are found in the vicinity. This reach of shoreline presents an excellent opportunity to observe the interaction and influence of a variety of structures on coastal processes for several shore types and the performance of coarse-grained beach fills.

On the first day of the trip we will visit sites along this reach via van; day two will include a long morning boat trip aboard the *Kitty Hawk* (a 40' ex-Navy liberty launch) and an optional overflight of the shoreline (weather permitting) on a 1920s Ford Tri-motor chartered from the Kalamazoo Aviation Museum. Saturday, April 30, and Sunday, May 1. Cost: \$125 (double occupancy). Options: Single occupancy Saturday night, \$145. Flyover on Sunday afternoon, \$100.

### 4. Glacial Geology of the Grand Valley, Michigan.

Grahame J. Larson, Dept. of Geological Sciences, Michigan State University, East Lansing, MI 48824; Alan E. Kehew, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5495; Norman Ten Brink, Dept. of Geology, Grand Valley State University, Allendale, MI 49401, (616) 895-3210.

The significance of the glacial Grand Valley of Michigan has been recognized since the pioneering work of Frank Leverett. The valley served as a major conduit for meltwater flow during retreat of the Saginaw Lobe and later for flows between lakes in the Huron and Michigan basins, sometimes in the form of high-discharge outbursts. The trip will begin at the outlet of glacial Lake Saginaw and progress downstream to examine terrace remnants and geomorphic features. It will end at the Allendale delta, a huge sediment fan deposited in glacial Lake Chicago. One day, Saturday, April 30. Cost: \$50.

### 5. Classic Silurian Reefs of the Chicago Area.

Don Mikulic, Illinois State Geological Survey, 615 E. Peabody Dr., Champaign, IL 61820, (217) 244-2518; Joanne Kluessendorf, Dept. of Geology, University of Illinois, 1301 W. Green St., Urbana, IL 61801.

The Silurian reefs of the Chicago area have had scientific and economic importance for more than 150 years. These structures have played a key role in our understanding of ancient reefs, hydrocarbon reservoirs, and paleoecological models. This one-day trip will visit the world-famous Thornton reef and several other localities to examine the geology and paleontology of these structures, trace the history of reef studies, and discuss new evidence for reef development models. Saturday, April 30. Cost: \$55.

## EXHIBITS

Exhibits of educational and commercial organizations will be on display in the Fetzer Center near the symposia, technical, and poster sessions. The exhibits coordinator is William A. Smith, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5497. ■

## Purchase your copy of 1994 GSA Abstracts with Programs

for any of the 1994 Section meetings  
or the Annual Meeting in Seattle,  
see order form on p. 55.

 Have enough abstracts forms  
for the 1994 Annual Meeting?

If not ... request them NOW.

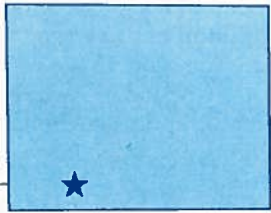
1-800-472-1988 or (303) 447-2020



**Final Announcement**

# ROCKY MOUNTAIN SECTION, GSA Annual Meeting

**Durango, Colorado  
May 4-6, 1994**



The Rocky Mountain Section of the Geological Society of America will hold its 1994 meeting, together with the Rocky Mountain Section of the Paleontological Society and the Southwest Section of the National Association of Geology Teachers, at the Tamarron Resort north of Durango, Colorado. The meeting is being hosted by the Department of Geology, Fort Lewis College.

**SETTING**

The Tamarron Resort, 18 miles north of Durango, Colorado, is one of the state's premier resorts. It offers lodging and a wide range of facilities and services for the visitor, as well as superb conference facilities for the meeting. The historic town of Durango, has a variety of restaurants and other attractions.

Tamarron is located at an elevation of 7500 ft in a beautiful mountain valley carved by the Animas River and Pleistocene Animas Valley glaciers. Several 14,000-ft-high peaks of the Needle Mountains of the San Juans lie to the east, the Silverton caldera and historic Silverton are to the north, and the rampart of the Hermosa Cliffs, beyond which are the La Plata Mountains, lies to the west. To the south, the boundary between the southern Rocky Mountains and the San Juan basin of the Colorado Plateau is marked by prominent hogbacks developed on resistant sandstones deposited in the Late Cretaceous interior sea.

The weather in early May should be warm and springlike, with daily temperatures in the 60s and 70s (°F) and overnight lows in the 30s and 40s. Mountain weather is notoriously unpredictable, however, so the May visitor should come prepared for anything, including the last blizzard of the winter!

Tamarron can be reached easily by automobile via US Route 550. The Durango-La Plata County Airport is serviced by United Express, Continental Express, America West Express, and Mesa Airlines, with connections to Denver and Phoenix.

**REGISTRATION**

**Preregister today! Preregistration deadline: March 25, 1994**

1. Considerable savings in registration fees accompany preregistration. Advance registration is strongly suggested for special events and all field trips because of the limited space available. Use the preregistration form included in this announcement.
2. Badges must be worn for access to all activities.
3. Registration discounts are given to GSA or associated society members.

Associated societies that qualify for this discount are indicated on the preregistration form. Please indicate your affiliation(s) and member number to register at member rates. Proper ID will be requested for K-12 earth science teachers.

4. Full payment MUST accompany the preregistration form. Unpaid purchase orders are NOT accepted as valid registration. Charge cards are accepted, as indicated on the form. Please check the charge card number given; errors will delay your registration. Your confirmation letter from GSA will be your only receipt.
5. Please register only one professional or student per form. Keep a copy for your records.
6. Current student ID is required to obtain student rates at both the preregistration and on-site counters. Students must present their current student ID when picking up registration materials in order to receive the student rate.
7. A reduced registration fee will be offered to precollege earth science teachers and students. Field trip and short course attendees (except precollege earth science teachers) must register for the meeting.
8. Guest registrations must be accompanied by a regular professional or student registration. A guest is defined as a nongeologist spouse or friend of a professional or student registrant.

**CANCELLATIONS, CHANGES, REFUNDS**

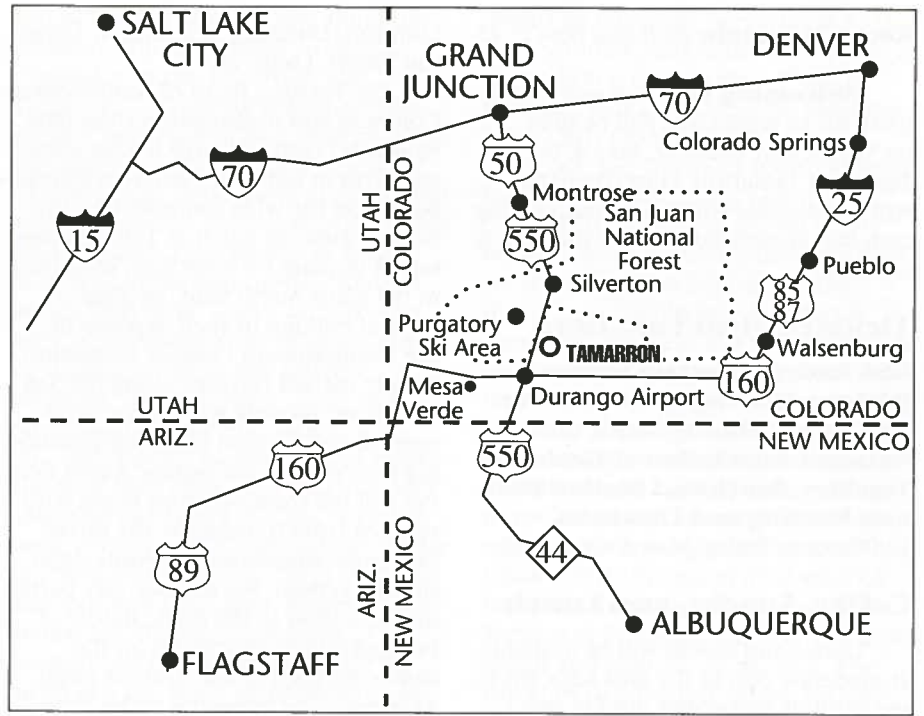
All requests for registration additions, changes, and cancellations must be made in writing (faxes accepted) and received at GSA headquarters by April 1, 1994. NO REFUNDS OR CREDITS WILL BE MADE ON CANCELLATION NOTICES RECEIVED AFTER THIS DATE. Refunds will be mailed from GSA after the meeting. Refunds for fees paid by credit card will be credited according to the card number on the preregistration form. NO refunds will be given for on-site registration and ticket sales.

**On-site Registration Schedule—Tamarron Resort**

Tues., May 3 4:00 p.m. to 8:00 p.m.  
Wed., May 4 7:30 a.m. to 5:00 p.m.  
Thur., May 5 7:30 a.m. to 5:00 p.m.  
Fri., May 6 7:30 a.m. to 12:00 noon

**REGISTRATION FEES**

	Advance (by 3/25/94)		On-site	
	Full	One day	Full	One day
Professional Member	\$40	\$20	\$50	\$25
Professional Nonmember	\$55	\$25	\$65	\$30
Student Member	\$15	\$10	\$20	\$15
Student Nonmember	\$20	\$15	\$30	\$20
Guest	\$10	N/A	\$10	N/A
Elementary and Secondary Teachers	\$10	N/A	\$10	N/A
Field Trip Nonregistrant	\$15	N/A	\$15	N/A



**DURANGO AND FOUR CORNERS AREA**

A message board and general information center will also be available in the registration area.

**ACCOMMODATIONS**

A block of rooms at the Tamarron Resort has been reserved for attendees. Special reduced rates of \$75 for deluxe guest rooms (accommodating up to three people) or \$115 for executive suites (up to four people) have been arranged; these rates are very competitive relative to other accommodations in the area. Tamarron is well equipped to serve the visitor. In addition to the conference facilities, the resort has a championship golf course, tennis courts, horseback riding, indoor/outdoor pool, health club, several shops, three restaurants, and a lounge. **Reservations can be made by calling the Tamarron Resort at 1-800-678-1000 or by sending the Tamarron Resort reservation form below.**

For other accommodations, call the Durango Area Chamber Resort Association at 1-800-525-8855.

**STUDENT HOUSING**

A limited number of rooms on the Fort Lewis College campus will be available to students, two persons to a room, at a rate of \$12 per person per night. Students must make reservations through Conferences and Institutes, Fort Lewis College, Durango CO 81301, (303) 247-7372. **Reservation deadline: April 1, 1994.**

**SPECIAL EVENTS**

Several special events are planned for the meeting. Tickets, for events requiring them, may be purchased on the preregistration form. If space is still available, they may also be purchased in the registration area at the meeting.

*Rocky Mountain continued on p. 46*

**TAMARRON RESORT HOUSING FORM**

**GSA Rocky Mountain Section Meeting  
May 4-6, 1994**

Please make a reservation for:

Name \_\_\_\_\_  
Address \_\_\_\_\_  
City \_\_\_\_\_ State \_\_\_\_\_ ZIP code \_\_\_\_\_  
No. of adults \_\_\_\_\_ Daytime Phone ( ) \_\_\_\_\_  
Arrival Date \_\_\_\_\_ Departure Date \_\_\_\_\_

Accommodations:  
Deluxe guest room  \$75 Executive suite  \$115

Room rates are subject to 6.9% Colorado state sales tax. Above rates also include a service charge, as Tamarron is a non-tipping resort. The charge covers all food and beverage service, which is subject to a 17% service charge and a 5% Colorado sales tax.

All reservation requests must be received by Tamarron no later than *March 21, 1994*. A deposit equal to the first night's room rate is required to guarantee reservations. All deposits apply to the last night's stay and are fully refundable if canceled within 14 days of arrival.

Please charge my credit card for a deposit to hold my room. Check one:

- American Express       Diners Club  
 MasterCard/VISA       Discover

Card Number \_\_\_\_\_ Expiration Date \_\_\_\_\_  
(Please send check under separate cover.) Exact room assignments cannot be guaranteed.

Will you be needing any special requirements during your stay? If yes, please list.

\_\_\_\_\_

Return to: Tamarron Resort, P.O. Drawer 3131, Durango, CO 81302-3131



**Welcoming Party.** A welcoming party for all registrants will be held on Wednesday evening, May 4, on the Terrace at Tamarron. Hors d'oeuvres will be available with an accompanying cash bar. Registration for the meeting is required.

### Ticketed Meal Functions

**GSA Rocky Mountain Section Business Meeting and Luncheon,** 12:00 noon, Thursday, May 5. Cost: \$15.  
**National Association of Geology Teachers, Southwest Section Business Meeting and Luncheon,** 12:00 noon, Friday, May 6. Cost: \$15.

### Coffee, Snacks, and Lunch

Coffee and snacks will be available at moderate cost in the area adjacent to the exhibits and poster display area. Tamarron houses several restaurants where lunch is available.

### FIELD TRIPS

Both premeeting and postmeeting field trips will be offered. Note also that a self-guided walking tour to examine the geology of the Tamarron area will be available during the meeting for those needing fresh air and a respite from sitting! Unless otherwise noted, all field trips will begin and end at Tamarron. For further details about the trips, please contact the field trip leader listed first in the trip description. General questions should be addressed to John A. Campbell, Department of Geology, Fort Lewis College, Durango CO 81301, (303) 247-7475.

Preregistration for all field trips is required. Participants will be accepted on a first-come, first-served basis through GSA headquarters.

**Preregistration deadline is March 25, 1994.**

The preregistration form is provided in this announcement. Participants preregistering for a field trip *only* must pay a \$15 nonregistrant fee in addition to the field trip charge.

The cancellation deadline is April 1, 1994. All cancellations must be in writing (faxes accepted); no refunds will be given if cancellation is received after this date. If GSA must cancel a trip, that cancellation will be announced by April 11, 1994. Full refunds will be issued after the meeting.

**Field Trip Guidebooks.** Field trip guidebooks containing articles and road logs for most of the field trips will be prepared for the meeting, and handouts will be available for other trips, including the self-guided walking tour of the geology of the Tamarron area. Guidebooks and handouts are included in the cost of all field trips. Copies will be sold at the meeting.

#### Premeeting

**1. High-resolution Sequence Stratigraphy of the Mixed Carbonate-Siliciclastic-Evaporite Depositional System Containing the Giant Aneth Oil Field, Paradox Basin, SE Utah.** Sunday, May 1, 8:00 a.m. through Tuesday, May 3, 5:00 p.m. A. Curtis Huffman, Jr., Branch of Sedimentary Processes, U.S. Geological Survey, M.S. 939, Box 25046, DFC, Denver, CO 80225, (303) 236-1543; and L. James Weber, J. F. (Rick) Sarg, and Frank M. Wright, Mobil Exploration and Producing Technology Center, Dallas.

Cost: \$230 (includes ground transportation, 2 night's lodging on trip and 1 night prior to trip, all based on double occupancy, raft trip, refreshments, and guidebook). Trip begins at the Red

Lion Inn, Durango, and ends at Tamar-  
ron Resort. Limit: 28.

The Paradox Basin of southwestern Colorado and southeastern Utah (late Paleozoic) contains large hydrocarbon resources in both the central evaporite basin and the wide southwestern carbonate shelf. As much as 1 billion barrels of in-place oil have been identified in the giant Aneth field, an algal mound buildup in shelf deposits of the Desmoinesian Paradox Formation. Deeply incised canyons along the San Juan River provide spectacular exposures of rocks lateral to the oil-producing reservoirs of the nearby Aneth field. We will use these outcrops along with selected cores to examine the mixed carbonate-siliciclastic-evaporite depositional system. We will also pay particular attention to the cyclic nature of Pennsylvanian deposition on the carbonate shelf of the Paradox basin. As many as 33 evaporite cycles have been defined in the central basin, and many are correlatable onto the shelf where there are no evaporites. Recent sequence stratigraphic analysis has proven very helpful in the recognition, interpretation, and correlation of these as well as other, higher order, sequences.

The principal goals of this trip are to show how outcrop and subsurface data are combined to develop a sequence stratigraphic framework for reservoir modeling within a regional depositional and tectonic setting. Such a model will be used to generate a series of maps that predict the distribution and quality of stratified carbonate reservoirs. Methods and concepts employed are applicable to exploration and production as well as basin analysis and the understanding of carbonate shelf depositional systems.

This trip will commence in Durango, Colorado, with a half day of lectures and core examination and then proceed west to Aneth for a tour of the field. On day two, we will raft down the San Juan River to observe lateral facies variability within the reservoir section. Day three will include a hike down Honaker Trail to look in detail at the vertical succession, compare lateral off-mound facies to the reservoir facies at Aneth, and extend the sequence stratigraphic framework.

Note: The field parts of this trip involve walking and climbing in rough terrain. Participants should be physically prepared for climbs and hikes that gain 300 to 1600 ft (100–500 m) elevation at 5000 to 6000 ft (1500–1800 m) altitude.

**2. Permian-Triassic Depositional Systems, Paleogeography, Paleoclimate, and Hydrocarbon Resources in Canyonlands, Utah.**

Four days, Saturday, April 30 through Tuesday, May 3; leave from the Super 8 Motel in Durango at 7:00 a.m. on April 30 (rooms are already booked for participants at the Super 8 for the night before the trip) and return to Durango May 3, in the evening. Russell F. Dubiel, Branch of Sedimentary Processes, U.S. Geological Survey, M.S. 939, Box 25046, DFC, Denver, CO 80225, (303) 236-1540; Jacqueline E. Huntoon, Michigan Technological University; John D. Stanesco, Red Rocks Community College and U.S. Geological Survey.

Cost: \$240 (includes transportation, 3 nights lodging on trip and 1 night prior to trip, all based on double occupancy, 4 lunches, refreshments, and guidebook; breakfasts and dinners not included). Limit: 12.

This four-day trip will examine Pennsylvanian to Jurassic strata in the Paradox basin on the Colorado Plateau in the spectacular scenery of the Canyonlands of Utah, and will focus

on Permian-Triassic stratigraphy, depositional systems, and paleogeography. We will follow depositional facies from distal marine facies within the Paradox basin to proximal continental settings near the ancestral Rocky Mountains, and the evolution of these systems from the late Paleozoic to the early Mesozoic, a key period in Pangaea for paleogeographic and paleoclimatic reconstructions. We will concentrate on unconformities and the effects of sea-level changes and salt diapirism, and integrate depositional sequences of red beds with paleoclimate interpretations and hydrocarbon resources.

From Pennsylvanian to Jurassic time, the Colorado Plateau in the western United States lay near the west coast of Pangaea, a critical location that records in the sedimentary record the effects of an evolving tropical monsoonal climate. The Colorado Plateau migrated northward from a location just south of the paleoequator in Pennsylvanian time to a position 20° north of the paleoequator in the Jurassic. The Paradox basin was formed in middle Pennsylvanian time and continued as a major site of deposition through the Permian, accumulating as much as 15,000 ft (5000 m) of Pennsylvanian and Permian evaporite, shale, limestone, and continental strata. Triassic and Jurassic sequences were dominated by fluvial, lacustrine, and eolian deposition. Laramide deformation produced the present structure, laccolithic intrusions, and volcanic plugs.

We will examine the structural, stratigraphic, and paleoclimatic evolution of the Paradox basin by following Pennsylvanian, Permian, and Triassic facies changes from the distal parts of the basin back toward the ancestral Rocky Mountains. Emphasis will be on regional facies changes, depositional systems, unconformities related to sea-level changes, and tar sand accumulations. Rocks examined in detail include the Permian Cutler Formation (Hal-  
gaito Shale, Cedar Mesa Sandstone, Organ Rock Shale, White Rim Sandstone, De Chelly Sandstone) and the Lower Triassic Moenkopi Formation. We will also examine Pennsylvanian rocks, the Upper Triassic Chinle Formation, and extensive Jurassic eolianites exposed in Canyonlands.

Participants can expect easy hiking and sunny and hot (90°F) to cool and rainy weather.

**3. Depositional History and Anasazi Occupation, Holocene of McElmo Canyon, Southwestern Colorado.** Sponsored by Archaeological Geology Division of GSA. One day, May 3; depart in vans from Tamarron at 7:30 a.m. and return about 5:00 p.m. Eric Force, U.S. Geological Survey, Tucson, Arizona, (602) 670-5506; Wayne Howell, Kelly Place, and Crow Canyon Archaeological Center staff, Cortez, Colorado.

Cost: \$30 (includes transportation, lunch, and handout). Limit: 36.

The Four Corners region is renowned for the density and richness of archaeological remains of the Anasazi culture (A.D. 100–1300). On this trip we will see excellent exposures of Holocene alluvial fill of McElmo Canyon, west of Cortez, Colorado, between Mesa Verde and Hovenweep. The deposits consist of channel, floodplain, and alluvial fan facies. Anasazi artifacts are used to date depositional packages and unconformities within this sequence; those artifacts include buried and surficial architectural features and ceramic assemblages ranging from Basketmaker III to Pueblo III in age. Feedbacks among depositional geomorphology, Anasazi agriculture, and occupation are emphasized.

Hiking on this trip is limited, but field attire is recommended. We will be as low as 5400 ft, where it may be warm.

#### Postmeeting

**4. Proterozoic Geology of the Western and Southeastern Needle Mountains.** Two days, Saturday, May 7, and Sunday, May 8; depart from Tamarron Resort at 7:30 a.m. and return about 6:00 p.m. each day. David A. Gonzales, Isotope Geochemical Laboratory, University of Kansas Center for Research, 2291 Irving Hill Dr., Campus West, Lawrence, KS 66045, (913) 864-7713; Clay M. Conway, U.S. Geological Survey; Jack A. Ellingson, Fort Lewis College.

Cost: \$54 (includes transportation, 2 lunches, and guidebook). Limit: 34.

This trip will highlight recent field and geochemical studies of Early to Middle Proterozoic rocks in the western and southeastern Needle Mountains. The evolution of concepts and controversies on the Precambrian events in this area will be addressed in light of new data and interpretations. Some of the current ideas are in conflict with old and recent work in the Needle Mountains, and resolution of these problems may have important implications for the Proterozoic evolution of the Southwest.

On the first day, participants will examine Early Proterozoic age metamorphosed and deformed basement rocks of the western Irving Formation and Twilight Gneiss, ca. 1.7 Ga Bakers Bridge Granite, and ca. 1.45 Ga Electra Lake Gabbro. Stops and discussions will focus on ideas that (1) the Irving Formation is a bimodal volcanic assemblage that is intruded by trondhjemitic-tonalitic-granodioritic rocks of the Twilight Gneiss; (2) numerous amphibolite layers in the Twilight are gabbroic sills that were emplaced during an extensional event prior to amphibolite facies regional metamorphism; and (3) the Electra Lake Gabbro was intruded during a tectonic event that was accompanied by brittle disruption of amphibolite layers and partial melting of trondhjemitic gneiss in the Twilight Gneiss. The second day of the trip will concentrate on the basement rocks of the eastern Irving Formation, fluvial siliciclastic rocks of the Vallecito Conglomerate, and ca. 1.45 Ga Eolus Granite. Principal objectives will be to show relations that are interpreted to indicate that the Irving Formation in this area is a volcanogenic suite that was metamorphosed and deformed prior to deposition of sedimentary rocks in the Vallecito. Features of the Eolus Granite and its contact with the Irving Formation will also be examined. Both trip days will involve hikes of between 2 and 4 miles in semi-rugged terrain; hiking attire, including a day pack to carry lunch and water, is recommended. We will be hiking at elevations of 7000–9000 ft, and participants should be prepared for all types of weather conditions.

**5. Upheaval Meteorite Impact Crater and Roberts Rift Natural Hydraulic Fracture.** Peter Huntoon, Dept. of Geology and Geophysics, University of Wyoming, Laramie, WY 82071, (307) 766-5316; H. Jay Melosh, University of Arizona. This trip will depart for Moab, Utah, Friday evening, May 6, at 7:00 p.m. from the Tamarron Resort, Durango, and will return to Durango the afternoon of May 8.

Cost: \$140 (includes transportation, 2 nights lodging, lunches, and handouts). Limit: 45.

This excursion will provide a thor-

Rocky Mountain continued on p. 47



ough examination of the Upheaval impact crater in the Island in the Sky District of Canyonlands National Park, Utah. Discussions will emphasize the stress indicators and morphologic form which reveal that the structure is of impact origin rather than being a salt dome. Parallel discussions will be held on impact cratering as a geologic process, with emphasis on the mechanics of cratering by Melosh, the world's foremost expert on impact cratering mechanics. The unsurpassed exposures in the crater allow for ready differentiation of the various classes of structures that accommodated opening of the transient crater during the excavation stage and others that were superimposed during the gravity-driven modification stage as the crater collapsed and the floor rebounded. Upheaval crater is a deeply eroded complex crater with a prominent central peak. The preserved deformed zone is about 5 km in diameter with a prominent central peak that stands in sharp relief. The ring structures are beautifully exposed in plan and profile. Rocks as low as the uppermost Permian Cutler Group crop out on the central peak, whereas the Triassic-Jurassic Navajo Sandstone is preserved in a well-exposed surrounding ring syncline. Interested participants can hike to the crater floor (10 miles round trip); the rest will tour the surrounding salt anticline geology, including a Texasgulf potash solution mine. Hikers require 2 liters of water and hiking boots.

On May 8 we will visit Roberts rift, a curious breccia- and sand-filled natural hydraulic fracture that crops out between 22 and 27 km to the northeast of Upheaval crater on a subradial orientation. The breccias comprise upwardly transported clasts, some of which were derived from the underlying Pennsylvanian Honaker Trail Formation about 1000 m below. The spatial proximity of the rift and crater, as well as the approximately radial orientation of the rift relative to the crater, hints of a mechanical linkage between the two. One primary incentive for attempting to forge this linkage is that the Upheaval impact is the only known energy source available in the region which could have accounted for development of the rift.

**6. Late Paleogene Geology and Paleoenvironments of Central Colorado.** Two and one-half days, Friday, May 6, through Sunday, May 8; Depart from the Tamarron Resort at 1:00 p.m. Friday, and return to Durango Sunday evening. Emmett Evanoff, University of Colorado Museum, Boulder, CO 80309, (303) 492-8069; Kathryn Gregory, Lamont Doherty Geological Observatory; Daniel Larsen, University of New Mexico.

Cost: \$155 (includes transportation, 2 lunches, 2 nights lodging, and guidebook). Limit: 25.

This trip focuses on the late Eocene to Oligocene geological history of central Colorado, with emphasis on the record in and near Florissant Fossil Beds National Monument. For much of the trip we will examine the detailed stratigraphy and sedimentology of the Florissant paleovalley sequence. The regional setting will also be stressed, with stops in the early volcanics of the San Juan Mountains, the large volcanic rock-filled paleovalleys of the southern Mosquito Range, and the Thirtynine Mile volcanic field. The last stops will be in the Creede caldera to examine the geologic setting and sedimentology of the fossiliferous lake shales. This trip will not be a fossil-collecting trip but

will be an opportunity to see the geologic settings of two important late Paleogene biotas. There will be ample opportunity to discuss the pros and cons of new paleoenvironmental, paleogeographic, and tectonic interpretations of the region. This field trip will accompany the symposium "Volcanoes, Sequoias, and Tsetse Flies: Geology and Paleontology of the Florissant Area," to be held on May 5.

**7. Overview of the Stratigraphy, Structure, and Ore Deposits of the Ouray (Uncompahgre) Mining District, Colorado.** One day, Saturday, May 7; depart by van Saturday from Tamarron at 7:30 a.m., and return around 6:00 p.m. Tom Westervelt, Dept. of Geology, Fort Lewis College, Durango, CO 81301, (303) 247-7463; and John Trujillo, consulting mine geologist.

Cost: \$65 (includes transportation and guidebook; lunch available in Ouray at own expense). Limit: 22.

Participants will be treated to an incredible diversity of geology spectacularly exposed in cliffs above Ouray

and in Uncompahgre gorge along the "Million Dollar Highway" (US 550). Highlights of this excursion will include (1) complexly deformed and variably metamorphosed quartzites and metapelites of the Middle Proterozoic Uncompahgre Formation; (2) structural and stratigraphic evidence for ancestral Rockies uplift; (3) a variety of subtle to profound unconformities, some of which span more than a billion years, such as the much-photographed angular unconformity at Box Canyon; (4) distal "Silverton-type" base- and precious-metal mineralization; and (5) "Ouray-type" precious-metal mineralization both distal and proximal to a Laramide laccolithic pluton. Access to some exposures and view points will be provided by open jeep and at least one underground mine tour. A general geological and historical overview of the western San Juan Mountains will be given at a few select stops en route to "the Little Switzerland of America."

**8. Geology and Geomorphology of the Animas Valley, Durango to Silverton.** One day, Saturday, May 7;

depart by bus from Tamarron at 8:00 a.m. Saturday, and return that evening about 6:00 p.m. Rob Blair, Dept. of Geology, Fort Lewis College, Durango, CO 81301, (303) 247-7263.

Cost: \$55 (includes transportation, lunch, and guidebook). Limit: 40.

This trip involves several short walks (5 to 15 minutes), during which we will see a local landslide, karst (bring your flashlight), and glacial moraines. The field trip will begin near Durango and will proceed up the Animas Valley, where we will examine the effects of glaciation on the morphology of the valley, recent history of the Animas River, and local hydrology. Stops near Coal Bank Pass and Molas Pass will review recent glacial erosional history. The trip passes through rock formations that span from the early Tertiary to Precambrian; only the Ordovician and Silurian are missing. The trip ends in Silverton, where we can view the interior of the Silverton caldera.

Rocky Mountain continued on p. 48

## Preregistration Form GSA Rocky Mountain Section

Preregistration deadline is March 25, 1994. Cancellation deadline is April 1, 1994. Durango, Colorado • May 4-6, 1994

**Please print clearly • THIS AREA IS FOR YOUR BADGE**

Name as it should appear on your badge (last name first) \_\_\_\_\_

Employer/University Affiliation \_\_\_\_\_

City \_\_\_\_\_ State or Country \_\_\_\_\_

Mailing Address (use two lines if necessary) \_\_\_\_\_

City \_\_\_\_\_ State \_\_\_\_\_ ZIP Code \_\_\_\_\_ Country (if other than USA) \_\_\_\_\_

Business Phone \_\_\_\_\_

fax \_\_\_\_\_

Home Phone \_\_\_\_\_

Please indicate if you or your guest will need services to accommodate a disability:  
 Yes  No

Circle member affiliation (to qualify for registration member discount\*): (A) GSA (B) PS (C) NAGT

Personal Profile (optional). Please check all that apply. Age:  18-24  25-34  35-44  55-65  Over 65  
 Female  Male

Employed as: (1)  Prof./Asst. Prof. (2)  Govt. Geologist (3)  Manager/Admin. (4)  Teacher/Instructor (5)  Corporate Geologist  
 (6)  Consultant (7)  Retired (8)  Self-Employed (9)  Other

**GUEST INFORMATION • Please print clearly • This area is for badge**

Name as it should appear on your guest's badge \_\_\_\_\_

City/State or Country \_\_\_\_\_

PREREGISTRATION	Full Meeting	One Day	Qty	Amount
Professional Member* .....	( 01) \$40 <input type="checkbox"/>	( 02) \$20 <input type="checkbox"/>	1	\$ _____
Professional Nonmember .....	( 03) \$55 <input type="checkbox"/>	( 04) \$25 <input type="checkbox"/>	1	\$ _____
Student Member* .....	( 05) \$15 <input type="checkbox"/>	( 06) \$10 <input type="checkbox"/>	1	\$ _____
Student Nonmember .....	( 07) \$20 <input type="checkbox"/>	( 08) \$15 <input type="checkbox"/>	1	\$ _____
Guest .....	( 09) \$10 <input type="checkbox"/>	N/A	_____	\$ _____
K-12 Earth Science Teacher .....	( 42) \$10 <input type="checkbox"/>	N/A	1	\$ _____
Field Trip Nonregistration Fee .....	( 98) \$15 <input type="checkbox"/>	N/A	1	\$ _____

\*Member fee applies to any current professional OR Student Member of GSA or Associated Societies listed above. Discount does not apply to guest registrants.

**TICKETED MEAL FUNCTIONS**

GSA Rocky Mountain Section Business Meeting and Luncheon .....	May 5	( 60) \$15	_____	\$ _____
NAGT Southwest Section Business Meeting and Luncheon .....	May 6	( 61) \$15	_____	\$ _____

**FIELD TRIPS**

1. Sequence Stratigraphy, Paradox Basin, SE Utah .....	May 1-3	(100) \$230	1	\$ _____
2. Permian-Triassic Depositional Systems, Canyonlands, Utah .....	April 30-May 3	(101) \$240	1	\$ _____
3. Depositional History and Anasazi Occupation, McElmo Canyon .....	May 3	(102) \$ 30	1	\$ _____
4. Proterozoic Geology, Needle Mountains .....	May 7-8	(103) \$ 54	1	\$ _____
5. Upheaval Meteorite Impact Crater .....	May 6-8	(104) \$140	1	\$ _____
6. Late Paleogene Geology, Central Colorado .....	May 6-8	(105) \$155	1	\$ _____
7. Stratigraphy, Structure, Ore Deposits; Ouray Mining District .....	May 7	(106) \$ 65	1	\$ _____
8. Geology and Geomorphology, Animas Valley .....	May 7	(107) \$ 55	1	\$ _____
9. Geology of Animas River—Durango-Silverton Narrow Gauge Railroad .....	May 7	(108) \$ 50	1	\$ _____

**TOTAL FEES** ..... \$ \_\_\_\_\_

Remit in U.S. funds payable to: 1994 GSA Rocky Mountain Section Meeting  
 (All preregistrations must be prepaid. Purchase Orders not accepted.)

Payment by (check one):  Check  American Express  VISA  MasterCard

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**MAIL TO: GSA Rocky Mountain Section Meeting, P.O. Box 9140, Boulder, CO 80301**



## GSA Penrose Conferences

### March 1994

**From the Inside and the Outside: Interdisciplinary Perspectives on the History of Earth Sciences**, March 19–21, 1994, San Diego, California. Information: Léo F. Laporte, Dept. of Earth Sciences, University of California, Santa Cruz, CA 95064, (408) 459-2248, fax 408-459-3074; Naomi Oreskes, Dept. of Earth Sciences, Dartmouth College, Hanover, NH 03755, (603) 646-1420, fax 603-646-3922; Kenneth L. Taylor, Dept. of History of Science, University of Oklahoma, Norman, OK 73019-0315, (405) 325-2213, fax 405-325-2363.

### April 1994

**Triple Junction Interactions at Plate Margins**, April 21–26, 1994, Eureka, California. Information: Virginia B. Sisson, Dept. of Geology and Geophysics, Rice University, P.O. Box 1892, Houston, TX 77251-1892, (713) 285-5234; Terry L. Pavlis, Dept. of Geology and Geophysics, University of New Orleans, New Orleans, LA 70148, (504) 286-6797; David J. Prior, Dept. of Earth Sciences, University of Liverpool, P.O. Box 147, Liverpool L69 3BX, UK.

### June 1994

**Fractured Unlithified Aquitards: Origins and Transport Processes**, June 15–20, 1994, Racine, Wisconsin. Information: John A. Cherry, Waterloo

Centre for Groundwater Research, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada, (519) 885-1211, ext. 2892, fax 519-746-5644; David M. Mickelson, Dept. of Geology and Geophysics, University of Wisconsin, 1215 W. Dayton St., Madison, WI 53706, (608) 262-7863, fax 608-262-0693; William W. Simpkins, Dept. of Geological and Atmospheric Sciences, 253 Science I, Iowa State University of Science and Technology, Ames, IA 50011, (515) 294-7814, fax 515-294-6049.

## 1994 Meetings

### February

**Geological Society of Australia Field Conference**, Deformation Processes in the Earth, February 6–11, 1994, Jindabyne, New South Wales, Australia. Information: Stephen Cox, RSES, ANU, Canberra, ACT 0200, Australia, phone 61 6 249 4076, fax 61 6 249 0738, E-mail: jdf152@cscgpo.anu.edu.au.

**New Developments Regarding the K/T Event and Other Catastrophes in Earth History**, February 9–12, 1994, Houston, Texas. Logistical information: Litta Holley, Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058-1113, (713) 486-2149, fax 713-486-2160, E-mail (Internet): holley@lpi.jsc.nasa.gov.; Technical information: Graham Ryder, Lunar and Plane-

tary Institute, 3600 Bay Area Blvd., Houston, TX 77058, (713) 486-2141, fax 713-486-2162, E-mail (Internet): zryder@lpi.jsc.nasa.gov.

**Breakthroughs in Karst Geomicrobiology and Redox Geochemistry**, February 16–19, 1994, Colorado Springs, Colorado. Information: Arthur Palmer, Earth Sciences Dept., SUNY, Oneonta, NY 13820-4015, (607) 436-3064, fax 607-436-2107.

**American Association for the Advancement of Science Annual Meeting**, February 18–23, 1994, San Francisco, California. Information: AAAS Meeting Office, 1333 H St. NW, Washington, DC 20005, (202) 326-6450, fax 202-289-4021.

**13th Annual Symposium on Caribbean Geology**, "Impact" of Geology on Global Climate, February 23–27, 1994, Puerto Rico. Information: Lewis Abrams, Dept. of Geology, University of Puerto Rico, P.O. Box 5000, Mayagüez, PR 00681-5000, (809) 832-4040, ext. 3845, fax 809-265-3845.

**U.S. Geological Survey, 9th V. E. McKelvey Forum on Mineral Resources**, February 22–25, 1994, Tucson, Arizona. Information: Warren C. Day, U.S. Geological Survey, Box 25046, MS 905, Federal Center, Denver, CO 80025, (303) 236-5568, fax 303-236-5603.

### March

**International Convention on Global Exploration and Development**, March 6–9, 1994, Toronto, Ontario, Canada. Information: Rita Plaskett, Convention Manager, Suite 1002, 74 Victoria Street, Toronto, Ontario M5C 2A5, Canada, (416) 362-1969, fax 416-362-0101.

**Lunar and Planetary Science 25th Annual Conference**, March 14–18, 1994, Houston, Texas. Information: 25th LPSC, Publications and Program Services Dept., Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058-1113, (713) 486-2166, fax 713-486-2160.

**Geology and Exploration and Development Potential of Energy and Mineral Resources of Vietnam and Adjoining Regions**, March 14–17, 1994, Hanoi, Vietnam. Information: Mary Stewart, 5100 Westheimer, Suite 500, Houston, TX 77056, (713) 622-1130, fax 713-622-5360.

**10th Mining and Geothermal Institute**, March 17–18, 1994, Reno, Nevada. Information: American Association of Professional Landmen, 4100 Fossil Creek Blvd., Fort Worth, TX 76137, (817) 847-7700.

**GSA South-Central Section Meeting**, March 21–22, 1994, Little Rock, Arkansas. Information: Philip L. Kehler, Dept. of

**Rocky Mountain** continued from p. 47

**9. Geology of the Animas River—Durango to Silverton via the Durango and Silverton Narrow Gauge Railroad**. Saturday, May 7; the train leaves Durango at 8:30 a.m. and returns about 6:00 p.m. John A. Campbell, Dept. of Geology, Fort Lewis College, Durango, CO 81301, (303) 247-7475.

Cost: \$50 (includes round-trip transportation and guidebook; lunch in Silverton not included). No limit.

The guidebook provided is keyed to the mile posts along the route. The return trip to Durango via bus, rather than train, can be arranged if enough people are interested. This is a great trip for all, especially train buffs!

## SYMPOSIA

Scheduled symposia and their conveners are:

**1. Volcanoes, Sequoias, and Tsetse Flies: Geology and Paleontology of the Florissant Area**. Emmett Evanoff and Kathryn Gregory, Campus Box 315, University of Colorado Museum, Boulder, CO 80309-0315, (303) 492-8069, fax 303-492-5105.

**2. Use of Soils in Rocky Mountain Geology**. Peter Birkeland and Ralph Shroba, Dept. of Geological Sciences, Campus Box 250, University of Colorado, Boulder, CO 80309, (303) 492-6985, fax 303-492-2606.

**3. Geology of the Paradox Basin**. A. Curtis Huffman, Jr., Karen Franczyk, and George Breit, U.S. Geological Survey, M.S. 939, Box 25046, DFC, Denver, CO 80225, (303) 236-1543, fax 303-236-0459.

**4. Boundaries and Provinces in the Proterozoic of the Southwestern United States**. A symposium in honor of Leon T. Silver, for his contributions to our understanding of the Precambrian of the Southwest. Clay Conway, U.S. Geological Survey, 2255

N. Gemini Drive, M.S. 9320, Flagstaff, AZ 86001, (602) 556-7199, fax 602-556-7169.

**5. Geology of the Gunnison, Colorado Country**. Richard Mauger, Dept. of Geology, East Carolina University, Greenville, NC 27858, (919) 757-6016.

**6. Coal Bed Methane and the Creaceous Geology of the Four Corners Area**. Dale Nations, Dept. of Geology, Box 4099, Northern Arizona University, Flagstaff, AZ 86011, (602) 523-7180, fax 602-523-9975.

**7. Hydrogeology of the San Luis Valley, Colorado**. Alan Mayo, Dept. of Geology, Brigham Young University, Provo, UT 84602, (801) 378-2338.

**8. National Park Service Paleontological Research Symposium**. Vincent Santucci, 833 Malvern Rd., Pittsburgh, PA 15202, (412) 766-6207.

**9. Earth Science Contributions to Water Resource Decision-Making in the Southwest**. Jack Schmidt, Dept. of Geography and Earth Resources, College of Natural Resources, Utah State University, Logan, UT 84322, (801) 750-1791, fax 801-750-4048.

**10. Innovative Geoscience Education, K–16**. Steve Semken, P.O. Box 580, Navajo Community College—Shiprock, Navajo Nation (New Mexico) 87420, (505) 368-5291, fax 505-368-4993.

## POSTER SESSIONS

Poster sessions will be located adjacent to the exhibits area. Each poster booth will provide three 4 ft by 8 ft surfaces. Posters will be available for viewing for one-half day.

In addition to the normal poster sessions, two special poster sessions will be presented.

**1. Undergraduate Research**. Sponsored by the Council on Undergraduate Research. The papers are to be written and presented by undergraduate stu-

dents. Coauthored papers for which the student is senior author will also be considered. Undergraduate students who have been involved in research are strongly urged to submit abstracts on their research projects, activities, techniques, and/or preliminary results for this session. Abstracts for this session should be sent by *April 1, 1994*, to Robert D. Shuster, Dept. of Geography and Geology, University of Nebraska, Omaha, NE 68182. Additional information can be obtained by contacting Shuster at (402) 554-2457, fax 402-554-3518.

**2. Map Fair Poster Session**. This informal poster session, for which *no abstract is required*, will be held after hours, from 4:00 to 5:30 p.m. on Wednesday and Thursday, for anyone wishing to display and discuss their work in the Rockies. Appropriate refreshments will be available to help promote lively discussions.

## SPECIAL EVENTS FOR EARTH SCIENCE EDUCATORS

Two events—Symposium 10, "Innovative Geoscience Education—K–16" and field trip 8, "Geology and Geomorphology of the Animas Valley, Durango to Silverton" (both described above), have been designed for teachers (K–16) and interested professionals. For further information, contact the individuals listed in the descriptions of these events.

## PROJECTION EQUIPMENT

All slides must be 2" by 2" and fit standard carousel trays. Two projectors and two screens will be available for all oral sessions. If possible, speakers should bring their own loaded carousel trays identified with their name, session, and speaker number. A speaker ready room equipped with projectors will be available for review and practice.

## EXHIBITS AND VENDORS

Exhibits will be located in the Silverton Center, adjacent to the poster session area. For further information and space reservations, contact Robert W. Blair, Jr., Dept. of Geology, Fort Lewis College, Durango, CO 81301, (303) 247-7263.

## STUDENT SUPPORT

The GSA Rocky Mountain Section has funds available for grants to support GSA Student Associates of the section who are presenting papers at the meeting. Students are strongly encouraged to apply for these grants; we anticipate that most students who qualify will be funded to some degree. Applications for grants should be sent to the Rocky Mountain Section Secretary, Kenneth E. Kolm, Dept. of Geology and Geological Engineering, Colorado School of Mines, Golden, CO 80401, (303) 273-3932. Applications should certify that the student is presenting a paper and is a GSA Student Associate of the Rocky Mountain Section. All letters must be received by *April 1, 1994*.

## GUEST PROGRAM

Tours of archaeological sites in the region, including Mesa Verde, Chimney Rock, and Aztec ruins, can be arranged if there is sufficient interest. For further information, check at the general information center in the registration area.

## GENERAL INFORMATION

Inquiries, additional information, special requests, and suggestions should be addressed to the meeting chairman, Douglas C. Brew, Dept. of Geology, Fort Lewis College, Durango, CO 81301, (303) 247-7254, fax 303-247-7660. ■



Earth Sciences, University of Arkansas, 2801 S. University Ave., Little Rock, AR 72204, (501) 569-3546, fax 501-569-8020.

**GSA Cordilleran Section Meeting**, March 21-23, 1994, San Bernardino, California. Information: Joan Fryxell, Dept. of Geological Sciences, California State University, 5500 University Parkway, San Bernardino, CA 92407-2397, (909) 880-5311, fax 909-880-7005.

■ **Second International Conference on Ground Water Ecology**, March 27-30, 1994, Atlanta, Georgia. Information: American Water Resources Association, 5410 Grosvenor Lane, Suite 220, Bethesda, MD 20814-2192, (301) 493-8600, fax 301-493-5844.

**Seventh Annual Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP)**, March 27-31, 1994, Boston, Massachusetts. Information: EEGS, Mark Cramer, P.O. Box 4475, Englewood, CO 80112, (303) 771-6101.

**GSA Northeastern Section Meeting**, March 28-30, 1994, Binghamton, New York. Information: H. Richard Naslund, Dept. of Geological Sciences, SUNY, Binghamton, NY 13902-6000, (607) 777-4313, fax 607-777-2288.

**Contaminated Soils and Ground Water**, Fifth Annual Association for the Environmental Health of Soils West Coast Conference, March 28-April 1, 1994, Long Beach, California. Information: Mary K. Terry, Association for the Environmental Health of Soils, 150 Fearing St., Suite 20, Amherst, MA 01002, (413) 549-5170, fax 413-549-0579.

**Simpson and Viola Groups in the Southern Midcontinent**, March 29-30, 1994, Norman, Oklahoma. Information: Kenneth S. Johnson, Oklahoma Geological Survey, 100 E. Boyd, Rm. N-131, Norman, OK 73019, (405) 325-3013.

**April**  
**GSA Southeastern Section Meeting**, April 7-8, 1994, Blacksburg, Virginia. Information: Lynn Glover, III, and Robert J. Tracy, Dept. of Geological Sciences, Virginia Tech, Blacksburg, VA 24061-0420, Glover's direct (703) 231-6213, fax 703-231-3886, Tracy's direct (703) 231-5980.

**Toxic Substances and the Hydro-logic Sciences**, April 10-13, 1994, Austin, Texas. Information: American Institute of Hydrology, 3416 University Ave. S.E., Minneapolis, MN 55414-3328, (612) 379-1030, fax 612-379-0169.

**Transport and Reactive Processes in Aquifers IAHR Symposium**, April 11-15, 1994, ETH-Zürich, Switzerland. Information: Th. Dracos or F. Stauffer, Institute of Hydromechanics and Water Resources Management (IHW), ETH-Hönggerberg, CH-8093 Zürich, Switzerland, phone 41-1-377 30 66 or 41-1-377 30 79, fax 41-1-371 22 83.

**Mid-America Paleontology Society National Fossil Exposition: Dinosaurs**, April 15-17, 1994, Macomb, Illinois. Information: Marvin Houg, 3330 44th St. NE, Cedar Rapids, IA 52402, (319) 395-0577, or Karl A. Stuekerjuergen, RR1, Box 285, West Point, IA 52656, (319) 837-6690.

**Extractive Industry Geology**, April 17-20, 1994, Sheffield, England. Information: Conference Office, Institution of Mining and Metallurgy,

44 Portland Place, London W1N 4BR, England, phone 44-71-580-3802, fax 44-71-436-5388.

**AAPG Hedberg Research Conference, Near-Surface Expressions of Hydrocarbon Migration**, April 24-27, 1994, Vancouver, British Columbia, Canada. Information: AAPG Continuing Education Department, P.O. Box 979, Tulsa, OK 74101, (918) 584-2555, fax 918-584-0469.

**European Association of Science Editors 5th General Assembly and Conference**, April 24-28, 1994, Budapest, Hungary. Information: EASE Secretariat, 49 Rosendale Way, London, NW1 0XB, UK, phone 44-71-388 9668, fax 44-71-383 3092.

**Petroleum Source Rocks: Formation, Diagenesis, and Expulsion**, April 25-29, 1994, Calgary, Alberta, Canada. Information: Han Wielens, Unocal Canada Exploration Ltd., Box 2120, Calgary, Alberta, Canada T2P 2M4, (403) 268-0370, fax 403-268-0101; Marc Bustin, Dept. of Geological Sciences, University of British Columbia, Vancouver, B.C., Canada V6T 1Z4, (604) 822-6179, fax 604-822-6088; or Steve Calvert, Dept. of Oceanography, University of British Columbia, Vancouver, B.C., Canada V6T 1Z4, (604) 822-5210, fax 604-822-6091.

■ **European Geophysical Society XIXth General Assembly**, April 25-29, 1994, Grenoble, France. Information: EGS 94, c/o LGGE BP 96, 38402 St. Martin D'Herès Cedex, France, phone 33-76-82 42 78, fax 33-76 82 42 01, E-mail: egs94@glaciog.grenet.fr.

**International Land Reclamation and Mine Drainage Conference, and Third International Conference on the Abatement of Acidic Drainage**, April 25-29, 1994, Pittsburgh, Pennsylvania. Information: D. Lowanse, U.S. Bureau of Mines, P.O. Box 18070, Pittsburgh, PA 15236, (412) 892-6708, fax 412-892-4067.

**GSA North-Central Section Meeting**, April 28-29, 1994, Kalamazoo, Michigan. Information: Alan Kehew, Dept. of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5495, fax 616-387-5513.

**May**  
**GSA Rocky Mountain Section Meeting**, May 4-6, 1994, Durango, Colorado. Information: Douglas Brew, Geology Dept., Ft. Lewis College, Durango, CO 81301, (303) 247-7254, fax 303-247-7310.

**Geologic Remote Sensing Tenth Thematic Conference**, May 9-12, 1994, San Antonio, Texas. Information: ERIM/Thematic Conferences, P.O. Box 134001, Ann Arbor, MI 48113-4001, (313) 994-1200, ext. 3234, fax 313-994-5123, Internet: wallman@vaxb.erim.org.

**Midwest Friends of the Pleistocene Annual Meeting**, May 13-15, 1994, Cincinnati, Ohio. Information: Tom Lowell, Dept. of Geology, University of Cincinnati, Cincinnati, OH 45226, (513) 556-4165, E-mail: Lowelltv@ucbeh.san.-uc.edu; or Scott Brockman, Division of Geological Survey, Ohio Department of Natural Resources, Columbus, OH 43224, (614) 265-6604.

**Geological Association of Canada and Mineralogical Association of**

**Canada Annual Meeting**, May 15-18, 1994, Waterloo, Ontario, Canada. Information: Alan V. Morgan, Dept. of Earth Sciences, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada, (519) 885-1211, ext. 3231, fax 519-746-7484.

■ **Pan-American Current Research on Fluid Inclusions (PACROFI V)**, May 19-21, 1994, Curenavaca, Morelos, Mexico. Information: David A. Vanko, Dept. of Geology, Georgia State University, Atlanta, GA 30303, fax 404-651-1376, E-mail: geodav@gsusgi1.gsu.edu. (Abstract deadline: February 14, 1994.)

**National Association of Geology Teachers, Eastern Section Annual Meeting**, May 20-22, 1994, Nyack, New York. Information: Michael J. Passow, 296 Central Ave., Englewood, NJ 07631, (201) 871-0846.

**High-Level Radioactive Waste Management International Conference**, May 22-26, 1994, Las Vegas, Nevada. Information: Tom Sanders, Attn: Transactions Office, American Nuclear Society, 555 N. Kensington Avenue, La Grange Park, IL 60525.

**Glacial Cycles at High Latitudes**, May 29-June 1, 1994, Fjærland, Norway. Information: Berit H. Barkley, Dept. of Geology, P.O. Box 1047 Blindern, 0316 Oslo, Norway, 47-22-856691, fax 47-22-854215.

**June**  
**1st North American Rock Mechanics Symposium**, June 1-3, 1994, Austin, Texas. Information: NARM Symposium, Continuing Engineering Studies, Cockrell Hall 10.324, University of Texas, Austin, TX 78712; or Priscilla Nelson, (512) 471-5664; or Stephen Laubach, fax 512-471-0140.

**Geochronology, Cosmochronology, and Isotope Geology Eighth International Conference (ICOG-8)**, June 5-11, 1994, Berkeley, California. Information: Garniss H. Curtis, Institute of Human Origins-Geochronology Center, 2453 Ridge Road, Berkeley, CA 94709, (510) 845-4003, fax 510-845-9453.

**Fifth International Conference on Ground Penetrating Radar**, June 12-16, 1994, Kitchener, Ontario, Canada. Information: GPR '94, Waterloo Centre for Groundwater Research, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada, (519) 885-1211, ext. 2892, fax 519-725-8720.

■ **Seventh International Symposium on the Ordovician System**, June 12-16, 1995, Las Vegas, Nevada. Information: Margaret N. Rees, 7th ISOS, Dept. of Geoscience, University of Nevada, Las Vegas, NV 89154-4010, (702) 739-3890, fax 702-597-4064, E-mail: Rees@Nevada.edu.

**First International Symposium on Protection and Development of Mountain Environment**, June 20-24, 1994, Ponte di Legno, Italy. Information: Man & Mountain '94, c/o Valdepur Service s.r.l., via Seradello 225, 25068 Serezzo (BS), Italy.

■ **Western Society of Malacologists 27th Annual Meeting**, June 26-30, 1994, Santa Barbara, California. Information: Henry W. Chaney, Santa Barbara Museum of Natural History, 2559 Puesta del Sol Rd., Santa Barbara, CA 93105, (805) 682-4711, ext. 334, fax 805-569-3170.

## United States Geological Survey 9th U.E. McKelvey Forum

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### Featuring:

- ▼ Environmental studies related to mineral resources
- ▼ Geology and mineral-deposit studies of the southwestern United States and Latin America
- ▼ Land-use planning and mineral-resource assessments of federal lands
- ▼ Field Trips

### For information contact:

U.S. Geological Survey, Attn: McKelvey Forum, Federal Center, Mail Stop 905, P.O. Box 25046, Denver, CO 80225-0046 (303) 236-5568; Fax: (303) 236-5603

### July

**FORAMS '94: International Symposium on Foraminifera**, July 5-9, 1994, Berkeley, California. Information: FORAMS '94, Museum of Paleontology, University of California, Berkeley, CA 94720, (510) 642-1821, fax 510-642-1822.

**Earthquake Engineering Fifth U.S. National Conference**, July 10-14, 1994, Chicago, Illinois. Information: Claudia Cook, Newmark Civil Engineering Laboratory, University of Illinois, 205 N. Mathews, Urbana, IL 61801-2397, (217) 333-0498.

**Geological Indicators of Rapid Change, International Workshop**, July 11-18, 1994, Corner Brook, Newfoundland. Information: A. R. Berger, Chairman, Geo-Indicators Working Group, 528 Paradise St., Victoria, BC V9A 5E2, Canada, (604) 480-0480, fax 604-480-0480.

**Basement Tectonics 11th International Conference**, July 25-29, 1994, Potsdam, Germany. Information: Onno Oncken, Conference Chairman, Geo-Forschungs Zentrum, Telegrafenberg, D-0-1561 Potsdam, Germany, phone 49-331-310601, fax 49-331-310306. (Abstract deadline: March 1, 1994.)

**Society for Industrial and Applied Mathematics Annual Meeting**, July 25-29, 1994, San Diego, California. Information: SIAM Conference Coordinator, 3600 University City Science Center, Philadelphia, PA 19104-2688, (215) 382-9800, fax 215-386-7999, E-mail: meetings@siam.org.

### August

■ **Clay Minerals Society 31st Annual Meeting**, August 13-18, 1994, Saskatoon, Saskatchewan, Canada. Information: Ahmet R. Mermut, Dept. of Soil Science, Saskatchewan Institute of Pedology, University of Saskatchewan, Saskatoon S7N 0W0, Canada, (306) 966-6839, fax 306-966-6881, E-mail: mermut@sask.usask.ca.

**West Australian Basins Symposium**, August 14-17, 1994, Perth, Australia. Information: Petroleum Exploration Society Australia, Attn.: J. B. O'Reilly/N. K. Guppy, P.O. Box 1102, West Perth, W.A. 6872, Australia, phone 61-9-481-6666, fax 61-9-481-1952.

**The South Atlantic: Present and Past Circulation**, August 15-18, 1994, Bremen, Germany. Information: South

Meetings continued on p. 50





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**EXPERIENCE** Must use specialty codes listed below.  
Choose three that best describe your expertise in order of importance.  
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**PRESENT SPECIALTY**  
Choose one from codes listed below \_\_\_\_\_  
**YEARS EXPERIENCE IN THIS SPECIALTY** \_\_\_\_\_

**PRESENT EMPLOYER** \_\_\_\_\_

**TYPE OF POSITION DESIRED** (Check as many boxes as apply.)  
Interested in:  Academic  Government  Industry  Other  
Specific interest:  Administration  Exploration/Production  Field  Research  Teaching  
Will accept employment in:  U.S. only  U.S. with foreign assignments  Either

**GIVE NUMBER OF YEARS EXPERIENCE FOR ANY OF THE FOLLOWING THAT ARE APPLICABLE**  
Administrative \_\_\_\_\_ Exploration/Production \_\_\_\_\_ Field \_\_\_\_\_ Research \_\_\_\_\_ Teaching \_\_\_\_\_ Total geological experience \_\_\_\_\_

**KNOWLEDGE OF FOREIGN LANGUAGES:**  French  German  Russian  Spanish  Other \_\_\_\_\_

**ACADEMIC TRAINING**

College or University	Degree (rec'd or expected)	Year	Major	Minor

Postgraduate work beyond highest degree in (field) \_\_\_\_\_ Number of years \_\_\_\_\_

**SPECIALTY CODES** Select those that best describe your ability. Use codes in bold face only when other breakdowns are inadequate.

<b>100 Economic Geology</b>	223 low temperature	<b>350 Mathematical Geology</b>	454 paleobotany	<b>620 Remote Sensing</b>
101 coal geology	224 stable isotopes	351 computer science	455 paleoecology	621 photogeology
102 geothermal, etc.	225 geochronology	352 statistical geology	<b>500 Petroleum Geology</b>	622 photogrammetry
103 metallic deposits	<b>250 Geomorphology</b>	<b>400 Mineralogy</b>	501 exploration	<b>630 Science Editing</b>
104 nonmetallic deposits	<b>300 Geophysics</b>	401 crystallography	502 subsurface strat.	<b>650 Sedimentology</b>
105 mining geology	301 seismic	402 clay mineralogy	<b>520 Petrology</b>	651 sed. processes
<b>120 Engineering Geology</b>	302 gravity/magnetics	<b>410 Museum (curator)</b>	521 igneous	652 sed. environments
<b>150 Environmental Geology</b>	303 seismicity	<b>420 Oceanography</b>	522 metamorphic	<b>720 Stratigraphy</b>
<b>160 Public Education &amp; Communication</b>	304 paleomagnetism	421 marine geology	523 sedimentary (clastic)	<b>750 Structural Geology</b>
<b>200 General Geology</b>	<b>320 Hydrogeology</b>	422 coastal geology	524 sedimentary (carb.)	751 tectonics
<b>220 Geochemistry</b>	321 hydrochemistry	<b>450 Paleontology</b>	525 experimental	752 tectonophysics
221 organic	322 ground water	451 invertebrate	<b>550 Planetology</b>	753 rock mechanics
222 high temperature	323 surface water	452 vertebrate	<b>575 Quaternary Geology</b>	<b>800 Volcanology</b>
	<b>330 Library</b>	453 micropaleontology	<b>600 Regional Geology</b>	

Résumé must be attached, **limited to two pages**, typewritten on one side only, to be acceptable for reproduction to employers. Include your name, address, and phone number; concise details of work experience; and majors/minors on degrees.  
Fee: \$30 if you are a Member or Student Associate of GSA in good standing (Member # \_\_\_\_\_), \$60 if you are not a member of GSA. Payment in U.S. funds (check, money order, or charge information **must accompany form**).  
**Make check payable to the Geological Society of America. = This application will be active for 1 year.**

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**Signature (required)** \_\_\_\_\_ I will/will not attend the 19\_\_\_\_ GSA Annual Meeting in \_\_\_\_\_

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Are you looking for a new position in the field of geology? The GSA Employment Service offers an economical way to find one. Potential employers use the service to find the qualified individuals they need.

You may register any time throughout the year. Your name will be provided to all participating employers who seek individuals with your qualifications. If possible, take advantage of GSA's Employment Interview Service, which is conducted each fall in conjunction with the Society's Annual Meeting. The service brings potential employers and employees together for face-to-face interviews. Mark your calendar for October 24-27 for the 1994 GSA Annual Meeting in Seattle, Washington.

To register, complete the application form on this page, prepare a one-to two-page résumé, and mail it with your payment to GSA headquarters. One-year listing for GSA Members and Student Associates in good standing: \$30, nonmembers: \$60.

**NOTE TO APPLICANTS:** If you plan to interview at the GSA Annual Meeting, GSA must receive your material no later than September 1, 1994. If we receive your materials by September 1, your record will be included in the information employers receive prior to the meeting. Submit your forms early to receive maximum exposure! Don't forget to indicate on your application form that you would like to interview in October. Good luck with your job search!

**For additional information or submission of forms, please contact T. Michael Moreland, Manager, Membership Services, Geological Society of America, P.O. Box 9140, Boulder, CO 80301, (303) 447-2020.**

**APPLICANT FORM**

**Meetings continued from p. 49**

Atlantic Symposium, Barbara Donner, Fachbereich Geowissenschaften der Universität, Postfach 33 04 40, D-28334 Bremen, Germany.

**14th International Sedimentological Congress**, Equatorial Gateway in Atlantic Symposium, August 21-26, 1994, Recife, Brazil. Information: Luba Jansa, Bedford Institute of Oceanography, Dartmouth, N.S., Canada B2Y 4A2, (902) 426-2734, fax 902-426-4465, E-mail: jansa@agcrr.bio.ns.ca. (Abstract deadline: February 15, 1994.)

**International Geographical Union Regional Conference**, Environment and Quality of Life in Central Europe: Problems of Transition, August 22-26, 1994, Prague, Czech Republic. Information: Conference Secretariat,

IGU RC 1994, Albertov 6, 128 43 Praha 2, Czech Republic, phone 42-2-24912060, or 42-2-296025, fax 42-2-24915817 or 42-2-296025, E-mail: kucera@prfdec.natur.cuni.cz

**International Symposium on Paleoenvironmental History of East and South Asia and Cretaceous Correlation (IGCP 350)**, Taegu, Korea. Information: Ki-Hong Chang, Dept. of Geology, Kyungpook National University, Taegu, Korea 702-701, phone 82-53-950-5355, fax 82-53-957-0431, E-mail: khchang@bh.kyungpook.ac.kr

**Proterozoic Crustal and Metallogenic Evolution**, August 29-September 1, 1994, Windhoek, Namibia. Information: G.I.C. Schneider, Geological Society of Namibia, P.O. Box 699, Windhoek, Namibia, phone 264-61-37240, fax 264-61-228324.

**V.M. Goldschmidt Conference**, August 29-September 2, 1994, Edinburgh, Scotland. Information: B. Harte or P. Symms, V.M. Goldschmidt Conference 1994, Dept. of Geology and Geophysics, University of Edinburgh, Grant Institute, West Mains Road, Edinburgh EH9 3JW, Scotland, UK.

**September Cyclicality in Global Geology, Australian Geological Convention Symposium**, September, 1994, Perth, Australia. Information: Bryan Krapez, C. McA. Powell, Dept. of Geology, University of Western Australia, Nedlands, 6009, Australia.

**Prospecting in Areas of Glaciated Terrain—Tenth Conference**, September 5-7, 1994, St. Petersburg, Russia. Information: The Conference Office, The Institution of Mining and Metallurgy,

44 Portland Place, London W1N 4BR, England, phone 44-71-580-3802, fax 44-71-436-5388.

**Biotic Recoveries from Mass Extinctions**, IGCP Project 335, September 5-8, 1994, Plymouth, United Kingdom. Information: Malcom B. Hart, Dept. of Geological Sciences, University of Plymouth, Drake Circus, Plymouth, Devon PL1 8AA, UK, fax 44-745-233-117; or Douglas H. Erwin, Dept. of Paleobiology, NHB-121, Smithsonian Institution, Washington, DC 20560, (202) 357-2053.

**International Conference on Arctic Margins**, (ICAM '94), September 5-9, 1994, Magadan, Russia. Information: Kirill V. Simakov, North East Science Center, Russian Academy of Sciences, 16 Portovaya St., Magadan, Russia 685000, (907) 474-7219 (USA) or 7-41-3-223-0953 (Russia); or Dennis K.



## Looking for a New Employee?

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How does it work? Complete the Employer's Request for Earth Science Applicants form on this page. Remember to specify educational and professional experience requirements as well as the specialty area or areas of expertise your applicant should have. The GSA computer will take it from there.

You will receive a printout that includes the applicants' names, addresses, phone numbers, areas of specialty, type of employment desired, degrees held, years of professional experience, and current employment status. Résumés for each applicant are sent with each printout at no additional charge. For 1994, the cost of a printout of one or two specialty codes is \$150. (For example, in a recent job search for an analyst of inorganic materials, the employer requested the specialty codes of geochemistry and petrology.) Each additional specialty is \$50. A printout of the applicant listing in all specialties is available for \$350. (Specialty codes printed in boldface type are considered major headings. If you request a listing of one of the subspecialties, applicants coded under the major category will be included but not those coded under the other related subspecialties.) If you have any questions about your personalized computer search, GSA Membership Services will assist you.

The GSA Employment Service is available year round. However, GSA also conducts the Employment Interview Service each fall in conjunction with the Society's Annual Meeting (this year in Seattle, Washington, October 24-27). You may rent interview space in half-day increments from GSA. Our staff will schedule all interviews with applicants for you, the recruiter. In addition, GSA offers a message service, complete listing of applicants, copies of résumés at no additional charge, and a posting of all job openings.

## EMPLOYER FORM



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## EMPLOYER'S REQUEST FOR EARTH SCIENCE APPLICANTS

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List the specialty code numbers that you wish to order, or  check here if you want the entire file of applicants in ALL specialties.

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In what area(s)? \_\_\_\_\_

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101 coal geology	224 stable isotopes	351 computer science	455 paleoecology	621 photogeology
102 geothermal, etc.	225 geochronology	352 statistical geology	<b>500 Petroleum Geology</b>	622 photogrammetry
103 metallic deposits	<b>250 Geomorphology</b>	<b>400 Mineralogy</b>	501 exploration	<b>630 Science Editing</b>
104 nonmetallic deposits	<b>300 Geophysics</b>	401 crystallography	502 subsurface strat.	<b>650 Sedimentology</b>
105 mining geology	301 seismic	402 clay mineralogy	<b>520 Petrology</b>	651 sed. processes
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<b>150 Environmental Geology</b>	303 seismicity	<b>420 Oceanography</b>	522 metamorphic	<b>720 Stratigraphy</b>
<b>160 Public Education &amp; Communication</b>	304 paleomagnetism	421 marine geology	523 sedimentary (clastic)	<b>750 Structural Geology</b>
<b>200 General Geology</b>	<b>320 Hydrogeology</b>	422 coastal geology	524 sedimentary (carb.)	751 tectonics
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222 high temperature	323 surface water	452 vertebrate	<b>575 Quaternary Geology</b>	<b>800 Volcanology</b>
	<b>330 Library</b>	453 micropaleontology	<b>600 Regional Geology</b>	

### Applicants seeking employment in:

Academic  Government  Industry  Other \_\_\_\_\_

### Minimum degree required:

None  B.A. or B.S.  M.A. or M.S.  Ph.D.

### Minimum professional experience:

None  1-5 years  6-plus years

Employment in:  U.S. only  U.S. with foreign assignments  Either

Foreign Languages:  French  German  Russian  Other \_\_\_\_\_  Not required

### Experience desired (years):

	None	1-5	6-plus
Administrative	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Exploration/Production	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Field	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Research	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Teaching	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

I am interested in interviewing applicants through the GSA Employment Service at the 19\_\_\_\_ Annual Meeting in \_\_\_\_\_.

1. I agree to use this service for valid recruiting purposes.

2. I agree that no placement charges will be assessed to any applicant participating in the GSA Employment Matching Service.

Signature (required) \_\_\_\_\_

Date \_\_\_\_\_

Total fee enclosed ..... \$ \_\_\_\_\_

Or invoice requested ..... \$ \_\_\_\_\_

Thurston, Minerals Management Service, 949 E. 36th Ave., Anchorage, AK 99508-4302, (907) 271-6545, fax 907-271-6565.

**First International Airborne Remote Sensing Conference and Exhibition:** Applications, Technology, and Science, September 11-15, 1994, Strasbourg, France. Information: Robert Rogers, ERIM, Box 13001, Ann Arbor, MI 48113-4001, (313) 994-1200, ext. 3234; fax 313-994-5123.

**Salt Tectonics**, September 14-15, 1994, London, England. Information: Ian Alsop, Derek Blundell, and Ian Davison, Dept. of Geology, Royal Holloway, University of London, Egham, Surrey, UK, phone 44-784-443615, fax 44-784-471780. (Abstract deadline: April 1, 1994.)

**Fifth International Mine Water Congress**, September 18-23, 1994, Nottingham, UK. Information: Conference Secretary, IMWA Conference, c/o Department of Mineral Resources Engineering, University of Nottingham, University Park, Nottingham NG7 2RD, UK.

**12th Australian Geological Convention**, September 26-30, 1994, Perth, Australia. Information: Secretary, 12AGC, P.O. Box 119, Cannington, WA 6107, Australia, 61-9-351-7968, fax 61-9-351-3153.

**Eco Rio '94, International Symposium on Resource and Environmental Monitoring**, September 26-30, 1994, Rio de Janeiro. Information: National Institute of Space Research—INPE c/o Mônica Oliveira, CRI, P.O. Box 515, Av. dos Astronautas, 1758-CEP 12227-010, San José dos Campos,

SP-Brazil, phone 55-123-22-9816 or 41-8977 (ext. 250), fax 55-123-21-8543 or 22-9325.

**October Association of Engineering Geologists Annual Meeting**, October 2-7, 1994, Williamsburg, Virginia. Information: AEG, 323 Boston Post Rd., Suite 2D, Sudbury, MA 01776, (508) 443-4369 or (508) 443-3639.

**Federation of Analytical Chemistry and Spectroscopy Societies Annual Conference**, October 2-7, 1994, St. Louis, Missouri. Information: FACSS, 198 Thomas Johnson Dr., Suite S-2, Frederick, MD 21702-4317, (301) 846-4797.

**German Geological Society (DGG) Annual Meeting**, October 4-7, 1994, Heidelberg, Germany. Information:

Th. Bechstädt and R. O. Greiling, Geologische-Paläontologisches Institut, Ruprecht-Karls-Universität, Im Neuenheimer Feld 234, D-6900 Heidelberg, Germany.

**Symposium on Porphyry Copper Deposits from Alaska to Chile**, October 5-7, 1994, Tucson, Arizona. Information: Jim Laukes, University of Arizona Extended University, 1955 East Sixth Street, Tucson, AZ 85719-5224, 1-800-955-UofA, fax 602-621-3269, E-mail (Internet): jlaukes.ccit.arizona.edu.

**Ninth Annual Conference on Contaminated Soils**, October 17-20, 1994, Amherst, Massachusetts. Information: Paul Kosteki, Environmental Health and Sciences, N344 Morrill, University of

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Massachusetts, Amherst, MA 01003,  
(413) 545-2934, fax 413-545-4692.

**LIRA Workshop on the Ross Orogen: Crustal Structure and Tectonic Significance**, October 21–23, 1994, Dallas, Texas. Information: John W. Goodge, Dept. of Geological Sciences, Southern Methodist University, Dallas, TX 75275, (214) 768-4140, E-mail: jgoodge@sun.cis.smu.edu.

**November**  
**Geology and Resources of the Eastern Frontal Belt, Ouachita Mountains, Oklahoma**, November 15–17, 1994, Poteau, Oklahoma. Information: Neil H. Suneson, Oklahoma Geological Survey, Sarkeys Energy Center Room N-131, 100 East Boyd St., Norman, OK 73019-0628, (405) 325-3031.

**International Geological Correlation Program Project 351, Early Paleozoic Evolution in Northwest Gondwana**, November 29–December 7, 1994, Rabat, Morocco. Information: Naima Hamoumi, Dépt. de Géologie, Faculté des Sciences de Rabat, B.P. 1226 RP Rabat, Morocco, phone 212-7-7719-57, fax 212-7-77-42-61, telex 36607 M.

**December**  
**Tectonic Evolution of Southeast Asia**, December 7–8, 1994, London, UK. Information: Robert Hall, Geological Sciences, University College, Gower St., London WC1E 6BT, UK, phone 44-784-443592, fax 44-71-387-1612, E-mail (Internet): robert.hall@ucl.ac.uk.

**Symposium on Inverse Problems: Geophysical Applications**, December 12–14, 1994, Yosemite Fish Camp, California. Information: SIAM Conference Coordinator, 3600 University City Science Center, Philadelphia, PA 19104-2688, (215) 382-9800, fax 215-386-7999, E-mail: meetings@siam.org. (Abstract deadline: April 25, 1994.)

## 1995 Meetings

**April**  
**Geological Society of Nevada Symposium III: Geology and Ore Deposits of the American Cordillera**, April 10–13, 1995, Reno, Nevada. Information: Bob Hatch, Chairperson, Geological Society of Nevada, P.O. Box 12021, Reno, NV 89510, (702) 323-4569, fax 702-323-3599.

**Geological Society of South Africa Centennial Geocongress**, April 3–7, 1995, Johannesburg, South Africa. Information: Congress Secretariat, Centennial Geocongress, P.O. Box 36815, Menlo Park, 0102, South Africa, phone and fax 27-12-47-3398.

**May**  
**Water Resources at Risk**, May 14–18, 1995, Denver, Colorado. Information: Helen Klose, American Institute of Hydrology, 3416 University Ave., S.E., Minneapolis, MN 55414, (612) 379-1030.

**17th International Geochemical Exploration Symposium**, Exploring the Tropics, May 15–19, 1995, Townsville, Queensland, Australia. Information: Russell Myers, 171GES, National Key Centre in Economic Geology, James Cook University, Townsville, Q4814, Australia, phone 61-77-814486, fax 61-77-815522.

Send notices of meetings of general interest, in format above, to Editor, *GSA Today*, P.O. Box 9140, Boulder, CO 80301.

# 1994 GEOVENTURES

## GEOHOSTEL

### Scenic Geology and Natural History of the Central Colorado Rocky Mountains

Western State College, Gunnison, Colorado

6 days, 7 nights: June 25–30, 1994

Scientific Leaders:  
**Kenneth E. Kolm** and **Gregory S. Holden**,  
*Department of Geology and Geological Engineering,*  
*Colorado School of Mines*

Gunnison is in the high core of the Colorado Rockies at the center of a wide, well-watered valley, surrounded by 14,000-ft peaks of the Elk, West Elk, Sawatch, and San Juan Mountains, which we will explore during the GeoHostel. At 7700 ft, our center is a small college and recreational town, famous for top-quality fishing in local trout streams. The geology, geomorphology, and geohydrological systems are diverse. We will see the full range of Colorado geological history and environmental systems, from Precambrian basement gneiss

through Laramide structural features; Tertiary intrusions, calderas, and ash flows; Pleistocene age glaciated mountains; and Quaternary events such as the famous Slumgullion Slide. The GeoHostel will include van tours to the Black Canyon of the Gunnison River, the Rio Grande Rift at Salida, Great Sand Dunes National Monument, the Cochetopa country, Lake City, and tram rides to the tops of Mount Crested Butte and Monarch Peak. The tours are both full and half day and will allow leisure time for late-day hikes, fishing, or further sightseeing. Come join us.

## Program Schedule

June 25, Saturday—Welcoming get-together  
June 26–30, Sunday through Thursday—Classes and field trips  
June 30, Thursday—Farewell party

## Fee and Deposit

Cost: GSA Member: \$480. Nonmember: \$530.  
\$100 deposit, due with your reservation, is refundable through April 30, less \$20 processing fee. Total balance due: May 1. Minimum age: 21. Limit: 32 persons

**Fee includes** classroom programs and materials, field trip transportation, lodging for 6 nights (single-occupancy,

## GEOTRIP

### Rim to River: Moab, Canyonlands, and Cataract Canyon

8 days, 9 nights: May 28–June 4, 1994

Scientific Leaders: **Kenneth Kolm**, *Department of Geology and Geological Engineering, Colorado School of Mines*  
**John A. Campbell**, *Ft. Lewis College*  
**John Emerick**, *Division of Science and Engineering, Colorado School of Mines*

This trip is an exceptional educational opportunity for the physically active person. The itinerary includes geologic features found nowhere else. More than 1500 natural stone arches stand in Arches National Park, which is the world's highest concentration of these remarkable features. Nearby is Canyonlands, Utah's largest national park, a unique area of sandstone pillars and mazes of incredible beauty that have been formed into three districts by the Colorado and Green rivers. Cataract Canyon is a major whitewater experience. We are glad to be offering these experiences, as well as the trip to the La Sal Mountains, at the very best time of year.

For pre- or post-trip interest, Moab is within driving distance of Natural Bridges, Capitol Reef, Bryce Canyon, Zion, Grand Canyon and the Glen Canyon Lake Powell recreational area.

For pre- or post-trip interest, Moab is within driving distance of Natural Bridges, Capitol Reef, Bryce Canyon, Zion, Grand Canyon and the Glen Canyon Lake Powell recreational area.

## Itinerary

**May 28, Saturday**—  
Travel day to Moab. Orientation at 7:30 p.m.  
**May 29, Sunday**—  
La Sal Mountains. Lodging in Moab.  
**May 30, Monday**—  
Arches National Park. Lodging in Moab.  
**May 31, Tuesday**—  
Upheaval Dome. Lodging in Moab.  
**June 1–3, Wednesday–Friday**—  
Hike to the River on Lathrop Trail. Hiking in Canyonlands (Island in the Sky, Maze, and Needles districts). Tent camping.  
**June 4, Saturday**—  
Rafting Cataract Canyon. Side hikes. Overflight of Canyonlands and return to Moab. Farewell Party.  
**June 5, Sunday**—  
Travel day.

## Transportation, Lodging, Meals

Travel will be by four-wheel drive vans, motorized rafts, or on foot. During the days in the Arches area, Behind-the-Rocks, and the La Sal Mountains, transportation will be in vans. Travel on the Colorado River will be in motorized rafts

## GEOVENTURES REGISTRATION FORM

If you would like to send a deposit to hold your reservation, please pay by check or credit card, which will be used only for this deposit. (Future charges will be authorized by you first.) You will receive further information and a confirmation of your registration within one week after your reservation.

**Cancellation:** Each GeoVenture has its own set of cancellation dates which will be sent out to registrants and provided in response to phone queries.

Name \_\_\_\_\_

Institution/Employer \_\_\_\_\_

Mailing Address \_\_\_\_\_

City \_\_\_\_\_ State \_\_\_\_\_ Country \_\_\_\_\_ ZIP \_\_\_\_\_

Phone: ( ) \_\_\_\_\_ ( ) \_\_\_\_\_  
Business Home

Guest Name \_\_\_\_\_

GSA Member # \_\_\_\_\_ Deposit Per Person \_\_\_\_\_ No. of Persons \_\_\_\_\_ Total Paid Deposit \_\_\_\_\_

GT941—Canadian Transect \$200 \_\_\_\_\_

GT942—Canyonlands/Cataract Canyon \$200 \_\_\_\_\_

GH943—Gunnison/Central Colorado \$100 \_\_\_\_\_

**TOTAL DEPOSIT** \_\_\_\_\_

I've enclosed no deposit, but I'm interested. Please send more information.

VISA  MasterCard  American Express

Credit Card # \_\_\_\_\_ Exp. Date \_\_\_\_\_

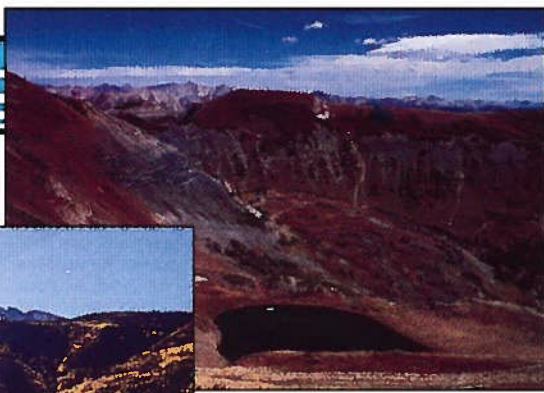
Signature \_\_\_\_\_

Make checks payable to: **GSA 1994 GeoVentures**

Mail registration form and check or credit card information to:  
1994 GSA GeoVentures, GSA Meetings Department,  
P.O. Box 9140, Boulder, CO 80301

Non-U.S.-based registrants are encouraged to use GSA's fax number:  
303-447-0648





Ken Kolm

Mt. Owen Ridge, Keebler Pass:  
Elk Range, Colorado.



Ken Kolm

Chair mountain, McClure's Pass: Elk Range, Colorado

## Central Colorado Rocky Mountains

or double for couples, dormitory rooms), breakfast and sack lunch daily through Thursday, tram rides, and welcoming and farewell events. **Not included** are transportation to and from Gunnison, Colorado, transportation during hours outside class and field trips, meals, and other expenses not specifically included.

(J-rigs). Lodging in Moab will be in a comfortable modern motel. Camping near the river for three nights will be in tents and sleeping bags provided by the rafting outfitter. Meals are provided except for the arrival night and the departure morning.

### Physical Requirements

This trip includes several substantial hikes for which each person will carry a day pack with camera, water, and snacks. The longest hike is 12 miles—downhill. Although taken at a reasonable pace with many points to rest or to explore the geology, these hikes should be undertaken only by persons in good health who are physically active. No rafting experience is necessary.

### Fee and Deposit

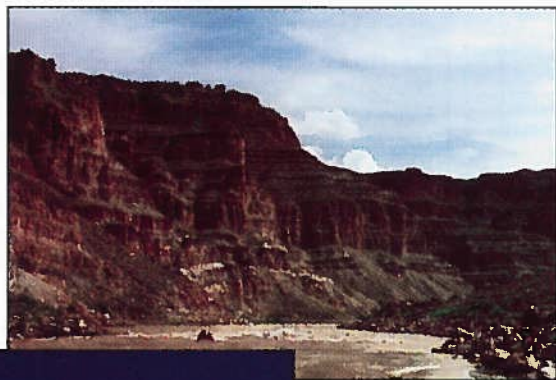
Estimated Cost: GSA Member: \$1220. Nonmember: \$1370.  
Based on 24 people. May be more if there are fewer registrants. If you have previously traveled on a GSA GeoTrip, the nonmember surcharge will be waived.  
\$200 deposit, due with your reservation, is refundable through April 1, less \$50 processing fee.  
Total balance due: April 1. Minimum age: 21. Limit: 24 persons.

**Fee includes** all meals except dinner on the arrival day and breakfast on the departure day; comfortable four-wheel-drive van transportation; double-occupancy lodging in Moab; tents, sleeping bags, and pads when camping; geological reading material and guidebook; over-flight of Canyonlands; and of course, the companionship of expert scientific leaders. **Not included** is airfare to and from Grand Junction, Colorado, or transfer to Moab, Utah. We will arrange for an optional group pick-up and return. The cost is about \$20 each way (100 miles).

### Air Transportation

Air transportation can be arranged by Cain Travel Agency in Boulder, 1-800-346-4747, Monday through Friday, 8:30 a.m. to 5:30 p.m. MST. Please ask for Robyn Langerak, who has been serving GSA travelers well for several years. She can also advise you on other travel in the Four Corners area, including Zion, Bryce, and Grand Canyon National Parks.

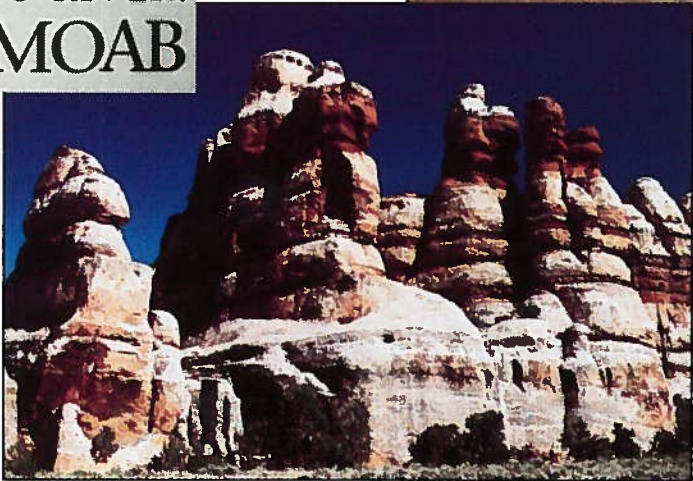
Please make your decision as soon as possible. There is active interest in this unusual trip, and it will fill soon.



Ken Kolm

Cataract Canyon

## RIM TO RIVER: MOAB



Ken Kolm

The Dollhouse, Maze District, Canyonlands



Peyto Lake, Banff National Park, Canada. Mark Duval

## GEOTRIP Calgary to Vancouver:

### Transect across the Southern Canadian Cordillera: A Cross Section through a Convergent Margin

15 days, 16 nights: August 13–27, 1994

#### Scientific Leaders:

**J. Murray Journeay, J.W.H. Monger, Randall R. Parrish,**  
*Geological Survey of Canada*  
**J. Brian Mahoney,** *University of British Columbia*  
**Philip S. Simony, Deborah A. Spratt,** *University of Calgary*

#### Itinerary

This trip is a geological excursion across the southern Canadian Cordillera, from Calgary, Alberta, to Vancouver, British Columbia. Participants will journey through the Canadian Rocky Mountain fold-and-thrust belt, the Omineca metamorphic complex and Mesozoic arc assemblages, sedimentary basins, and plutonic complexes of the accreted terranes. The trip will focus on the tectonic evolution of the region and will emphasize the current level of understanding and areas of current research. As with all GeoTrips, the daily itinerary is planned with both the geologist and nongeologist in mind.

#### Physical Requirements, Transportation, Lodging, Meals

The leaders have planned several extensive day hikes. Persons in good physical health with the ability to hike several miles uphill are encouraged to consider this trip; however, bus will be the primary transportation mode. Also included will be a trip by horseback, another with jeeps, and very possibly one by jet boat. Lodging (double occupancy) will be in comfortable hotels or inns. Camping may be planned for two or three nights. Meals, including a final farewell dinner, will be included, with the exception of the arrival night, "the on-your-own day," and the departure morning.

Orientation is the evening of August 13. Departure is the morning of August 28. The arrival point is Calgary, and the end point is Vancouver. For most departure points there is a modest differential for the airfare from Vancouver back to Calgary or the continuing airfare from Vancouver to your home destination. Call Cain Travel Group and ask for Robyn Langerak if you want an estimate: 1-800-346-4747, 8:30 a.m. to 5:30 p.m. MST, Monday through Friday.

#### Fee and Deposit

Cost: Member: \$2300. Nonmember: \$2450.  
Based on 24 people. The trip may be slightly more if fewer register. If you have previously traveled on a GSA GeoTrip, the nonmember surcharge will be waived.  
\$200 deposit is due with your reservation, and is fully refundable through April 30 less a \$50 processing fee.  
Total balance due: June 15. Minimum age: 21. Limit: 30 persons.



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## GSA ANNUAL MEETINGS

### 1994

Seattle, Washington  
Washington State  
Convention and Trade Center  
Seattle Sheraton Hotel, October 24-27



**General Chairman: Darrel S. Cowan**

**Technical Program Chairmen: Mark S. Ghiorso, Thomas Dunne**  
*Symposia and theme proposals were due January 4, 1994.*

**Field Trip Chairman: Donald A. Swanson**  
*Field trip proposal deadline was May 15, 1993.*

All of these chairmen are located at the Dept. of Geosciences, University of Washington, Seattle, WA 98195, (206) 543-1190, fax 206-543-3836.

*For information call the GSA Meetings Department, 1-800-472-1988 or (303) 447-2020.*

### 1995

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

**General Chairman: William R. Craig, University of New Orleans**

**Technical Program Chairman: Laura Serpa, University of New Orleans**

**Call for Field Trip Proposals: Please contact the Field Trip Chairmen listed below.**

**Whitney Autin**

Louisiana Geological Survey  
P.O. Box G, University Station  
Baton Rouge, LA 70893-4107  
(504) 388-5320

**Duncan Goldthwaite**

4608 James Drive  
Metairie, LA 70003  
(504) 887-4377

*For general information call the GSA Meetings Department, 1-800-472-1988 or (303) 447-2020.*

## FUTURE

Seattle	October 24-27	1994
New Orleans	November 6-9	1995
Denver	October 28-31	1996
Salt Lake City	October 20-23	1997

For general information on technical program participation (1994 or beyond) contact Sue Beggs, Meetings Manager, GSA headquarters.

## GSA SECTION MEETINGS

**South-Central Section, University of Arkansas, Little Rock, Arkansas, March 21-22, 1994.** Philip L. Kehler, Department of Earth Sciences, University of Arkansas—Little Rock, 2801 S. University Ave., Little Rock, AR 72204, (501) 569-3546, fax 501-569-8020. *Abstract Deadline was November 30, 1993.*

**Cordilleran Section, California State University, San Bernardino, California, March 21-23, 1994.** Joan E. Fryxell, Department of Geological Sciences, California State University, 5500 University Parkway, San Bernardino, CA 92407-2397, (909) 880-5311, fax 909-880-7005. *Abstract Deadline was November 29, 1993.*

**Northeastern Section, SUNY at Binghamton, Binghamton, New York, March 28-30, 1994.** H. Richard Naslund, Department of Geological Sciences, SUNY, Binghamton, NY 13902-6000, (607) 777-4313, fax 607-777-2288. *Abstract Deadline was December 2, 1993.*

**Southeastern Section, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, April 7-8, 1994.** Lynn Glover, III and Robert J. Tracy, Department of Geological Sciences, Virginia Tech, Blacksburg, VA 24061-0420, Glover's direct (703) 231-6213, Tracy's direct (703) 231-5980, fax 703-231-3886. *Abstract Deadline was December 1, 1993.*

**North-Central Section, Western Michigan University, Kalamazoo, Michigan, April 28-29, 1994.** Alan Kehew, Department of Geology, Western Michigan University, Kalamazoo, MI 49008, (616) 387-5495, fax 616-387-5513. *Abstract Deadline was January 6, 1994.*

**Rocky Mountain Section, Fort Lewis College, Durango, Colorado, May 4-6, 1994.** Douglas Brew, Department of Geology, Fort Lewis College, Durango, CO 81301, (303) 247-7254, fax 303-247-7310. *Abstract Deadline was January 13, 1994.*

## Student Travel Grants

The GSA Foundation will award matching grants up to a total of \$3500 each to the six GSA Sections. The money, when combined with equal funds from the Sections, will be used to assist GSA Student Associates traveling to the 1994 GSA Annual Meeting in Seattle in October and to the 1994 Section meetings. Contact your Section Secretary for application procedures.

<b>Cordilleran</b>	Bruce A. Blackerby, (209) 278-2955
<b>Rocky Mountain</b>	Kenneth E. Kolm, (303) 273-3932
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## Positions Open

### SURFICIAL PROCESSES GEOLOGY

The Department of Earth and Atmospheric Sciences of Purdue University invites applications for a tenure-track Assistant Professor faculty position in Surficial Processes Geology, with emphasis in Environmental Geosciences, for research and teaching in both theoretical and applied studies. The position is expected to be filled by the fall 1994 semester. Applicants must have a Ph.D. degree, and postdoctoral experience is preferred. The successful candidate will be expected to teach at both the graduate and undergraduate level, and to develop a strong funded research program in his/her area of specialization. The individual must have strong quantitative capabilities with extensive course work and emphasis in the geological sciences, and with demonstrated abilities in data collection, modeling, and analysis of earth systems. Familiarity with remote sensing is desirable. The candidate may be one of the following specialists: Quaternary Geologist/Geomorphologist, Specialist in Natural Geologic Hazards, Specialist in Fluvial Processes, Low-Temperature Geochemist, or Hydrogeologist (physical or chemical). Applications from minority and female candidates are particularly welcome. Consideration of applications began December 1, 1993 and the search will continue until the position is filled. Applicants should send their resume, publications list, statement of their long-term research and teaching interests, and the names, addresses, and phone numbers of three references to: Professor Darrell I. Leap, Chairman, Surficial Processes Search Committee, Department of Earth and Atmospheric Sciences, Purdue University, West Lafayette, IN 47907-1397. Purdue University is an equal opportunity/affirmative action employer.

### DIRECTOR/EARTH SCIENTIST

The Foundation for Glacier and Environmental Research, based in the Pacific Northwest, invites applications for Director of its major field teaching and research programs, conducted annually on the fifth largest ice field in North America, the Juneau ice field, Alaska. Excellent field facilities and infrastructure exist.

We seek an earth scientist with a background in research and teaching and experience in mountain and arctic environments. Ph.D., excellent leadership, organization and communication skills and strong commitment to field training and graduate, undergraduate, and secondary education required. Ability to continue and enhance the current program's philosophy with creativity and vision necessary. Successful record in grant-writing and fund-raising desired.

Please submit letter of application, resume, and three letters of reference to Chair, Search Committee, Box 241003, Douglas, AK 99824-1003. Applications accepted until position is filled.

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### INTRODUCTORY GEOLOGY COORDINATOR/LECTURER

The Department of Geology and Geophysics at the University of Minnesota is searching for an Introductory Geology Coordinator/Lecturer. The successful candidate will coordinate the graduate teaching assistants for the Introductory Geology lecture and lab courses and Historical Geology lab courses, develop innovative course and lab materials, and teach one or more sections of Introductory Physical Geology. This is an annually renewable, 10-month, 75%-appointment starting on September 1, 1994. An M.S. in geology is essential with a Ph.D. preferred, and teaching experience is required for the position. Candidates should send resume, teaching evaluations, transcripts, statement of research interests, and names of three referees to: Dr. Christian Teyssier, Department of Geology and Geophysics, University of Minnesota, 310 Pillsbury Dr., S.E., Minneapolis, MN 55455. Application deadline is March 1, 1994. The University of Minnesota is an equal opportunity educator and employer.

### ASSISTANT PROFESSOR GEOLOGY DEPARTMENT

Applications are invited for a tenure-track position at the rank of Assistant Professor. Teaching responsibilities will include physical geology, environmental geology, and an upper division course in the specialty of the successful candidate. Desired specializations include quantitative geomorphology, low-temperature/contaminant geochemistry, or paleoclimatology. We are seeking an individual who is committed to high-quality undergraduate teaching and who will develop a research program that involves our geology majors. A Ph.D. in the geological sciences is required. The appointment will begin September 1, 1994. Furman University is a private, liberal arts university with 2500 students, located in the South Carolina Piedmont at the foot of the Blue

Ridge Front. The Department of Geology consists of four full-time and one adjunct faculty and offers the B.S. and B.A. degrees in geology. Major equipment items include XRD, XRF, EM, AND AA.

Applicants should send a resume, a statement of research and teaching interests, transcripts, and the names of three references to Kenneth A. Sargent, Chairperson, Department of Geology, Furman University, Greenville, SC 29613. Screening of applications will begin January 31, 1994 and will continue until the position is filled. Women and minorities are encouraged to reply. Furman University is an equal opportunity/affirmative action employer.

### STRUCTURAL GEOLOGY/GEOPHYSICS AT INDIANA STATE UNIVERSITY

Applications are invited for a tenure-track assistant professor position. The successful candidate is expected to teach upper-level undergraduate courses in structural geology and geophysics, a graduate-level course in the area of the candidate's expertise, and introductory geology. The candidate is also expected to establish and maintain an externally funded research program that involves both undergraduate and graduate students. Preference will be given to an individual who is field-oriented and who is willing to establish and maintain a seismic station. His/her research interests should mesh with current areas of expertise at ISU including volcanology, petrology, sedimentology, geomorphology, and remote sensing/GIS. A Ph.D. is required. Applicants should send resume, statements of teaching and research philosophy and interest, and names of three references to Dr. Robert Howe, Department of Geography and Geology, Indiana State University, Terre Haute, IN 47809. Preference will be given to applications received prior to February 15, 1994. The position will begin in August 1994. ISU is an equal opportunity affirmative-action employer.

### APPLIED GEOLOGY/NEOTECTONICS CALIFORNIA STATE POLYTECHNIC UNIVERSITY POMONA

The Geological Sciences Department invites applications for a tenure-track faculty position at the Assist. Prof. level, to begin Sept. 94. At time of appointment an earned Ph.D. in Geology, Geol. Eng., or Geohydrology is required. Applicants must have expertise in Neotectonics/Applied Geology. Responsibilities include teaching and developing upper division courses, e.g.: Geotectonics, Geohydrology, Eng. Geology, and Env. Geol. lower division Gen. Ed. courses, and directing undergraduates in field-oriented research concentrating on geologic problems in s. Calif. Participation in student advising, committee assignments, development of interdisciplinary studies, an active research, publication, and grant funding record, and forging liaison with local industry and the community are also expected. For information send resume to: Dr. John A. Klasik, Chair, Geological Sci. Dept., Cal Poly Pomona, 3801 W. Temple Ave., Pomona, CA 91768. (E-mail: JAK-LASIK@CSUPomona.EDU.) Application deadline Mar. 18, 1994. Official transcripts required of all finalists. Cal Poly Pomona is an EO/AA employer.

### IDAHO STATE UNIVERSITY

We seek a field-based geologist to fill a tenure-track position in the subject area of Surficial Processes/Environmental Geophysics. A Ph.D. or A.B.D. is necessary. Teaching duties include five undergraduate/graduate classes per year such as: Physical and Historical Geology, Hydrogeology, Geomorphology, and courses in specialty area. Active participation in our Geology Field Camp is expected. Supervision of M.S. students and pursuit of a funded research program is required, while expertise in the geology of Idaho is desirable. The successful candidate will have broad geologic interests and be comfortable in a small department where cooperation and shared teaching and research are standard. Send resume, transcripts, statement of academic philosophy and interests, and names of 3 referees to Search Committee, Department of Geology, Idaho State University, Pocatello, ID 83209-8072. Applications will be reviewed beginning February 15. ISU is an Equal Opportunity Affirmative Action Employer.

### ENVIRONMENTAL GEOLOGY BOWLING GREEN STATE UNIVERSITY

The Department of Geology invites applications for a new position in environmental geology with a specialization in geochemistry (low-temperature aqueous, environmental, and/or groundwater geochemistry) or hydrology (groundwater hydrology, surface water hydrology, contaminant transport, or engineering hydrology). Experience with GIS is also desirable. The opening is a tenure-track position to be filled at the Assistant Professor level beginning in August 1994. A Ph.D. is required. Responsibilities include supervision of M.S. theses, graduate and undergraduate teaching, and research.

Applications should include teaching and research interests, vita, and three letters of reference. Screening will begin March 1, 1994, but applications will be accepted until March 15. Applications should be sent to: Chair, Search Committee, Department of Geology, Bowling Green State University, Bowling Green, OH 43403. Women and minority candidates are encouraged to apply. BGSU is an affirmative-action/equal-opportunity employer.

### STRUCTURAL GEOLOGIST PORTLAND STATE UNIVERSITY

The Department of Geology seeks to fill a tenure-track position in structural geology at the Assistant Professor level for fall 1994. The successful candidate is expected to teach undergraduate and graduate courses and conduct a vigorous research program, including supervision of masters students in Geology and Ph.D. students in the interdisciplinary Environmental Sciences and Resources program. Primary interest should be in structural geology relevant to field-based work in the Pacific Northwest, with applications of quantitative and computer methods. Portland State University is developing a gen-

eral education program emphasizing lifelong learning skills in an interdisciplinary approach. Candidates should be interested in applying their knowledge and skills to the general education of all undergraduate students.

The Ph.D. is required by the date of hire. A detailed resume including two letters of professional reference and a statement of research and teaching interests should be received by March 1, 1994. Address the Structural Geology Search Committee, Geology Department, Portland State University, Portland, OR 97207-0751. Fax (503) 725-3025. Portland State University is an equal opportunity/affirmative action employer and the Geology Department is committed to diversifying its faculty.

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## Opportunities for Students

**Student Travel Grants.** The GSA Foundation will award matching grants to each of the six GSA Sections to assist students wishing to travel to GSA Section and Annual meetings. For applications contact individual Section secretaries. For Section information, contact GSA (1-800-472-1988).

**Graduate Assistantships, Texas Christian University.** The Geology Department has assistantships available for students working toward an M.S. degree. Areas of department expertise include carbonate and clastic sedimentology, paleovolcanology, structure and tectonics, paleontology, hydrogeology, computer applications in geology, remote sensing, and environmental geology. Field-oriented thesis topics include Paleozoic and Mesozoic volcanic arc rocks in the Sierra Nevada, California, Cambrian rhyolites and Paleozoic carbonates in southern Oklahoma, Devonian carbonates in Scotland, and Mesozoic and Cenozoic geology of Big Bend National Park, West Texas. Financial aid includes a yearly stipend of \$7,000, full tuition waiver, and up to \$1,500 for research expenses. Contact the Graduate Advisor, Department of Geology, Texas Christian University, Fort Worth, TX 76129 (817-921-7270).

**JOI/USSAC Ocean Drilling Fellowships.** JOI/U.S. Science Advisory Committee is seeking doctoral candidates of unusual promise and ability who are enrolled in U.S. institutions to conduct research com-

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patible with that of the Ocean Drilling Program. Both one-year and two-year fellowships are available. The award is \$20,000 per year to be used for stipend, tuition, benefits, research costs, and incidental travel, if any. Applicants are encouraged to propose innovative and imaginative projects. Research may be directed toward the objectives of a specific leg or to broader themes.

Applications are available from JOI and should be submitted according to the following schedule: Leg 159: Site 735, 5/1/94; Leg 160: Equatorial Atlantic Transform, 5/1/94; Leg 161: Mediterranean I, 5/1/94; Leg 162: Mediterranean II, 5/1/94; Leg 163: Atlantic Arctic Gateways II, 5/1/94; Leg 164: Gas Hydrates, 5/1/94; Shorebased Research (regardless of leg), 12/1/94.

These legs will be staffed during the next few months. Students interested in participating as shipboard scientists must apply to the ODP Manager of Science Operations in College Station, Texas. An application form is available in the JOI/USSAC Ocean Drilling Fellowship application packet. For more information and to receive an application packet, contact: JOI/USSAC Ocean Drilling Fellowship Program, Joint Oceanographic Institutions, Inc., 1755 Massachusetts Ave., NW, Suite 800, Washington, DC 20036-2102 (Andrea Leader: 202-232-3900).

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