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## Road Salt Impacts on Ground-water Quality — The Worst is Still to Come!

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### ABSTRACT

Throughout snow-belt regions of Canada, Europe, and the United States, millions of tonnes of road de-icing agents are applied to roads and highways each year. The problem is particularly acute in the Metropolitan Toronto area of southern Ontario, Canada, which receives well over 100 000 t (tonnes) (Mg) of NaCl annually, a rate approximating 200 g for every square metre of land. Historically, the common presumption has been that most of the applied salt is flushed from the system each season by overland flow and that impact on subsurface water is minimal and at steady state. However, there is now evidence that continued deployment of road de-icing chemicals may compromise ground-water quality for generations to come.

The results of a detailed salt budget determined for the Highland Creek basin of Metropolitan Toronto reveal that only 45% of the salt applied is being removed annually from the catchment in surface-water flow, the remainder entering temporary storage in shallow subsurface waters. The data from this study indicate that if present rates of salt application are maintained, chloride concentrations in ground waters discharging as stream base flow will eventually reach a steady-state concentration of >400 mg/L. This value represents a threefold increase over present average base-flow concentrations and well exceeds guidelines for drinking-water quality. The impact of sodium will be delayed by ion exchange, but similar calculations suggest that steady-state

sodium concentrations will reach an equally unacceptable 250 mg/L.

Although the salt balance calculations are useful in determining the average steady-state concentrations of sodium and chloride in ground-water discharge, numerical models are necessary to determine temporal and spatial changes in water quality. As expected, these models indicate that rates of ground-water degradation are highly dependent on the local hydrogeology, including catchment size. In Toronto, where Quaternary sediments form the major aquifer units, models indicate that steady state may take 200 yr, by which time average concentrations of sodium and chloride in ground-water will be similar to predicted base-flow concentrations. Locally, however, particularly within a few hundred metres of highways, concentrations three to four times the base-flow concentrations can be anticipated.

\*Present address: Jacques Whitford Environment Ltd., 2781 Lancaster Road, Ottawa, Ontario K1B 1A7, Canada

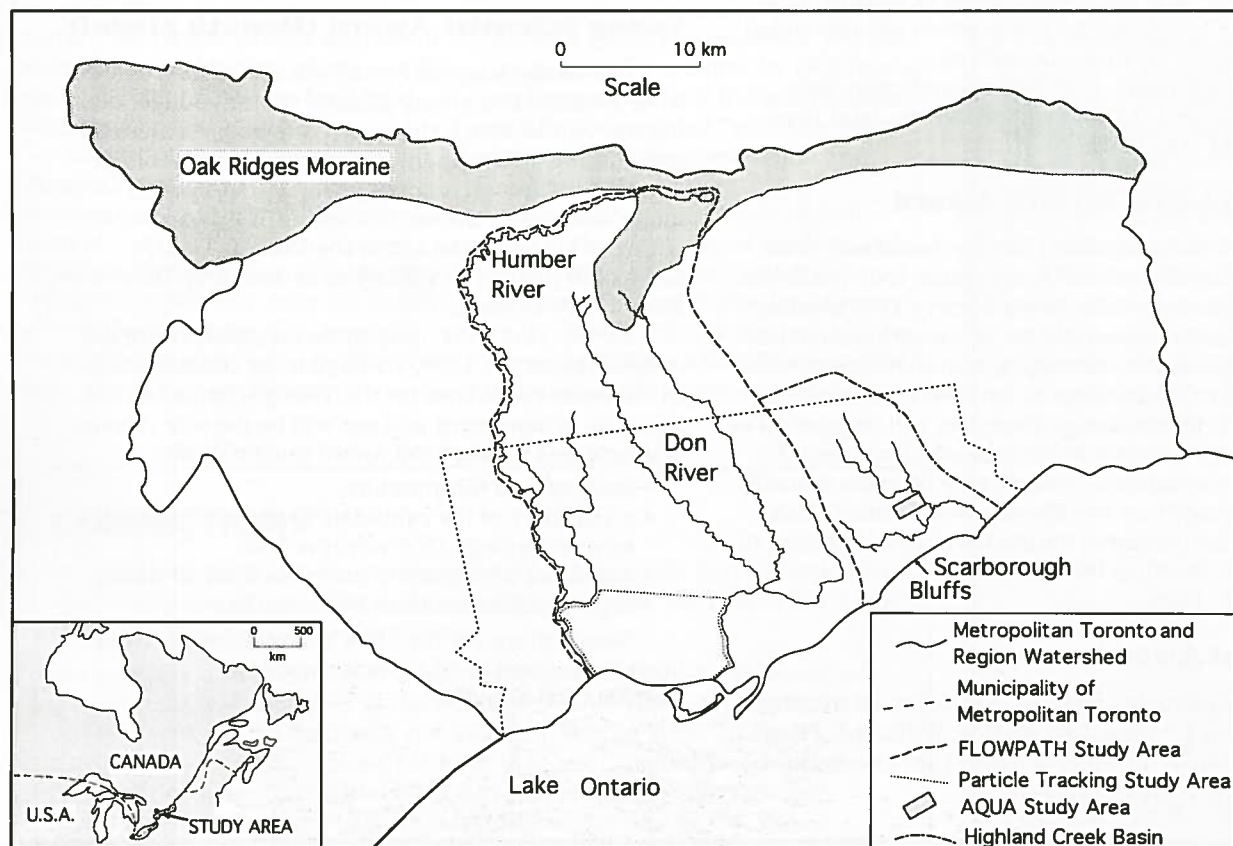


Figure 1. The Metropolitan Toronto and Region Watershed, showing locations of the study areas.



### INTRODUCTION

Throughout snow-belt regions of Canada, Europe, and the United States, many millions of tonnes of de-icing chemicals are applied to roads and highways every year. These chemicals, usually in the form of sodium chloride (NaCl), are readily mobilized in air-borne spray and surface-water runoff and usually appear in streams and lakes within months, if not weeks of their application. Although there have been many documented instances of ground-water pollution resulting from application of salt to roads (Huling and Hollocker, 1972; Diment et al., 1973; Toler and Pollock, 1974; Field et al., 1974; Wulkowicz and Saleem, 1974; Eisen and Anderson, 1980; Locat and Gélinas, 1989), it is generally assumed that relatively little salt enters the subsurface, and that when it does, only shallow road-side wells are affected.

In the Toronto area of southern Ontario, Paine (1979) first suggested that impacts of road salting on ground-water quality could be more serious. Paine performed a relatively coarse chloride mass balance determination on the Don River watershed (Fig. 1) and found that as little as 50% of the yearly application of NaCl was being removed by surface-water flow. His suggestion that the remaining salt was being stored in the shallow subsurface was strongly supported by Joy (1979), who, working in the same region, found elevated concentrations of sodium (>20 mg/L) in 141 road-side wells. It was not until the mid-1980s that follow-up studies confirmed the severity of the problem. Pilon and Howard (1987) recorded concentrations of chloride as high as 14 000 mg/L in pore waters from the unsaturated zone adjacent to highways in Metropolitan Toronto. Howard et al. (1985) found that the chloride concentration of urban springs of the Scarborough Bluffs (Fig. 1) averaged 380 mg/L, and local concentrations were as high as 2800 mg/L. Although Metropolitan Toronto ground waters are not generally used for domestic consumption, fears were raised that shallow contaminated ground waters could threaten the quality of urban streams and would ultimately affect the quality of the Great Lakes (Hodge, 1989; Duda, 1989;

Ground Water continued on p. 319

Each month, *GSA Today* features a short science article on fast-breaking items or current topics of general interest to the 17,000 members of GSA. What do you think of these articles? Do you have an idea for an article that you would like to see published in *GSA Today*? If so, please contact Eldridge Moores, Science Editor, *GSA Today*, (916) 752-0352, fax 916-752-0951.

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## GSA TODAY *December* Vol. 3, No. 12 1993

**GSA TODAY** (ISSN 1052-5173) is published monthly by The Geological Society of America, Inc., with offices at 3300 Penrose Place, Boulder, Colorado. Mailing address: P.O. Box 9140, Boulder, CO 80301-9140, U.S.A. Second-class postage paid at Boulder, Colorado, and at additional mailing offices. **Postmaster:** Send address changes to *GSA Today*, Membership Services, P.O. Box 9140, Boulder, CO 80301-9140.

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Classifieds and display: contact Ann Crawford  
(303) 447-2020; fax 303-447-1133

Printed with pure soy inks in the U.S.A.

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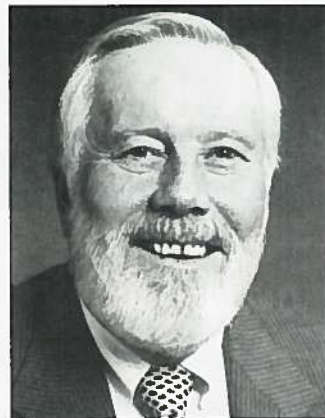
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### Reminders

## CALL FOR NOMINATIONS

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

### Officers and Councilors

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

Nominations for 1995 officers and councilors must be received at GSA headquarters no later than **FEBRUARY 15, 1994.**

### Distinguished Service Award

The GSA Distinguished Service Award was established by Council in 1988 to recognize individuals for their exceptional service to the Society. GSA Members, Fellows, 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 the Council. Awards may be made annually, or less frequently, at the discretion of Council. This award will be presented during the Annual Meeting of the Society. Deadline for nominations for 1994 is **MARCH 1, 1994.**

### National Awards

The deadline is **April 30, 1994**, for submitting nominations for these four awards: William T. Pecora Award, National Medal of Science, Vannevar Bush Award, Alan T. Waterman Award.

### Penrose and Day Medals, and Honorary Fellowship

Nominations for GSA's Penrose and Day Medals and for Honorary Fellowship in the Society are due at headquarters by **FEBRUARY 1, 1994.**

### Young Scientist Award (Donath Medal)

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

For the year 1994, only those candidates born on or after January 1, 1959, are eligible for consideration. In choosing candidates for the Young Scientist Award, scientific achievement and age will be the sole criteria. Nominations for the 1994 award must include

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

Nominations for the 1994 Young Scientist Award must be received at GSA headquarters by **FEBRUARY 1, 1994.**

Bruce F. Molnia

Washington Report provides the GSA membership with a window on the activities of the federal agencies, Congress and the legislative process, and international interactions that could impact the geoscience community. In future issues, Washington Report will present summaries of agency and interagency programs, track legislation, and present insights into Washington, D.C., geopolitics as they pertain to the geosciences.

## Reinventing Government: Part II The National Biological Survey

*"I am asking the Interior Department to create a National Biological Survey to learn more about where we stand in protecting all our biological resources here at home."*

—President Bill Clinton in his Earth Day message to the nation, April 21, 1993

*"The National Biological Survey will produce the map we need to avoid the economic and environmental 'train wrecks' we see scattered across the country. NBS will provide the scientific knowledge America needs to balance the compatible goals of ecosystem protection and economic progress. Just as the U.S. Geological Survey gave us an understanding of America's geography in 1879, the National Biological Survey will unlock information about how we protect ecosystems and plan for the future."*

—Secretary of Interior Bruce Babbitt, quoted in *A Biological Survey for the Nation*

*"Proposal: Through an internal reorganization within the Department of the Interior, the Secretary proposes to combine substantial portions of the biological research and survey activities of eight Departmental bureaus—the Fish and Wildlife Service; National Park Service; Bureau of Land Management; Bureau of Reclamation; Minerals Management Service; Office of Surface Mining; Geological Survey; and Bureau of Mines—into a new National Biological Survey (NBS)."*

—Department of the Interior Proposal, March 1993

Within weeks of being confirmed as Secretary of Interior, Bruce Babbitt raised the issue of a National Biological Survey (NBS). In an April 1, 1993, letter to his "Interior Colleagues" Babbitt described his proposal to consolidate biological research and inventory activities within the Department of Interior (DOI) into a new, independent bureau composed of "only research biologists." Biological stewardship and other biological activities would continue to be performed by other DOI bureaus. Babbitt stated "To find balance between environmental protection and economic growth, we must rely on the best science available. By separating the science from resource management, we can elevate the credibility of the science itself, forcing others to make decisions based not on ideology, but on science." The DOI Proposal states that "NBS will serve as a national source for objective information and analysis, not for advocacy. By focusing on biological research, NBS will not supplant the staffs of land management agencies or their operational biologists who apply ecological information to local land management decisions...."

Babbitt's letter acknowledges a "historical precedent" and likens the formation of the NBS to the establishment of the U.S. Geological Survey (USGS) in 1879. According to Babbitt, "While the USGS was designed to help us 'win the West,' the NBS, in many ways, is designed to help save the West. Both, however, were designed to make

sound data available to planners, developers and scientists. ... Both will be unimpeachable in reputation." Babbitt's letter noted that like the USGS, the formation of the NBS will be a "collaborative effort" of the DOI, the National Academy of Sciences, and the Smithsonian Institution. One of Babbitt's first actions was to appoint Thomas E. Lovejoy, the Smithsonian's Assistant Secretary for External Affairs, as DOI science advisor.

The DOI implementation proposal states that "NBS will include a National Biological Technical Center to transfer research results to users, and a network of state units to provide local research support and technical assistance and information transfer." Considering the controversy surrounding the National Science Foundation and its perceived failure to facilitate technology transfer, it's easy to understand the importance of these provisions in the NBS proposal. The proposal also describes both a science board and a policy board on research needs and priorities. The policy board will be staffed by DOI bureau representatives, and the science board will be composed of "scientists from other Federal agencies, States, and academia."

In February, Secretary Babbitt sought the assistance of the National Academy of Sciences' National Research Council in the development of the NBS. Babbitt requested that the council establish a Committee on the Formation of the National Biological

Survey to evaluate the NBS concept. The committee, which issued its findings in a report, *A Biological Survey for the Nation*, released on October 5, was asked to evaluate five questions: (1) What should a biological survey for the nation entail? (2) What should the NBS in the DOI be, if it is to serve the needs of the department? (3) How should information relevant to the survey be managed? (4) How can existing and

new survey-related activities and information be made most useful for policy, management, and scientific purposes within and outside the DOI? (5) How can federal and other entities best collaborate for these purposes? It is interesting that the charge to the committee did not request an evaluation of whether the NBS was needed or should exist. It is clear that the decision to form the NBS had been made by President Clinton and Secretary Babbitt before the National Academy of Sciences, the National Research Council, and the Smithsonian were contacted.

The 205-page National Research Council report presents 47 specific recommendations to implement the NBS, including more than a dozen focused on the formation and operation of a National Partnership for Biological Survey, a partnership led by the NBS, that would pull together "federal, state, and local agencies; museums; academic institutions; and public and private organizations" for gathering information to prevent costly environmental confrontations over the nation's plant and animal life.

According to Committee Chairperson Peter Raven, director of the Missouri Botanical Garden, "The partnership goes one step further towards preventing the many 'economic and environmental train wrecks' Interior Secretary Babbitt pointed to when he first proposed the National Biological Survey."

DOI plans called for the NBS to be operational on October 1, 1993, the start of Fiscal Year 1994. Delays in finalizing the FY94 DOI budget and concerns raised in Congress about NBS employees violating the rights of private property owners and about the NBS becoming the federal government's endangered species police substantially delayed the finalization of the establishment of the NBS. As we go to press, the NBS has not yet been formalized. ■

### CORRECTIONS

In the November issue, the statement on p. 295 "Initially published in Summer 1993 issue of *AEG News*" should have appeared with the 1994 Jahns Lecturer article on p. 283 of that issue.

In the listing of recipients of research grants awarded by GSA divisions and sections that was published in the October issue of *GSA Today*, the name of one recipient was inadvertently not included. Sharon Stern, University of Kansas, Lawrence, received a grant from the South-Central Section for her project titled "The Timing and Nature of Deformation in the Riverside Mountains, Southeastern California." We apologize for this omission.



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**

# 1994 GEOVENTURES (to date)

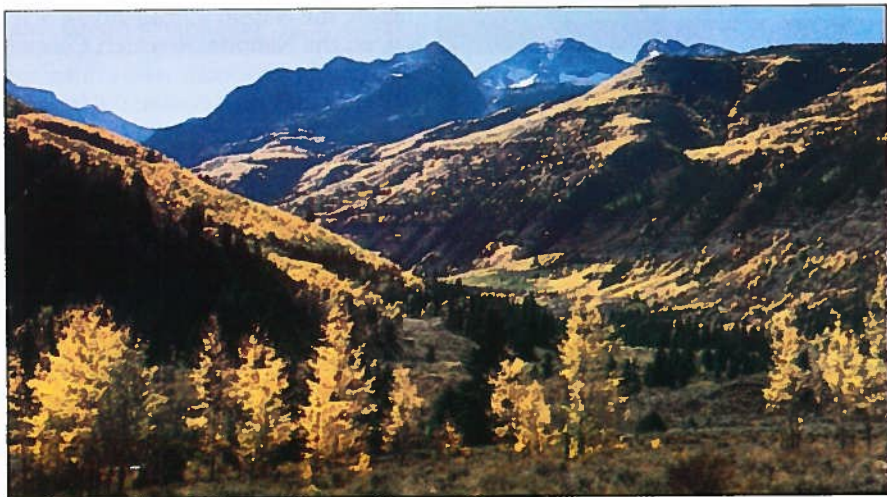
## GEOHOSTEL

### Central & Southwestern Rockies: Gunnison, Colorado

Lodging at Western State College

JUNE, 5 days

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



## GEOTRIPS

### Canyonlands and the Colorado

Starting from Moab, Utah

MAY, 9 days

Leaders: William K. Hamblin, Emeritus, Brigham Young University  
Kenneth Kolm, Colorado School of Mines

### Transect Across the Southern Canadian Cordillera: A Cross-Section through a Convergent Margin. Calgary to Vancouver

AUGUST, 14 days

Scientific leaders from Canadian universities and the Geological Survey of Canada to be announced.

Full information appears in the January issue of GSA Today

REGISTRATION BEGINS JANUARY 4, 1994  
Call 1-800-472-1988 or (303) 447-2020  
fax 303-447-0648

## GSA and AAAS Sponsor Seminar on Evolution and Extinction

About 20 eminent geologists and biologists will speak at a three-day seminar, "Evolution and Extinction," in San Francisco February 21-23, 1994. The seminar, cosponsored by GSA and the American Association for the Advancement of Science (AAAS), will be held in conjunction with the AAAS annual meeting (February 18-23). John G. Weihsaupt, University of Colorado, Denver, is the organizer of the seminar. Subseminars and keynote addresses will deal with current issues and concepts of evolution and extinction as revealed in the paleontological and geologic records from early Precambrian to Holocene time.

### PROGRAM

#### Day 1

**Monday, Feb. 21:**

#### Evolution: Initial Conditions

Following an introduction by John G. Weihsaupt (University of Colorado), Andrew H Knoll, Harvard University, will lecture and conduct the first seminar session on the origin, early evolution, and diversity of Earth life. Stuart A. Kaufman of the Santa Fe Institute will then deliver a keynote address on self-organization and selection in evolution. Next will be a seminar session conducted jointly by Jeffrey S. Levinton, SUNY—Stony Brook, and Stephan Bengtson, University of Uppsala, on the role of sensitive dependence on initial conditions in evolution. George Boyajian, University of Pennsylvania, and J. T. Fraser, International Society for the Study of Time, will conduct the day's closing session on the role of time in evolution.

#### Day 2

**Tuesday, Feb. 22:**

#### Extinction: Causes and Consequences

Frank Asaro, Lawrence Berkeley Laboratory, and Richard A. Muller, University of California, Berkeley, will present a session on the role of astronomic events in extinctions. This will be followed by a session on the role of geologic events in extinctions, presented by Keith Rigsby, Notre Dame University; Gary Landis, U.S. Geological Sur-

vey, Denver; and Alan Rice, University of Utrecht. Norman L. Gilinsky, Virginia Polytechnic Institute, will give a keynote address on the role of alternative environments in evolution and extinction, to be followed by a session on the role of biological factors in extinctions led by Daniel Simberloff, Florida State University. Jane Lubchenco, Oregon State University, Annette Olson, University of Washington, and Linda Graham, University of Wisconsin, Madison, will conduct the day's closing session on evolutionary patterns and alternative life histories of algae.

#### Day 3

**Wednesday, Feb. 23:**

#### Evolution and Extinction: Principles and Projections

The first session, led by Paul S. Martin, University of Arizona, and David Stedman, New York State Museum at Albany, will deal specifically with human impact on extinctions during the Pleistocene. This session will be followed by one on human impact on extinctions on contemporary Earth, led by Stuart Pimm, University of Tennessee; David Skole, University of New Hampshire; and Norman Myers, Oxford University. William J. Schopf, UCLA, will then deliver a keynote address on emerging principles from our knowledge of evolution and extinction in the paleontological record. The afternoon session will begin with presentations on escalation of and biological factors in evolution, by Patricia Kelley, University of North Dakota, and Thor Hansen, Western Washington University. The concluding session will provide a glimpse of the enormous potential of biologic matter in a session conducted by David Des Marais and Jack Farmer, NASA—Ames Research Center, on projections of evolutionary trends and potentials on other terrestrial bodies, with a focus on the planet Mars.

A poster session will be offered by interested seminar registrants not presenting seminar or keynote addresses. Those interested in attending the seminar should contact the AAAS Meetings Office, 1313 H Street, NW, Washington,

DC 20005. Registrants who wish to make poster-session presentations should direct their inquiries to Sue O'Connell (at AAAS address given),

along with a title and abstract not to exceed 500 words. Other inquiries can be directed to John G. (Jack) Weihsaupt at (303) 556-2276. ■

*The Geological Society of America*

## Research Grants Program 1994



The primary role of the Research Grants Program is to provide partial support for research by graduate students at universities in the United States, Canada, Mexico, and Central America. GSA strongly encourages women, minorities, and persons with disabilities to participate fully in this grants program. Eligibility is not restricted to GSA

members. New application forms are available each fall in the geology departments of colleges and universities offering graduate degrees in earth sciences. Forms are mailed annually to GSA Campus Representatives and department secretaries and chairmen in the United States, Canada, and Mexico. They are also available upon request from the Research Grants Administrator, Geological Society of America, P.O. Box 9140, Boulder, Colorado 80301. Please use only the 1994 application and appraisal forms.

Confidential evaluations from two faculty members are required from candidates for the M.S. or Ph.D. degree and must accompany applications submitted. PLEASE USE THE "APPRAISAL OF APPLICANT" FORMS, WHICH ACCOMPANY THE 1994 APPLICATION FORMS. Application forms will not be accepted by facsimile.

The Geological Society of America awarded \$257,882 in grants in 1993. The grants went to 178 students doing research for advanced degrees. The average amount awarded was \$1449. The largest grant was \$2200, but there is no predetermined maximum amount.

The Committee on Research Grants will meet in March to evaluate applications and award grants. In April, all applicants for grants will be informed of the committee's actions by the Executive Director of the Geological Society of America.

ALL APPLICATIONS MUST BE SUBMITTED ON THE 1994 FORMS  
AND POSTMARKED BY FEBRUARY 15, 1994

## GSAF UPDATE

Robert L. Fuchs

### A Potpourri of Tax Planning Ideas

December always seems to be a time for financial soul-searching, and this year is certainly no exception. Tax rates for 1993 are higher, but not necessarily for all taxpayers. Each personal situation deserves careful analysis.

Charitable contributions remain one of the few deductions available to reduce one's tax liability. The 1993 changes made by Congress through what is officially called "The Omnibus Budget Reconciliation Act of 1993" not only preserved the substantial tax advantages for charitable gifts, they actually improved the climate for giving by eliminating alternative minimum tax as a hindrance to contributing appreciated assets.

Direct gifts of cash are the most common form of contribution to the GSA Foundation. Such gifts may be made unrestricted to GSA or to the Foundation, or designated for any of a number of special funds such as Research Grants, Publications, Headquarters Addition, SAGE, and IEE.

Gifts of appreciated securities produce a double tax benefit for the donor. First, there is a current tax deduction, the amount of which is equal to the value of the securities on the day of the transfer to the Foundation. Second, the donor pays no capital gains tax as a result of the transaction, even though there may have been a significant gain on paper. Similar attributes apply to gifts of personal property, such as works of art, and to gifts of real estate.

Life insurance can be an excellent year-end gift. If a policy is no longer needed for family financial security, a transfer of ownership to the Foundation will allow a 1993 deduction equal to the fair market value of the policy. Payment of future premiums by the donor will create deductions in the years paid.

Planned giving is the current gift of a future interest. By making a planned gift the donor can receive annual income for life as well as a tax deduction at the time of the gift. The amount of the tax deduction is an actuarial calculation based on the life expectancy of the donor and the projected income stream. In essence it is the present value of a future gift to the Foundation at the time of the donor's death.

The principal tools of planned giving are the pooled income fund, the charitable remainder trust, and the charitable gift annuity. The GSA Foundation Pooled Income Fund is for contributions in the \$5000 to \$50,000 range, pays income quarterly, and can be easily augmented with subsequent contributions. Larger gifts can form the basis of charitable remainder annuity trusts, which pay a fixed amount in regular payments, or unitrusts, which pay a percentage of the trust's value. Finally, there is the charitable gift annuity, in which the Foundation agrees to make annual payments for life in return for the donor's contribution.

Information about any of these gift ideas can be obtained by calling the GSA Foundation office at 1-800-472-1988.

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

Co-sponsored by University of Arizona,  
Arizona Geological Survey, and  
Arizona Geological Society

February 22-25, 1994  
Tucson Convention Center  
Tucson, Arizona

#### 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

### Facts about Taxes

If your will directs that charitable contributions be made from your estate, and if you have one or more IRAs or similar tax-advantaged plans, here is a hint that will save your surviving spouse and heirs some money.

Use an IRA as the source for charitable contributions. If such a tax-sheltered plan is willed to an individual, the heir will pay taxes on the difference between your total contributions and the value of the plan. By using the IRA as the source for charitable gifts, you ensure that the full value of the bequests will pass to the institutions. This results from the tax-free status of the GSA Foundation and similar organizations. ■

## Ground-Water Modeling Software

IGWMC distributes over 100 ground-water modeling software packages and data sets. Software purchases include complete documentation and user support.

#### Our collection includes:

- Enhanced public domain software
- Third party proprietary software
- Numerical and analytical models
- Preprocessors and menu systems
- Historical software
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#### Reminder:

All 1993 contributions to the Foundation must be postmarked no later than midnight, December 31.

## Alternates Receive Research Grants

Each year the Committee on Research Grants selects recipients for grants up to the maximum amount of funding available for that year. An alternate group of recipients is also selected in the event that some of the grantees return part or all of their funds due to their having received funding elsewhere or a change in their research plans. As the returned funds become available they are re-awarded by the Research Grants Administrator to the alternates named by the committee.

In 1993 six alternates received funding following the initial awarding of grants. They are: Kenneth L. Copenhaver, Indiana State University, Terre Haute; Stephen C. Kuehn, Washington State University, Pullman; Rebecca Olivia Ramirez, New Mexico State University, Las Cruces; Kim Ternes, University of Missouri, Columbia; Ricardo Torres, University of Arizona, Tucson; John R. Williams, University of North Carolina, Chapel Hill.



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# General Statement of the 1994 Scientific Theme and Suggestions for Theme Topics

Mark S. Ghiorso and Thomas Dunne,  
Department of Geological Sciences, University of Washington  
1994 Technical Program Chairmen

Geology "At the Leading Edge" will be the scientific theme of the 1994 GSA Annual Meeting in Seattle. The theme will draw emphasis both to the geographical position of Seattle, situated on the leading edge of a convergent plate margin, and to the application of "leading edge" theoretical approaches and technological advances to the elucidation of geological problems. Theme sessions and symposium proposals are sought in all aspects of Pacific Rim and convergent margin geology, with particular emphasis on the utilization of new technology. The 1994 Annual Meeting Committee will sponsor a GSA Symposium entitled "The Birth and Death of a Plate," which will include invited talks on topics such as arc volcanism, kinematics of plate motion, accretionary wedges, and evolution of ocean ridge spreading centers. Speakers will illuminate these issues with results from remote sensing, geodesy, seismic imaging, experimental studies of geologic materials, and computational advances in modeling geologic systems. The 1994 Annual Meeting Committee proposes to have several more informal evening sessions aimed at bringing attendees up-to-date on new techniques such as GIS (Geographical Information Systems), GPS (Global Positioning System), and major nationally funded research projects such as the RIDGE initiative and the Continental Drilling Program. The 1994 GSA Annual Meeting in Seattle promises an exciting opportunity to discuss important geological questions in a nontraditional way.

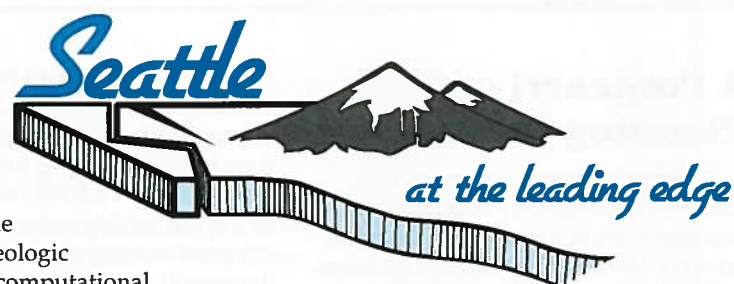
We call for innovative theme session and symposium proposals on issues that illuminate the geology of the entire Pacific rim. To this end we invite proposals on topics such as arc volcanism, kinematics of plate motion, displacements along faults, accretionary wedges, fold and thrust belts, seismic and aseismic margins, large-scale intense geomorphologic processes, volcanic and earthquake hazards, and the chemistry of the oceans and of volcanoes. Additionally, we encourage proposals that demonstrate approaches to the solution and investigation of these geological issues using modern theoretical, experimental, and observational methods. Approaches we would like to see highlighted include remote sensing, geodesy and seismic imaging, experimental studies of rock and material deformation, experimen-

tal studies of the properties of geologic materials, and computational advances in modeling geologic systems.

We encourage interdisciplinary proposals, and we invite GSA divisions and associated societies to coordinate activities and consider joint sponsorship of symposia and theme sessions. Additionally, a large division or associated society might want to consider the possibility of generating a matrix structure for their technical sessions. Each day an "approach" (e.g., computational advances) would be applied to several relevant issues. For example, Monday might be remote-sensing day, and the Structure and Tectonics Division might have sessions on aseismic margins, plate motion, fold and thrust belts, etc., that emphasize investigation using techniques from remote sensing. This matrix structure could be accomplished by coordinating sponsored symposia and themes and by soliciting theme proposals and advocates from the division or society membership in a coordinated way consistent with the programmatic objectives. The 1994 Program Committee would be happy to help division or associated society representatives in these efforts and will assist in coordinating activities across divisions and societies.

In summary, we want to see GSA's divisions and associated societies come to Seattle in 1994 excited by the prospect of a technical program that embodies the state-of-the-art in their science. Carefully constructed and coordinated symposia and themes go a long way toward making this possible, because they focus membership attention on relevant issues and automatically organize abstract submission into topical groupings.

Please take the time now to consider your symposia and theme session proposals in the context of the entire technical program for 1994. We hope the 1994 theme, "At the Leading Edge," gives you an exciting context upon which to build your proposals. ■



## How to Propose Theme Sessions for the 1994 GSA Annual Meeting

Deadline for proposals: January 4, 1994 — Please submit with Theme Proposal Form

### THEME SESSION GUIDELINES

Theme sessions are topically focused but do not require formal sponsorship by an organization. The stronger theme sessions, however, do benefit from active support (hard work) by those interested in the success of the session. Theme sessions are a way of arranging *volunteered* abstracts into interdisciplinary groupings that make for scientific sense.

The sessions, which can be either oral or poster but not mixed, have variable lengths depending on the submitted number of pertinent and high-quality abstracts. However, a *minimum of eight oral or eight poster abstracts is required for either an oral or a poster theme session. If, at the abstracts deadline, sufficient abstracts have not been received, the theme session will be dropped, and the papers continued in the review process for standard discipline sessions.*

Persons or groups who wish to nominate a theme session should:

1. **Designate a theme session advocate.** This person would encourage (*not invite*) abstracts that will fit the theme session's concept. Society or division membership may help the advocate in this process. No doubt, when the theme session title is announced, other papers will be voluntarily submitted in addition to those that were solicited or intended. The theme session advocate will serve as liaison with GSA's Joint Technical Program Committee (JTPC). Therefore, the name of the

theme session advocate should be included with the proposal. The theme session advocate will generally contribute an abstract to the session and (for oral presentations) will usually assume the responsibility of session chairman. The theme session advocate will not otherwise be identified or linked to the theme session in the published *Abstracts with Programs* volume.

2. After choosing a theme title, *select no more than three of the categories that are listed in the right-hand margin of the 1994 Abstract Form.* These should be the categories that best describe the

interdisciplinary aspects of the theme session. Pick carefully, *because authors who submit abstracts to a theme session will need to select both the theme session and one of the abstract categories.*

3. **Choose a presentation mode.** The standard modes of presentation are *half-day oral or poster sessions scheduled Monday through Thursday.* Theme modes are to be either all poster or all oral, not mixed. Between 8 and 16 papers are presented. If many more papers are submitted, a second session on the same topic may be scheduled.
4. **Fill in the cover sheet (available from the GSA Meetings Department) and send it with your proposal.** Particularly, include a brief (50 words) description of the theme session. It will be used for publication later, in the Call For Papers in *GSA Today* and other GSA mailings.

Items 1, 2, 3, and 4 must be completed and communicated to JTPC prior to January 4, 1994.

5. **Review abstracts for topicality.** Immediately following the July 6, 1994, abstract submittal deadline, the theme session advocates will be given ONE day to evaluate all abstracts submitted to their themes and select for appropriateness. *These are not decisions based on quality, but only on how well papers fit into the theme.* Note that this is the first time advocates will become aware of abstracts voluntarily submitted to the theme. The advocate should not reject appropriate abstracts simply because their number exceeds expectations. More than one session can be warranted if there are enough abstracts. Those papers that are re-

jected by the advocate as inappropriate will be considered by JTPC for sessions related to the discipline category checked by the author.

6. **Review abstracts for scientific quality.** Abstracts (including those for the theme session) will next go out for review for *quality.* The members of the JTPC will be responsible for obtaining reviews of these abstracts. These reviewers are not named by the advocate, but chosen by the JTPC organizations.

The theme session advocate will be the fourth reviewer and will have the opportunity at this time to arrange the abstracts he or she has deemed appropriate into a tentative order of presentation. This will aid the JTPC in scheduling the presentation order of abstracts for the theme session.

**Remember: Abstracts submitted for theme sessions are not invited. None can be guaranteed acceptance.**

The JTPC meeting on August 5-6, 1994, will arrange the technical program for the 1994 Annual Meeting. In this task, the JTPC will keep in mind suggestions from various societies and divisions as well as those from theme session advocates in an attempt to accommodate the needs and desires of as many persons as possible. *The theme advocate does not control the time or date of the session.* Theme sessions are scheduled Monday through Thursday. *Quality of the technical program as a whole, however, will take precedence over all other considerations.* The selection of an appropriate time slot for any theme session will be arrived at after consultations with the JTPC representatives and the Technical Program Chairmen. ■

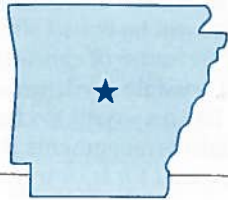
Call GSA Meetings Department today  
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**1994 THEME  
PROPOSAL FORM.**

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# SOUTH-CENTRAL SECTION, GSA 28th Annual Meeting

Little Rock, Arkansas  
March 21-22, 1994



The South-Central Section of the Geological Society of America, the Texas Section of the National Association of Geology Teachers, and the South-Central Section of the Paleontological Society will meet in Little Rock, Arkansas, March 21-22, 1994. The meeting is sponsored by the Department of Earth Science of the University of Arkansas at Little Rock, the Arkansas Geological Commission, and the geology department of Arkansas Tech University.

## ENVIRONMENT

Little Rock, the capitol of Arkansas, is located in the center of the state, on the south bank of the Arkansas River. The city was incorporated on October 7, 1831. It was named from an outcrop, known as "La Petit Roche," of Jackfork Sandstone on the south bank of the Arkansas River. Farther up the river on the north side, there is a bluff in the Jackfork known as "Big Rock." The city lies on the Fall Line between the Paleozoic rocks of the eastern Ouachita Mountains and the unconsolidated sediments of the Mississippi embayment.

The population of Little Rock is 187,413, but the population of the Greater Little Rock metropolitan area is over 500,000. The temperature in March should average about 70 °F.

The University of Arkansas at Little Rock (UALR), a part of the University of Arkansas system since 1969, is located on a 150-acre campus in west-central Little Rock. Enrollment for the 1993-1994 year is more than 12,000 students. The Earth Science Program was instituted in 1973, and in 1993 the Department of Earth Science conferred its first B.S. degree in geology. The department currently has 18 geology majors.

The Arkansas Geological Commission is an agency of state government and has the primary responsibility of providing geological, hydrological, and mineral-resource information on Arkansas. Norman F. Williams is the State Geologist.

Arkansas Tech University (ATU), founded in 1909, is located 75 miles west of Little Rock on a 517-acre campus in Russellville, Arkansas. Current enrollment is more than 4500. ATU granted its first B.S. degree in geology in 1962; currently, there are 20 geology majors.

## REGISTRATION

Preregister today! Preregistration deadline is *February 18, 1994*. Preregistration will be handled by the local committee. Use the registration form provided in this announcement. For lower registration fees for yourself and to assist the local committee in planning, please preregister.

### REGISTRATION FEES

	Advance (by Feb.18)	On-site	One day advance	One-day on-site
Professional Member	\$45	\$55	\$30	\$35
Professional Nonmember	\$60	\$70	\$35	\$40
Student Member	\$25	\$25	N/A	N/A
Student Nonmember	\$30	\$30	N/A	N/A
School Teacher	\$12	\$12	N/A	N/A
Guest	\$10	\$10	N/A	N/A

Preregistrants may pick up their registration materials at the registration desk in the lobby of the Holiday Inn West on Sunday, March 20, 1994, between 3:00 p.m. and 8:00 p.m. On-site registration will also be available at that time and will continue on Monday, March 21, 7:00 a.m. to 5:00 p.m., and on Tuesday, March 22, 7:00 a.m. to 11:00 a.m., at the registration desk.

Please note:

- Badges must be worn for access to all activities.
- Registration discounts are given to members of GSA and to members of societies associated with GSA. Associated societies that qualify for this discount are indicated on the registration form. Please indicate your affiliation(s) and member number to register at member rates. Students and secondary school teachers are given a special discount.
- Full payment must accompany registration. Unpaid purchase orders are not accepted as valid registration. Credit cards are not accepted. Your confirmation letter will be your receipt. No other receipt will be sent.
- Each professional or student registering for the meeting must send a separate registration form. Copy the form for your records.
- Guests must register to attend the Welcoming Party or any guest activity. 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.
- A current student ID is required to obtain student rates. Students must show their current ID when registering or picking up preregistration materials, or they will be required to pay the regular registration fee for professionals.

**Cancellations, Changes, and Refunds.** All requests for refunds resulting from changing or canceling registration must be made in writing and must be received by March 1, 1994 (faxes accepted). **NO REFUNDS WILL BE MADE ON CANCELLATION NOTICES RECEIVED AFTER THIS DATE.** Refunds will be mailed after the meeting. Refunds will not be given for on-site registration.

## HOUSING

Blocks of rooms have been reserved at the Holiday Inn West in Little Rock. Reservations can be made by calling or writing the hotel directly (reservation form in this announcement). You must ask for the ARK/GSA rate when reserving a room to receive the discount rate. The rooms will be held until February 26, 1994. **Reserve your room before February 26.**

**Holiday Inn West**  
201 South Shackleford  
Little Rock, AR 72211  
(501) 223-3000  
\$60, single or double  
(Housing form below)

Other motels in the local area:

**LaQuinta Inn**  
200 Shackleford Road  
Little Rock, AR 72211  
(501) 224-0900

**Motel 6**  
10524 West Markham  
Little Rock, AR 72211  
(501) 225-7366

**Budgetel**  
1010 Breckenridge Drive  
Little Rock, AR 72211  
(501) 225-7007

**Amerisuites**  
10920 Financial Centre Parkway  
Little Rock, AR 72211  
(501) 225-1075

**Courtyard by Marriott**  
10900 Financial Centre Parkway  
Little Rock, AR 72211  
(501) 227-6000.

The Holiday Inn Restaurant is open for lunch, and numerous other eating establishments are within walking distance. A list of restaurants will be included in the registration package.

## TECHNICAL PROGRAM

Papers will be presented in technical sessions, symposia, and poster sessions. All abstracts should be submitted

to William V. Bush, c/o GSA Program Committee, Arkansas Geological Commission, 3815 West Roosevelt Rd., Little Rock, AR 72204, (501) 324-9165, fax 501-663-7360.

**Symposia.** The following symposia are planned for the meetings. Please note that abstracts for symposia should be submitted directly to the Program Committee (address above), and a copy will be forwarded to the conveners. For information concerning a symposium, contact the conveners listed below.

**1. Ouachita Mountains of Arkansas and Oklahoma.** Charles G. Stone and Boyd R. Haley, Arkansas Geological Commission, 3815 West Roosevelt Rd., Little Rock, AR 72204, (501) 324-9165.

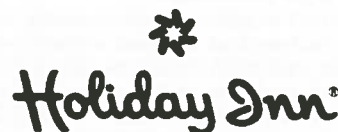
**2. Industrial Minerals with Emphasis on Diamonds.** Drew F. Holbrook, Twin City Bank Bldg., Suite 730-A, One Riverfront Pl., North Little Rock, AR 72114, (501) 372-3362; and Charles T. Steuart, Malvern Minerals Company, P.O. Box 1246, 220 Runyan St., Hot Springs, AR 71901, (501) 623-8893.

**3. New Madrid Seismic Zone.** John David McFarland III, Arkansas Geological Commission, 3815 West Roosevelt Rd., Little Rock, AR 72204, (501) 324-9165; and Roy Van Arsdale, Dept. of Geology, Memphis State University, Memphis, TN 38152, (901) 678-2177.

**4. Hydrogeology and Environmental Geology.** Kenneth F. Steele, Arkansas Water Resources Center, University of Arkansas, 113 Ozark Hall, Fayetteville, AR 72701, (501) 575-3410; and John Van Brahana, U.S. Geological Survey, WRD, University of Arkansas, 114 Ozark Hall, Fayetteville, AR 72701, (501) 575-2570.

**5. Planetary Geology in Geological Education—NAGT.** Donald Lokke, 7721 El Padra Lane, Dallas, TX 75248, (214) 239-7920.

South-Central continued on p. 308



Holiday Inn West  
201 S. Shackleford  
Little Rock, Arkansas 72211  
(501) 223-3000

Reservations will be held until 6:00 p.m. unless guaranteed by credit card or advance deposit. Checkout time is 12 Noon.

### South-Central Section • Geological Society of America March 19-23, 1994

Name \_\_\_\_\_ Arrival Date \_\_\_\_\_  
Address \_\_\_\_\_ Check-in time **3:00 p.m.**  
City, State, ZIP \_\_\_\_\_  
Telephone ( ) \_\_\_\_\_ Departure Date \_\_\_\_\_  
Names of Additional Persons Sharing Room \_\_\_\_\_  
Check-out time **12:00 noon**

Reservations Due No Later Than **February 26, 1994.**

**RATES:** Please check type of room requested at rate requested.

- \$60.00—Single Occupancy
- \$60.00—Double Occupancy (2 beds)
- \$60.00—Double Occupancy (King bed)
- \$60.00—Triple Occupancy (2 beds)
- \$60.00—Quadruple Occupancy (2 beds)
- Executive Level Single
- Executive Level Double
- Suites

I will arrive by 6:00 p.m. and do not wish to guarantee arrival after 6:00 p.m.

I will not arrive by 8:00 p.m. and wish to guarantee for late arrival by the following method.

The enclosed check for one night's stay

Credit Card Guarantee

Credit Card Name and Number Required \_\_\_\_\_

**6. GIS Technology for the Environmental Earth Sciences—IEE Symposium.**

Sponsored by the Institute for Environmental Education. Ken Morgan and John Breyer, Dept. of Geology, Texas Christian University, Box 30798, Fort Worth, TX 76129, (817) 921-7270; and Al Karlin, Dept. of Biology, University of Arkansas, 2801 South University, Little Rock, AR 72204, (501) 569-3522.

**POSTER SESSIONS**

A poster session will be held at the Holiday Inn West, Sunday night, March 20 during the Welcoming Party. Areas convenient to the technical sessions will be available Monday and Tuesday for display of posters.

**SCIENCE TEACHER WORKSHOP**

A workshop for secondary science teachers, "Earth Systems Education—

An Approach to Integrated Science Teaching," will be conducted on Sunday, March 20, at 2:30 p.m. in the Donaghey Student Center at the University of Arkansas, Little Rock. The workshop will last about 2 hours. Rene Carson, Science Coordinator, Little Rock School District, 810 West Markham St., Little Rock, AR 72207, (501) 324-0518.

**FIELD TRIPS**

Preregistration is required for all field trips. Limited space is available, and participants are accepted on a first-come, first-served basis.

All field trips begin and end at the Holiday Inn West in Little Rock. For further details contact the field-trip leaders. General questions should be directed to Mike Howard, field-trip coordinator, Arkansas Geological Commission, 3815 West Roosevelt Rd., Little Rock, AR 72204, (501) 324-9165.

Preregistration deadline: February 18, 1994. The registration form is provided in this announcement.

Cancellation deadline: February 28, 1994. No refunds will be given for cancellations received after this date. All cancellations must be in writing. If GSA must cancel a field trip due to logistics or registration requirements, a full refund will be issued after the meeting. Be aware of cancellation deadlines and possible penalties imposed by airlines. You may wish to change or cancel flight arrangements if a trip you have registered for is canceled.

**Premeeting**

- Eastern Ouachita Mountains**—with emphasis on thrust faults, nappes, quartz veins, and the Benton uplift. Sunday, March 20. Charles G. Stone and Boyd R. Haley, Arkansas Geological Commission, 3815 West Roosevelt Rd., Little Rock, AR 72204, (501) 324-9165. Cost: \$25 (includes lunch, transportation, and guidebook). Limit: 35.
- Crater of Diamonds State Park**—tour of the park and an opportunity to look for diamonds and keep what you find. Sunday, March 20.

- Karst Hydrogeology and Environmental Geology of the Southern Ozarks, Arkansas and Missouri.** Saturday and Sunday, March 19 and 20. John Van Brahana, U.S. Geological Survey, Office of Hydrogeologic Research, 114 Ozark Hall, University of Arkansas, Fayetteville, AR 72701, (501) 575-2570. Cost: \$160 (includes two lunches, one supper, transportation, one night lodging, and guidebook). Limit: 40.
- Center for Earthquake Research and Information at Memphis, Tennessee.** Sunday, March 20. John David McFarland, Arkansas Geological Commission, 3815 West Roosevelt Rd., Little Rock, AR 72204, (501) 324-9165. Cost: \$35 (includes lunch, transportation, and guidebook). Limit: 40.

**Postmeeting**

- Spillway Cut at DeGray Lake. The Jackfork Formation of Arkansas: A Test of the Walker-Mutti-Vail Models for Deep-Sea Fans.** Wednesday, March 23. James Coleman, Gordon Van Swearingen, and Curtis Breckon, AMOCO, Houston, Texas, (713) 366-3970. Cost: \$30 (includes lunch, transportation, and guidebook). Limit: 40.
- ALCOA—Bauxite Mines.** Wednesday, March 23. Jarvis Harper, ALCOA, P.O. Box 300, Bauxite, AR 72011, (501) 776-4907. Cost: \$20 (includes lunch, transportation, and guidebook). Limit: 40.
- Industrial Minerals, Central and West-Central Arkansas.** Wednesday, March 23. Charles Steuart, Malvern Minerals Company, P.O. Box 1246, Hot Springs, AR 71901, (501) 623-8893. Cost: \$30 (includes lunch, transportation, and guidebook). Limit: 40.

**PROJECTION EQUIPMENT**

Two slide projectors, one overhead projector, and two screens will be set up for each technical session and symposium. All slides must be 2" x 2" and fit in standard carousel trays. Only a small number of slide trays will be available. Please bring your own slide trays, if at all possible. A speaker's viewing and rehearsing room will be available adjacent to the meeting rooms.

**EXHIBITS**

Exhibits of interest to geologists in industry, academia, and public service will be on display in the lobby of the Holiday Inn West. The exhibits will be open for viewing on Monday and Tuesday, March 21 and 22, from 8:30 a.m. until 5:00 p.m. Exhibit fees and information can be obtained from the Exhibits Committee: Bill Prior or Doug Hanson, Exhibits Coordinators, Arkansas Geological Commission, 3815 West Roosevelt Rd., Little Rock, AR 72204, (501) 324-9165, fax 501-663-7360.

**STUDENT AWARDS**

Cash awards of \$200, \$100, and \$50 will be made for the three best student papers given at the meeting. An award of \$200 for the best student poster will also be given. Awards for outstanding papers will be based on quality of research and effectiveness of presentation. To be eligible, the

**Preregistration Form**

**GSA South-Central Section**  
Little Rock, AR • March 21–22, 1994

Preregistration deadline is February 18, 1994.

Please print clearly. This area is for your badge.

Name as it should appear on your badge \_\_\_\_\_

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

City \_\_\_\_\_ State \_\_\_\_\_

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 will need services to accommodate a disability  Yes

Circle member affiliation (to qualify for registration discount):

(A) GSA Member # \_\_\_\_\_, (B) NAGT Member # \_\_\_\_\_, (C) PS Member # \_\_\_\_\_

Guest information. Please print clearly. This area is for your badge.

Name as it should appear on your badge \_\_\_\_\_

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

**PREREGISTRATION**

	Full Meeting	Qty	One Day	Qty	Amount
Professional Member*	\$ 45 <input type="checkbox"/>	1	\$ 30 <input type="checkbox"/>	1	\$ _____
Professional Nonmember	\$ 60 <input type="checkbox"/>	1	\$ 35 <input type="checkbox"/>	1	\$ _____
Student Member*	\$ 25 <input type="checkbox"/>	1	N/A	1	\$ _____
Student Nonmember	\$ 30 <input type="checkbox"/>	1	N/A	1	\$ _____
Science Teacher**	\$ 12 <input type="checkbox"/>	1	N/A	1	\$ _____
Guest/Spouse	\$ 10 <input type="checkbox"/>	1	N/A	1	\$ _____

\*Member fee applies to any existing professional OR Student Member of GSA or Associated Societies listed above. Discounts do not apply to guest registrants.

\*\*Science Teacher workshop on Sunday, March 20, 1994 is included in Science Teacher registration. Indicate below whether you plan to attend the workshop.

Will attend the Science Teacher workshop.  Yes  No

**SPECIAL EVENTS**

Banquet	March 21	\$ 18	1	\$ _____
Paleontological Section Luncheon	March 21	\$ 12	1	\$ _____
Texas Section NAGT Luncheon	March 22	\$ 12	1	\$ _____

**FIELD TRIPS**

Premeeting				
1. Eastern Ouachita Mountains	March 20	\$ 25	1	\$ _____
2. Crater of Diamonds	March 20	\$ 30	1	\$ _____
3. Karst, North Arkansas	March 19–20	\$160	1	\$ _____
4. Earthquake Center	March 20	\$ 35	1	\$ _____
Postmeeting				
1. Jackfork Formation	March 23	\$ 30	1	\$ _____
2. ALCOA—Bauxite	March 23	\$ 20	1	\$ _____
3. Industrial Minerals	March 23	\$ 30	1	\$ _____

**TOTAL FEES** .....

Remit in U.S. funds payable to:

1994 GSA South-Central Section Meeting

(All preregistrations must be prepaid. Purchase Orders or credit cards not accepted.)

**MAIL TO: GSA South-Central Section Meeting**  
c/o Arkansas Geological Commission  
3815 West Roosevelt Rd.  
Little Rock, AR 72204

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Check # \_\_\_\_\_

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abstract form must list only students as authors and must clearly identify the abstract as a student paper. For further information, contact Philip Kehler, Dept. of Earth Science, University of Arkansas, 2801 South University, Little Rock, AR 72204, (501) 569-3545, fax 501-569-8020.

**STUDENT SUPPORT**

Funds are available for travel grants for students who are making presentations at the meeting. Students are encouraged to apply for these travel grants, and we hope to be able to provide some support to all students who are eligible. Application for support should be made to Philip Kehler, Dept. of Earth Science, University of Arkansas, 2801 South University, Little Rock, AR 72204, (501) 569-3545, fax 501-569-8020. Letters of application should include a copy of the abstract and must be received by February 18, 1994.

**SPECIAL EVENTS**

**Welcoming Party and Poster Session**

A welcoming party will be held at the Holiday Inn West from 5:30 to 8:00 p.m., Sunday, March 20. A cash bar will be open, and light snacks will be served. Poster sessions will be held at this time and also displayed during the technical sessions.

**Banquet**

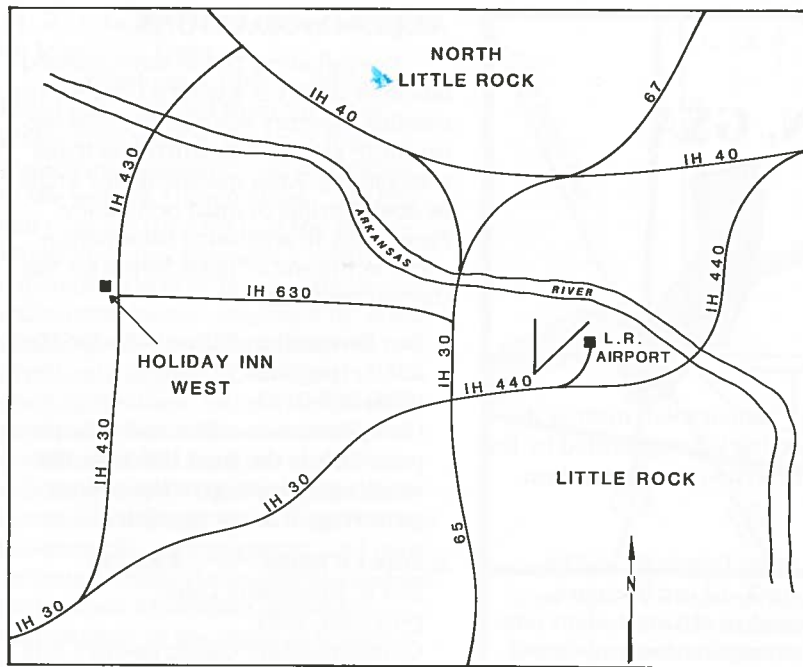
The annual banquet will be held at the Holiday Inn West on Monday, March 21. A cash bar will open at 6:00 p.m. and dinner will begin at 7:00. Cost is \$18. Use the preregistration form to purchase tickets. Preregistration is required.

**Paleontological Society Luncheon**

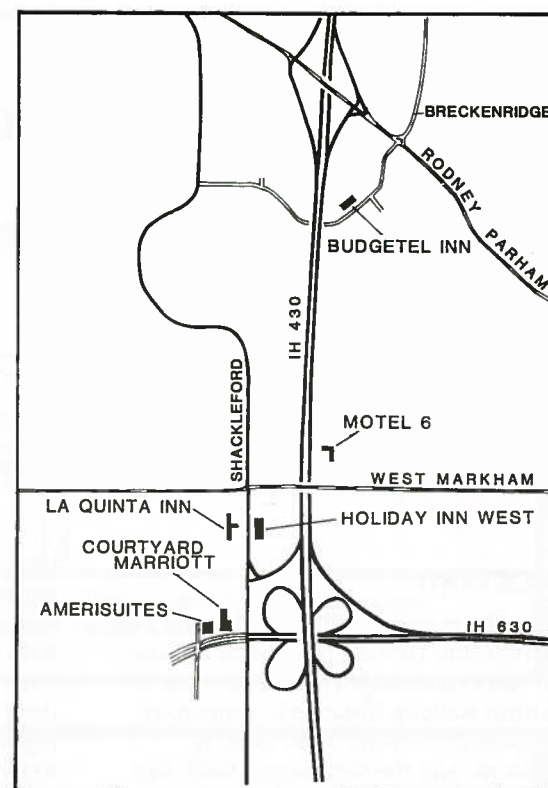
The South-Central Section of the Paleontological Society will hold a luncheon at noon on Monday, March 21, at the Holiday Inn West. The annual business meeting will follow immediately. For more information, contact Walter Manger, Dept. of Geology, University of Arkansas, 118 Ozark Hall, Fayetteville, AR 72701, (501) 575-3370. Cost is \$12. Use the preregistration form to purchase tickets. Preregistration is required.

**Texas Session—NAGT Luncheon**

The Texas Session of the National Association of Geology Teachers (NAGT) will hold a luncheon at noon



**GREATER LITTLE ROCK**



on Tuesday, March 22, at the Holiday Inn West. The annual business meeting will follow immediately. For more information, contact Donald F. Reaser, Dept. of Geology, University of Texas, Arlington, TX 76019, (817) 273-2987. Cost is \$12. Use the preregistration form to purchase tickets. Preregistration is required.

**TRANSPORTATION**

Little Rock is served by the Little Rock Municipal Airport. After landing you can arrange to take a taxi to the hotel or call the Holiday Inn West for a van to pick you up. The trip from the airport takes about 20 minutes.

The Holiday Inn West is located at the intersection of I-630 and I-430 (see map). Parking should not be a problem. People attending the meeting will be able to park free in the hotel parking lot.

**BUSINESS MEETINGS**

**GSA South-Central Section Management Board.** The management board will meet on Sunday, March 20, at 4:30 p.m.

**GSA South-Central Section Business Meeting.** The annual business meeting of the South-Central Section will take place on Monday, March 21, following the last session, at about 5:00 p.m.

**South-Central Section Education Committee.** There will be a business meeting of this newly formed committee. Time and room will be listed in the registration package.

**GUEST PROGRAM**

We look forward to seeing you in Little Rock. We have two days, Monday, March 21, and Tuesday, March 22, of appropriate activities planned for your enjoyment.

1. Daily tours of the Arkansas Geological Commission, Geology Learning Center.
2. Tour of the Territorial Capitol Restoration, old state capitol, and new state capitol.
3. Van rides available daily to local shopping malls.

**ADDITIONAL INFORMATION**

For additional information concerning the technical program, please contact William V. Bush, Arkansas Geological Commission, 3815 West Roosevelt Rd., Little Rock, AR 72204, (501) 324-9165, fax 501-663-7360; or Philip Kehler, Dept. of Earth Science, University of Arkansas, 2801 South University, Little Rock, AR 72204, (501) 569-3545, fax 501-569-8020. Inquiries about field trips should be directed to the field trip leader or to Mike Howard, field trip coordinator, Arkansas Geological Commission, 3815 West Roosevelt Rd., Little Rock, AR 72204, (501) 324-9165, fax 501-663-7360. Please call the hotels or motels directly for information about the availability of rooms. ■

**ORDER FORM—1994 GSA Abstracts with Programs**

For advance-copy purchases of *GSA Abstracts with Programs*, use this form and submit by the deadline listed for each section (deadlines vary). *Prepayment is required.* **Members**, check your records to make sure that you have not previously purchased any of these publications on either your dues statement or through Publication Sales. **No refunds for duplicate orders.** The *Abstracts with Programs* books will be mailed about three weeks prior to the meeting.

Meeting	Deadline	Price	Quantity	Amount
South-Central	1/12/94	\$10		\$
Cordilleran	1/20/94	\$10		\$
Northeastern	1/28/94	\$10		\$
Southeastern	2/3/94	\$10		\$
North-Central	3/2/94	\$10		\$
Rocky Mountain	3/8/94	\$10		\$
Annual Meeting (Seattle)	8/18/94	\$22		\$
<b>Total</b>				<b>\$</b>

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# CORDILLERAN SECTION, GSA 27th Annual Meeting

San Bernardino, California  
March 21-23, 1994



The Cordilleran Section of the Geological Society of America will meet at the San Bernardino Hilton in San Bernardino. The meeting is being hosted by the Department of Geological Sciences, California State University, San Bernardino.

## SETTING

The meeting will be held at the San Bernardino Hilton on Hospitality Lane in San Bernardino. The meeting site is within walking distance to numerous restaurants, several other lodging options, and the San Jacinto fault. San Bernardino is on the south side of the Transverse Ranges, formed by a constraining bend in the San Andreas fault. These ranges contain the three highest peaks in southern California: Mt. San Geronio (11,502'), Mt. San Jacinto (10,831'), and Mt. San Antonio (a.k.a. Mt. Baldy, at 10,080'), all of which are visible from the Hilton. The active tectonics in southern California give this area a dramatic and highly varied landscape: beach, desert, and alpine environments are all within a 1-2 hour drive from San Bernardino. The weather in late March is pleasant and/or interesting, with an average high of 66 °F, and an average low of 54 °F. The area receives an average of 3.25 inches of rain in March. Access to San Bernardino is easy; Interstate 10 passes east-west through San Bernardino, and Interstate 215 (a branch of I-15) passes north-south. The two intersect just west of the Hilton. For other modes of transportation, Ontario Airport is the closest airport, and San Bernardino has an Amtrak station. See below for specific information.

## REGISTRATION

**Preregister today! Preregistration deadline: February 11, 1994**

1. Considerable savings in registration fees accompany preregistration. Advance registration is strongly suggested for all field trips and many of the special activities because of the limited space available. Use the preregistration form provided in this announcement.
2. Badges must be worn for access to ALL activities.
3. Registration discounts are given to members of GSA, the National Association of Geology Teachers, the Paleontological Society, and the Society of Vertebrate Paleontology. Please indicate your affiliation(s) and member number and register using the

member rates. Proper ID will be required for K-12 earth science teachers, and to obtain student rates both for preregistration and on site. Students not carrying a current student ID when they arrive to pick up registration materials will be required to pay the professional fee.

4. Full payment MUST accompany registration. Unpaid purchase orders are NOT accepted as valid registration. Charge cards are accepted as indicated on the preregistration form. Please recheck the charge card number given—errors will delay your registration. Your confirmation letter from GSA will be your only receipt.
5. Register one professional or one student per form. Copy the form for your records.
6. Guest registration is required to attend activities or to visit the exhibit hall. To obtain the guest rate, all guests must be accompanied by either a registered professional or student.
7. Preregistration forms received after the February 11 deadline will be charged the on-site rates.

## CANCELLATIONS, CHANGES, AND REFUNDS

All requests for registration additions, changes, and cancellations must be made in writing and received by the GSA Registration Coordinator by February 18, 1994. NO REFUNDS 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 Hilton Hotel Foyer

Sun., March 20, 2:00 p.m. to 8:00 p.m.  
Mon., March 21, 7:30 a.m. to 5:00 p.m.  
Tues., March 22, 7:30 a.m. to 5:00 p.m.  
Wed., March 23, 7:30 a.m. to 12:00 noon

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

## REGISTRATION FEES

	Advance*		On site	
	Full Meeting	One day	Full Meeting	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
K-12 Earth Science Teachers	\$10		\$10	
Guest	\$10		\$10	
Field Trip Only	\$15		\$15	

\*Deadline is February 11, 1994.

## ACCOMMODATIONS

The following hotels have reserved blocks of rooms at a reduced rate for the meeting. Identify yourself as a GSA registrant to get this rate when you make reservations. Rates quoted are for single or double/triple or quad occupancy. Please refer to additional information codes at the end of hotel listing for further information.

1. **San Bernardino Hilton**<sup>1,2,3</sup>—\$65/\$65  
285 E. Hospitality Lane  
(909) 889-0133  
Complimentary coffee and newspapers. **This is the host hotel for the meeting—please give them your patronage if at all possible.**
2. **Super 8 Motel**<sup>2,3,4,5</sup>—\$40/\$40  
294 E. Hospitality Lane  
(909) 381-1681  
Complimentary coffee, pastries, and newspapers.
3. **Travelodge**<sup>2,3,4</sup>—\$36/\$45  
225 E. Hospitality Lane  
(909) 888-6777
4. **Comfort Inn**<sup>3,4</sup>—\$41/\$46  
1909 S. Business Center Dr.  
(909) 889-0090  
Complimentary coffee and pastries.
5. **La Quinta Inn**<sup>2,3,4,5</sup>—\$48/\$48  
205 E. Hospitality Lane  
(909) 888-7571  
Complimentary coffee, juice, and pastries.
6. **Radisson**<sup>1,2,3,6</sup>—\$60/\$70  
295 North E Street  
(909) 381-6181  
About 4 miles from the Hilton.
7. **Best Western Sands**<sup>3</sup>—  
\$32, \$34/\$36, \$38  
606 North H Street  
(909) 889-8391  
Complimentary coffee and newspapers. About 5 miles from the Hilton. Use the 5th/6th St. exit on I-10.
8. **Ramada Inn**<sup>1,2,3,6</sup>—\$55/\$55  
2000 Ostrem's Way  
(909) 887-3001  
About 9 miles from the Hilton. Use the University Pkwy. exit on I-10.

- <sup>1</sup> Free prearranged transportation to and from Ontario Airport available.
- <sup>2</sup> Wheelchair-accessible rooms available.
- <sup>3</sup> Nonsmoking rooms available.
- <sup>4</sup> Walking distance to the Hilton.
- <sup>5</sup> Reduced-rate prearranged transportation to and from Ontario Airport available.
- <sup>6</sup> Free prearranged transportation to and from the Hilton available.

## AIR TRAVEL

Ontario International Airport is about 20 miles west of the Hilton, on I-10. It is served by several major airlines including Aero Mexico, Alaska, America West, American, Continental, Delta, Mexicana, Northwest, Reno Air, Southwest, United, and USAir. To make reservations, call GSA's official travel agent, **Cain Travel: 1-800-346-4747 toll-free, (303) 443-2246 collect from outside U.S., fax 303-443-4485**, or your local travel agent. As with all airline reservations, please use caution regarding change and cancellation penalties that accompany low-fare tickets. This applies especially to field trip participants whose trips may be canceled by the February 25, 1994, notification deadline. Be sure you understand the restrictions on the type of ticket you purchase.

## GROUND TRANSPORTATION

**Airport Shuttles.** The Hilton, Radisson, and Ramada Inn offer a complimentary prearranged shuttle service to and from Ontario International Airport for their registered guests. Call the number listed for each hotel to make arrangements.

**Rental Cars.** Avis, Budget, Enterprise, and Hertz have offices at Ontario Airport. In addition, several other companies rent cars in the area. Check with Cain Travel (numbers listed above) or your local travel agent for rates.

**Rail.** The local Amtrak station is at 1130 W. 3rd St., San Bernardino. For information and reservations, call 1-800-872-7245. Metrolink service is also available from Union Station in Los Angeles to this station. For Metrolink information, call 1-800-371-5465.

**Shuttle Buses.** The Radisson Hotel and Ramada Inn offer a prearranged shuttle service for their registered guests to and from the Hilton. Call the number listed for each hotel to make arrangements.

## SPECIAL EVENTS

Special Events registration is available on the preregistration form and, if space is still available, in the registration area at the meeting.

**Welcoming Party.** A welcoming party for all registrants will be held on Sunday evening, March 20, from 7:00 to 9:00 p.m. at the Hilton. Hors d'oeuvres will be available, along with beer and soft drinks. A cash bar will also be available. Registration for the meeting is required.

**Wine and Cheese Reception at the San Bernardino County Museum.** Monday, March 21, 5:00 to 7:00 p.m. Shuttle service will be available. Cost: free, preregistration suggested.

**GSA Cordilleran Section Business Meeting and Luncheon.** Tuesday, March 22, 12:00 noon. Cost: \$15.

**Latin Fiesta.** Tuesday, March 22, 5:30 to 8:00 p.m. Shuttle service will be available. Come up to the California State University, San Bernardino campus for the evening to enjoy the park-like campus, tucked into the corner of the San Bernardino Mountains, adjacent to the San Andreas fault. Partake of a lavish Mexican buffet prepared by Chef Tito Calderon, while listening to music with a Latin beat. Cost: \$15. Please preregister if possible.

**Association for Women Geoscientists Luncheon.** Wednesday, March 23, 12:00 noon. Cost: \$15.

**Education Program Social Hour.** Monday, March 21, 7:30 p.m., cash bar.

## Coffee, Food, and So Forth

Free coffee and soft drinks will be available in the Poster and Exhibits area in the Hilton. The Hilton houses a full-service restaurant and a lounge. In addition, about 25 restaurants are within walking distance of the Hilton and offer a wide variety of lunch and dinner choices. Flyers listing these restaurants will be available at the information center next to meeting registration.

## FIELD TRIPS

Field trips will be offered before and after the meeting. Unless otherwise noted, all field trips will begin and end at the San Bernardino Hilton. For further details about the trips, please contact the trip leader listed first in the trip description. General questions may be addressed to Sally McGill, Field Trip Coordinator, Department of Geological Sciences, California State University, 5500 University Parkway, San Bernardino, CA 92407-2397, (909) 880-5347, fax 909-880-7005.

Preregistration for all trips is required. Participants will be accepted on a first-come, first-served basis through GSA headquarters. **Preregistration deadline is February 11,**

Cordilleran continued on p. 311

**1994.** The preregistration form is provided in this announcement. Participants registering for a field trip *only* must pay a \$15 fee in addition to the field trip charge. Some trips will provide all meals for the trip duration, whereas on other trips participants will pay for some meals. Codes for items included in trips: B—breakfast, L—lunch, D—dinner, and ON—overnight lodging. Lodging is double occupancy.

The cancellation deadline is February 18, 1994. No refunds will be given if cancellation is received after this date. All cancellations must be in writing. If GSA must cancel a trip, that cancellation will be announced by February 25, 1994. Full refunds for trips canceled by GSA will be issued after the meeting. Be aware of cancellation deadlines and possible penalties imposed by airlines.

A guide book containing articles and road logs for all trips is included in the cost of each trip. Guidebooks will also be sold at the meeting at the San Bernardino County Museum exhibit booth.

### Premeeting Trips

**1. Reconstruction of the Mojave Block.** Thursday, March 17 (evening) through Sunday, March 20 (6:00 p.m.). Allen F. Glazner, Dept. of Geology, University of North Carolina, Chapel Hill, NC 27599-3315, (919) 962-0689, E-mail: afg@unc.edu; J. Douglas Walker, University of Kansas; John M. Fletcher and John M. Bartley, University of Utah; Elizabeth R. Schermer, Western Washington University; Mark W. Martin, Pecten International; Stephan Boettcher, University of Texas; Jonathan S. Miller, University of North Carolina; Jonathan K. Linn and Robert P. Fillmore, University of Kansas. Cost: \$210 (3 L, 2 D, 3 ON). Limit: 40.

The Mojave Desert region of southern California has been battered by several episodes of Phanerozoic deformation and magmatism. Despite complex overprinting, the tectonic signature of each event can be recognized. This trip focuses on process-oriented problems in each belt and reconstructs the crustal evolution of the central Mojave Desert. We will sort out the various deformational and magmatic events by working back in time. Emphasis will be on current controversies in Cordilleran geology and on how relations in the Mojave Desert can be used to resolve them. Some of these controversies include the following: (1) Is Neogene deformation of the western Mojave block fundamentally extensional or transpressional? (2) Was the Jurassic arc extensional, contractional, or both? (3) How are magmatism and deformation related in metamorphic core complexes? (4) How widespread was Miocene extension, and what happens at the boundaries of extended terranes? (5) How is strain expressed in the footwalls of metamorphic core complexes? (6) Do major lithospheric boundaries that have been projected into the Mojave Desert exist, and if so where? The trip will focus on ranges that lie within 60 km of Barstow, California, and will involve several hikes of 2–3 hours duration.

**2. Black Mountains Crustal Section, Death Valley Extended Terrane, California.** Thursday, March 17 (5:00 p.m.) through Sunday, March 20 (6:00 p.m.). Daniel K. Holm, Dept. of Geology, Kent State University, Kent, OH 44242, (216) 672-4094; Terry L. Pavlis, University of New Orleans; David J. Topping, University of Washington, Seattle. Cost: \$281 (3 B,

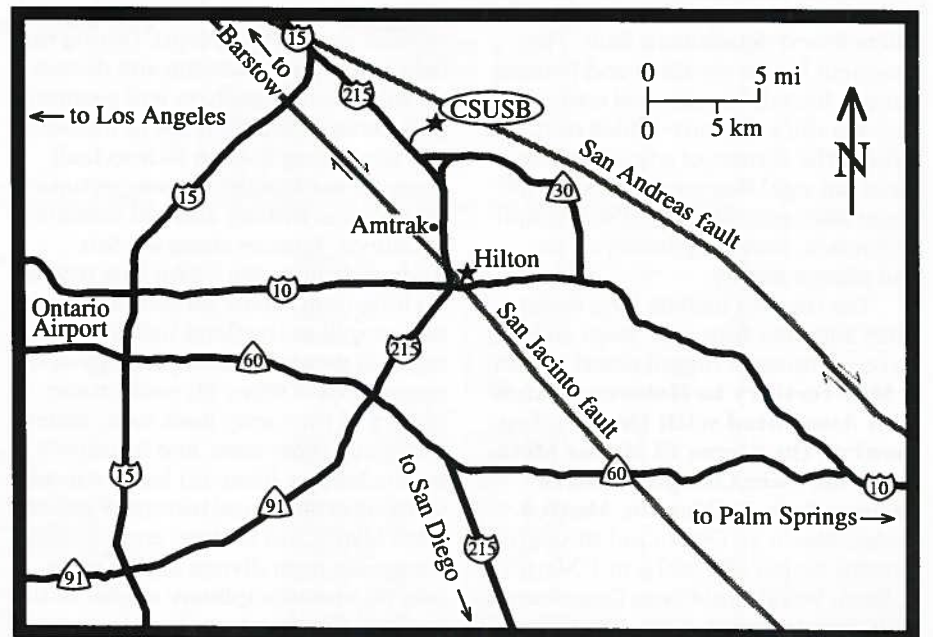
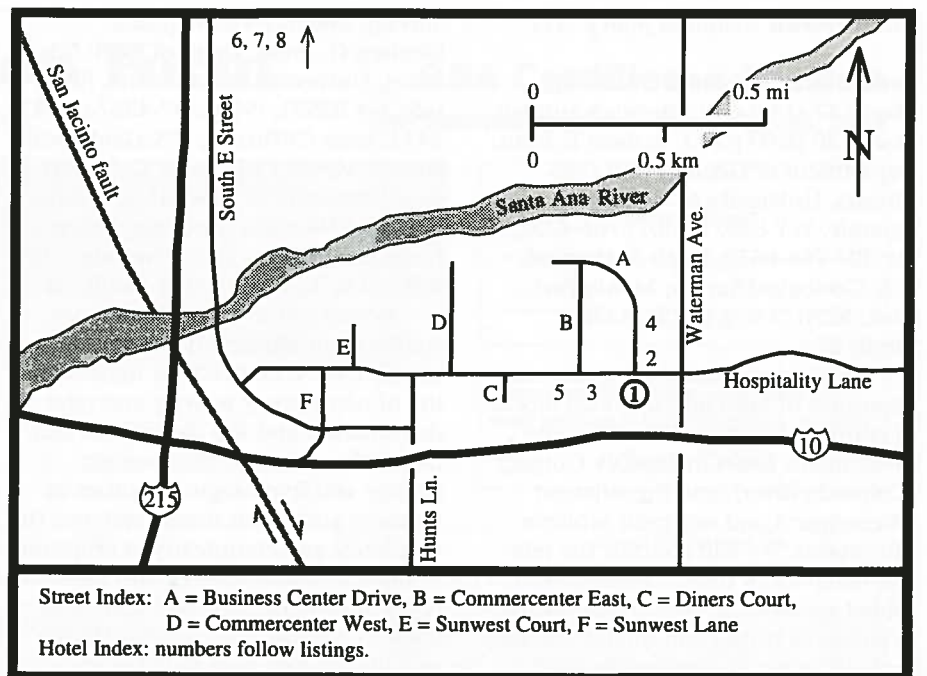
3 L, 2 D, 3 ON). Dinner is not provided on March 17. Limit: 25.

In recent years, diverse data sets have been collected from the Black Mountains, making it one of the best studied metamorphic core complexes in the western United States. This trip will evaluate the idea that the Black Mountains may represent a nearly coherent section of the preextensional crust unroofed and emplaced by extensional tectonism. Participants will investigate important structural relations, syntectonic intrusive chronologies, and synextensional depositional systems and will integrate their observations with published geochemical, thermochronologic (both  $^{40}\text{Ar}/^{39}\text{Ar}$  and fission track), geobarometric, and paleomagnetic data. The excellent exposure in the Black Mountains allows for examination of the entire extensional system (Precambrian and Tertiary Amargosa chaos hanging-wall rocks, Amargosa detachment, and footwall rocks of the crystalline core). Integration of large, diverse data sets will allow participants to address important questions regarding the timing, nature, and amount of both footwall and hanging-wall deformation in normal fault systems. In addition, the data provide important constraints for the geologic and paleotopographic reconstruction of the Death Valley region from 13 Ma to the present. There will be one very long and two shorter strenuous hikes.

**3. New Approaches to Ichnofabric and Trace-Fossil Analysis: Examples from Mesozoic and Cenozoic Outcrops of Coastal California.** Sunday, March 20 (8:30 a.m. through 10:00 p.m.). Mary L. Droser, Dept. of Earth Sciences, University of California, Riverside, CA 92521, (909) 787-3797; David J. Bottjer, University of Southern California. Cost: \$67 (1 L). Limit: 30.

Ichnofabric analyses are a rapidly evolving area of ichnology. The focus of this field trip is to demonstrate new approaches to ichnofabric and trace fossil analysis in various environmental settings. We will focus on terrigenous clastic environments, both nearshore and deep-sea fan. We will visit two main localities. The first, Solana Beach, approximately 45 minutes north of San Diego, exposes the Eocene Torrey and Delmar Formations. This outcrop provides an excellent laboratory for examining lateral variations in ichnofabric at various scales (core vs. extensive outcrops). New techniques for examining burrow morphologies will be explored through discussions of *Ophiomorpha*. The second stop, Sunset Cliffs, just north of San Diego, exposes deep-sea fans of the Cretaceous Point Loma Formation. In these strata, *Ophiomorpha* occurs with a variety of other well-preserved trace fossils. This outcrop demonstrates the broad environmental range of *Ophiomorpha* in sandy substrates and provides a backdrop for discussions on onshore-offshore trends in the history of benthic macroinvertebrates.

**4. Structural and Stratigraphic Relations of the Mississippian Rocks at the Nevada Test Site.** Thursday, March 17 (4:00 p.m.) through Sunday, March 20 (3:00 p.m.). Patricia H. Cashman, Dept. of Geological Sciences/168, University of Nevada, Reno, NV 89557-0138, (702) 784-6924; James H. Trexler, Jr., University of Nevada, Reno; James C. Cole and Mark R. Hudson, U.S. Geological Survey, Denver. Cost: \$75 or \$127 including one-way airfare from Las Vegas to Ontario airport after the trip. (3 L, 3 ON). Trip begins and ends in Las Vegas, with optional airfare to Ontario, California (near San Bernardino) for up to 20 participants. Limit: 36.



### SAN BERNARDINO AREA

Due to Nevada Test Site security considerations, the trip will be limited to U.S. citizens. At the time of preregistration, please submit full name, date of birth, place of birth, Social Security number, employer, and (if applicable) naturalization information to James C. Cole, U.S. Geological Survey, MS 913, Box 25046, Denver, CO 80225-0046, (303) 236-1417.

This trip will afford an opportunity to examine parts of the Upper Devonian through Lower Pennsylvanian sections that are usually inaccessible to the general scientific community because they lie within the Nevada Test Site. Relations in the Mississippian rocks are especially complex and have been interpreted under different conceptual models with contrasting implications for paleogeography, tectonics, and regional hydrology. The complicating factors are the following. (1) The site spans a major facies change from the western siliciclastic Antler foreland-basin turbidite sequence to the eastern siliciclastic and carbonate shelf sequence. (2) East-vergent and possible west-vergent thrusts are present. (3) New evidence indicates significant pre-Miocene extension, in part older than middle Cretaceous, and possible major strike-slip faults. (4) Miocene volcanic cover conceals the site. (5) Cenozoic extension and strike-slip faulting have overprinted the site.

Structural stratigraphic and sedimentologic features will be examined in outcrop and in drill core. Evening sessions will consider new data from paleontology, geochronology, fault-slip analysis, and conodont-alteration-index studies, and serve to focus discus-

sion on the implications of contrasting models.

**5. Geology and Geophysics of the Sierra Madre–Cucamonga Fault Zones, San Gabriel Mountains, California.** Sunday, March 20 (7:00 a.m. to 6:00 p.m.). Margaret C. Van Buskirk, School of Physical, Health, and Life Sciences, Chaffey College, 5885 Haven Ave., Rancho Cucamonga, CA 91737-3002, (909) 941-2367; Debra A. Brooks, Rancho Santiago College. Cost: \$76 (1 L). Limit: 18.

The Sierra Madre–Cucamonga fault zones extend along the southern front of the San Gabriel Mountains, in the central part of the enigmatic Transverse Ranges of southern California. Recent earthquake activity on these fault zones includes an event of M4.9 on December 3, 1988, near Pasadena, one of M4.6 near Upland on June 26, 1988, one of M5.5 near Upland on February 28, 1990, and one of M5.8 on June 28, 1991, near Sierra Madre. In addition, the M6.8 San Fernando event of February 9, 1971, occurred on a western segment of the Sierra Madre fault zone. This continuing earthquake activity indicates that the relatively youthful San Gabriel Mountains are still being uplifted along the Sierra Madre–Cucamonga fault systems. Participants in this one-day field trip will have a first-hand look at the geology and geophysics of the basement terranes and Cenozoic faults of the San Gabriel Mountains.

**6. Disharmonic Drape Folds in the Highly Attenuated Colorado River Extensional Corridor, Cali-**

Cordilleran continued on p. 312

**California and Arizona**, Thursday, March 17 (1:00 p.m.) through Sunday, March 20 (6:00 p.m.). Barbara E. John, Department of Geology and Geophysics, University of Wyoming, Laramie, WY 82071, (307) 766-4232, fax 307-766-6679; Keith A. Howard, U.S. Geological Survey, Menlo Park. Cost: \$270 (3 B, 3 L, 2 D, 3 ON). Limit: 27.

This trip will focus on spectacular exposures of folds and upended blocks of continental crust above Miocene detachment faults in Toplock Gorge (Colorado River), and the adjacent Chemehuevi and northern Mohave Mountains. We will contrast the relative behavior of tilted basement and folded syntectonic cover rocks during extensional tilting and rotation. Transfer faults separate structurally thick ( $\geq 5$  km) blocks of plutonic and gneissic rocks above the regionally developed Chemehuevi detachment fault. The basement blocks are tilted and faulted, but not folded. Supracrustal cover rocks  $\leq 2.5$  km thick are force-folded over and around the corners of adjoining fractured but rigid basement blocks. The drape folds exhibit sheared stratigraphic contacts, have amplitudes  $> 2$  km, and plunge steeply.

The trip will include long desert hikes and boat trips with stops and traverses through rugged desert terrain. **7. Mid-Tertiary to Holocene Extension Associated with the Development of the Sierra El Mayor Metamorphic Core Complex, North-eastern Baja California, Mexico.** Friday, March 18 (7:00 a.m.) through Sunday, March 20 (7:00 p.m.). Martin E. Siem, Woodward-Clyde Consultants, 2020 East 1st Street, Suite 400, Santa Ana, CA 92705, (714) 835-6886, ext. 489; R. Gordon Gastil, San Diego State University. Cost: \$237. (2 B, 3 L, 2 D, 2 ON camping). Limit: 20.

The Sierra El Mayor metamorphic core complex provides an excellent opportunity to investigate the structural geometries associated with the formation of the northern gulf extensional province. On this trip we will hike along the trace of a north-south cross section through the highly extended terrain associated with Tertiary east-west-directed extension. The extended terrain consists of Pliocene-Pleistocene nonmarine deposits of the Palm Springs Formation and marine deposits of the late Miocene to early Pliocene Imperial Formation. The non-metamorphosed sedimentary sequence is juxtaposed against amphibolite grade Paleozoic(?) tectonites along a cataclastic detachment fault, informally referred to as the Canada David Detachment (CDD) fault. The CDD fault truncates a basal shear zone or tectonic melange that represents an exhumed part of the Gulf of California floor. Structural fabrics within the basement have strongly influenced subsequent structural trends and represent a period of Cretaceous flattening and associated igneous activity.

On the first day of the trip we will drive down the axis of the Salton Trough to the international border at Mexicali. South of the border, we will leave the paved roads and all other conveniences of civilization until our return on Sunday afternoon or evening. We will be camping in Sierra El Mayor for two nights and three days. Drinking water, food, tents, and other beverages will be provided.

**8. Quaternary Stratigraphy and Dating Methods: Understanding Geologic Processes and Landscape Evolution in Southern California.** Thursday, March 17 (evening) through

Sunday, March 20 (6:30 p.m.). Stephen G. Wells, Dept. of Earth Sciences, University of California, Riverside, CA 92521, (909) 787-4367 or 787-3434; John C. Tinsley, U.S. Geological Survey, Menlo Park; Leslie D. McFadden, University of New Mexico, Albuquerque; Nicholas Lancaster, Desert Research Institute, Reno, Nevada. Cost: \$282 (3 B, 3 L, 2 D, 3 ON). Limit: 35.

Recent advances in Quaternary stratigraphic studies and dating techniques have enhanced our understanding of neotectonic activity and rates of deformation and slip along folds and faults, the nature of climatologic change and hydrologic responses in semiarid and desert fluvial systems, the frequency and complexity of eruptions at small volcanic centers, and rates and types of surficial processes and landscape evolution. Southern California provides an excellent field laboratory for examining how Quaternary stratigraphy and dating methods can be used to solve geologic problems. During this field trip we will examine and discuss (1) soil chronosequences and geomorphic surfaces and their use to measure slip rates along the San Jacinto fault zone; (2) earthquake records, tectonic geomorphic history, and soil formation on alluvial terraces along the San Andreas fault in the Cajon Pass region; (3) long-term fluvial geomorphic evolution as well as the flood hydrology and regional ground-water hydrology of the upper Mojave River; (4) neotectonic history of the Camp Rock fault, Eastern California shear zone, and its impact on the Mojave River; (5) long-term and short-term lacustrine history of pluvial lakes Manix and Mojave, emphasizing the results from diverse dating methods; (6) multidisciplinary studies of the eruptive history of a polycyclic volcano in the Cima volcanic field; (7) surficial processes and evolution of desert pavements and the use of cosmogenic  $^3\text{He}$  to understand pavement formation; (8) eolian geomorphic history of sand ramps and the Kelso dune field using thermoluminescence dating methods; and (9) influence of dust and lithology on the formation of desert soils on alluvial fans and stone pavement evolution as well as of desert pavements. Thursday night, March 17 will include a field trip overview from 8:00 to 9:00 p.m.

### Postmeeting

**9. Volcanic to Plutonic Transect Across the Peninsular Ranges Batholith, San Diego County, California.** Wednesday, March 23 (5:00 p.m.) through Friday, March 25 (5:00 p.m.). Victoria R. Todd, U.S. Geological Survey, c/o Dept. of Earth Sciences, University of California, Riverside, CA 92521, (909) 276-6397; D. L. Kimbrough, San Diego State University; Marty Grove, University of California, Los Angeles. Cost: \$211 (2 B, 2 L, 1 D, 2 ON). Limit: 30.

The Mesozoic Peninsular Ranges batholith is composed of axial Late Jurassic-age "S-type" granitoids and their Triassic-Jurassic supracrustal wall-rocks intruded by Early to mid-Cretaceous "I-type" plutons whose compositions range from gabbro to granite. The western limit of Late Jurassic-age metaplutonic rocks approximately marks the pre-Cretaceous continental margin, a boundary that exerted a major influence on the distribution and petrology of the Cretaceous magmatic arc. Cenozoic tectonic uplift and westward tilting and erosion of the Peninsular Ranges resulted in a west-to-east-increasing depth profile across the composite batholith.

The field trip traverses eastward across the batholith from Lower Creta-

ceous volcanic and shallow plutonic rocks to mid-crustal mid-Cretaceous plutons and includes typical examples of western and eastern zoned plutonic complexes. Stops include exposures of Late Jurassic-age granitoids and their high-grade metasedimentary country rocks in a ductile shear zone that formed near the pre-Cretaceous continental margin during successive episodes of Late Jurassic and Cretaceous intrusion and deformation. View stops include early Cenozoic erosion surfaces and the Neogene Elsinore fault.

**10. Miocene Sedimentary Rocks in the Whipple Mountains, South-eastern California: Sedimentation Patterns Resulting from Detachment Faulting.** Wednesday, March 23 (5:00 p.m.) through Saturday, March 26 (1:00 p.m.). Kathi Beratan, 321 EH, Dept. of Geology and Planetary Science, University of Pittsburgh, Pittsburgh, PA 15260, (412) 624-1408. Cost: \$191 (2 L, 1 D, 3 ON). Limit: 30.

Sedimentary strata deposited during Miocene detachment faulting are well exposed in the southern and eastern Whipple Mountains, a classic "metamorphic core complex" within the Colorado River extensional corridor. These strata preserve a record of the nature and timing of upper-crustal structural events. This particular synextensional basin is unusual in that it received very little volcanic input, and thus sedimentation patterns were controlled solely by the geometry and rates of motion of the basin-bounding faults.

This trip will focus on changes in paleotopography through time as evidenced by sedimentary facies patterns and on implications for the structural evolution of the extensional terrane. Evidence for a basin-bounding transfer fault will be examined, as well as two distinct episodes of extensional deformation separated by an interval of relative quiescence. A variety of sedimentary facies will be examined, including deposits from rock avalanche, alluvial fan, braid-plain and lacustrine depositional environments.

**11. Landers: Earthquakes and Aftershocks.** Thursday, March 24 (8:00 a.m.) through Friday, March 25 (4:00 p.m.). Robert Reynolds, San Bernardino County Museum, 2024 Orange Tree Lane, Redlands, CA 92374, (909) 798-8571; Bob Lemmer, Leighton and Associates; Frank Jordan, Rasmussen and Associates. Cost: \$113 (1 B, 2 L, 1 D, 1 ON camping). Limit: 28.

This two-day trip will visit surface ruptures from the June 28, 1992, Richter magnitude 7.6 Landers earthquake in the area between Twentynine Palms and Barstow, San Bernardino County, California. Stops will view scarps and fractures in bedrock and Quaternary alluvium, sites of boulder falls, and structural damage. Ruptures stepped northward across the northwest-trending Johnson Valley fault, Homestead Valley fault, Emerson fault, and Calico fault. Camping at the end of day 1 will be in the folded Miocene Barstow Formation along the Coon Canyon (Fossil Bed Road) fault. Day 2 of the trip will visit sympathetic (triggered) northeast-trending ruptures near Newberry Springs. The trip will include stops at the Manix fault, a west-trending fault in the Mojave Desert, the northwest-trending Calico-Coon Canyon fault zone, and the Waterman Hills detachment fault, and will have final stops at the Squaw Peak and San Andreas faults in Cajon Pass, 30 miles north of San Bernardino.

**12. Mesozoic Structure of the Maria Belt, Southeastern California and Southwestern Arizona.** Wednesday, March 23 (5:00 p.m.)

through Saturday, March 26 (6:00 p.m.). Stephen M. Richard, Arizona Geological Survey, 845 N. Park Ave., Tucson, AZ 85719, (602) 882-4795; Stan N. Ballard, Wagner and Brown Oil Producers; Warren B. Hamilton, U.S. Geological Survey; Stefan Boettcher, University of Texas; Thomas D. Hoisch, Northern Arizona University; Richard M. Tosdal, U.S. Geological Survey. Cost if camping: \$167 (3 B, 3 L, 2 D, 0 ON). Cost including motel: \$198 (0 B, 3 L, 0 D, 3 ON). Limit: 36.

The Maria belt is an east-trending segment of the Cordilleran fold and thrust belt situated between the classic thrust belts of southern Nevada and Chihuahua. Proterozoic, Paleozoic, and Mesozoic rocks in this region record a complex Mesozoic history including local Triassic(?) erosion of the entire Paleozoic section, Jurassic volcanism, and Jurassic to Cretaceous high-angle faulting, basin formation, thrust faulting, and normal faulting. We will examine faults and unconformities in the Cretaceous McCoy Mountains Formation and related rocks exposed at high structural levels in the southern Plomosa Mountains and Livingston Hills, and polydeformed Paleozoic and Mesozoic metasedimentary rocks representing deeper parts of the orogen in the northern Dome Rock, Big Maria and Little Maria Mountains. Major problems to be addressed include the interaction of deformation and sedimentation at high structural levels in the southern part of the belt, style and kinematics of ductile deformation in the northern part of the belt, and the relation between these two domains. March weather in the area we will visit is unpredictable; anything from cold rain and wind to warm sun is possible. Short hikes with some hill climbing will be necessary at some stops.

**13. Late Miocene Stratovolcano Complex on the South Ranges, Naval Air Weapons Station, San Bernardino County, California.** Wednesday, March 23 (5:00 p.m.) through Saturday, March 26 (4:00 p.m.). Frank Monastero, Geothermal Program Office (C8306), Naval Air Weapons Station, China Lake, CA 93555-6001, (619) 939-4046; Andy Sabin, Colorado School of Mines. Cost: \$287 (3 B, 3 L, 2 D, 3 ON). Limit: 24.

Geologic mapping, petrographic analysis, geochemical analysis of rocks, geophysical investigations, and geochronology have shown that the southern two-thirds of the Randsburg Wash and Mojave B test ranges of the Naval Air Weapons Station are covered with rocks emplaced through repeated eruption, subsequent collapse, erosion, and extension within a stratovolcano complex.  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology has bracketed the ages of this complex between 12.5 and 18.6 Ma.

This volcanic center is a trapdoor-type caldera hinged on the northeast side and down-dropped on the southwest side. It has undergone at least one and possibly multiple periods of hydrothermal overprinting resulting in hot-spring-related features, including amorphous silica (opal and chalcedony); veining; anomalously high concentrations of mercury, arsenic, antimony, barium, and other trace metals typical of the hydrothermal suite, hydrothermal breccias, stringer or boxwork-style veining; and high geothermometric equilibrium temperatures from local springs.

The rocks in this caldera consist of a basal sequence of interlayered ignimbrites and basaltic andesites followed by rhyodacites and rhyolites and ending with thick, moat-filling rhyolite

Cordilleran continued on p. 313

flows. Stratigraphy indicates that this volcano produced strombolian and plinian ignimbrites, interspersed with intense outpourings of lavas. Caldera collapse was synchronous with collapse of the volcanic edifice. Petrogenetic modeling indicates that intermediate and silicic volcanic rocks were probably comagmatic and probably are the result of mixing of deep-seated basaltic magmas with normal continental crust.

The caldera is defined by a well-exposed topographic rim described by a 150° arc with an inferred ring-fracture diameter of at least 6 km. Geophysical data define a large regional Bouguer gravity low beneath the main vent area with a smaller, parasitic low to the west. A thick sequence of extra-caldera lahars and lava flows makes up the entire southern and southwestern side of the caldera.

Field trip stops will include the main vent area, the topographic rim, outcrops of intracaldera andesitic lava flows, and some spectacular hydrothermal breccia vent sequences. Thick exposures of ignimbrite and interlayered flows provide an excellent opportunity to explore the dynamics of high-silica eruptive processes.

**14. Stratigraphy and Gravity-glide Elements of a Miocene Supradetachment Basin, Shadow Valley, East Mojave Desert.**

Wednesday, March 23 (6:00 p.m.) through Saturday, March 26 (7:00 p.m.). S. Julio Friedmann, Dept. of Geological Sciences, University of Southern California, Los Angeles, CA 90089-0740, (213) 740-6119. Cost: \$196 (3 L, 1 D, 3 ON). Limit: 30.

This trip will focus on the stratigraphy and sedimentology of the Miocene Shadow Valley basin, with special emphasis on the glide blocks and rock-avalanche breccias that compose much of the fill. The basin is exceptionally well exposed, the master fault well mapped, the basin strata well dated, and the glide blocks very large (several >10 km<sup>2</sup>). The first stop will be at the breakaway of the Kingston Peak-Halloran Hills detachment. From there we will proceed to several very large and distinct glide blocks. Day 2 will focus on the middle and upper members of the stratigraphy. This will include long stops at both glide blocks and rock avalanche breccias, as well as fan-delta, lacustrine, and distal and proximal fan settings. On day 3 we will examine the lowermost and uppermost strata, including a glide block that recycles the basin margin. The day will end with an open discussion on the outcrop. Moderate to strenuous hiking. Bring boots and day pack.

**15. Stratigraphy and Deformational History of the Mecca Hills, Southern California.** Wednesday, March 23 (7:00 p.m.) through Friday, March 25 (7:00 p.m.). Ray J. Weldon II, Dept. of Geological Sciences, University of Oregon, Eugene, OR 97403, (503) 346-4584; John P. Stimac, University of Oregon; Michael J. Rymer, U.S. Geological Survey, Menlo Park. Cost: \$148 (2 B, 2 L, 2 D, 1 ON motel and 1 ON camping). Limit: 35.

This trip examines the structure and stratigraphy of the eastern half of the Mecca Hills, California, which are one of the best-exposed examples of transpressive deformation. The first day focuses on the Box Canyon-Hidden Spring area and includes a moderately strenuous traverse through a Pleistocene section that has been sampled for magnetostratigraphic and rotation studies. Excellent exposures of folds and faults associated with the Painted Canyon and Hidden Spring fault zones

# Preregistration Form

Preregistration deadline is February 11, 1994.

**GSA Cordilleran Section**  
San Bernardino, CA • March 21-23, 1994

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

\_\_\_\_\_ Name as it should appear on your badge \_\_\_\_\_

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

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

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

\_\_\_\_\_ fax \_\_\_\_\_

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

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

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

Please indicate if you or your guest will need services to accommodate a disability:

Yes  No

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

*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	\$	_____
K-12 Earth Science Teacher	( 42 ) \$ 10	<input type="checkbox"/>	N/A		1	\$	_____
Guest	( 09 ) \$ 10	<input type="checkbox"/>	N/A			\$	_____
Field Trip Only	( 98 ) \$ 15	<input type="checkbox"/>	N/A		1	\$	_____

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

**GUEST PROGRAM**

An Afternoon at the San Bernardino County Museum	March 22	( 20 ) \$ 6	_____	\$	_____
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**LUNCHES/SPECIAL EVENTS**

Wine and Cheese Reception, Museum	March 21	( 20 ) FREE	_____	\$	_____
GSA Cordilleran Section Business Meeting and Lunch	March 22	( 22 ) \$ 15	_____	\$	_____
Latin Fiesta	March 22	( 23 ) \$ 15	_____	\$	_____
Association for Women Geoscientists Lunch	March 23	( 24 ) \$ 15	_____	\$	_____

**FIELD TRIPS**

1. Reconstruction of the Mojave Block	March 17-20	(100) \$210	1	\$	_____
2. Black Mountains Crustal Section, Death Valley	March 17-20	(101) \$281	1	\$	_____
3. New Approaches, Ichnofabric/Trace Fossil Analysis	March 20	(102) \$ 67	1	\$	_____
4a. Mississippian Rocks at Nevada Test Site (without airfare)	March 17-20	(103) \$ 75	1	\$	_____
4b. Mississippian Rocks at Nevada Test Site (with airfare)	March 17-20	(104) \$127	1	\$	_____
5. Sierra Madre-Cucamonga Fault, San Gabriel Mountains	March 20	(105) \$ 76	1	\$	_____
6. Miocene Synextensional Hanging-Wall Basins, Colorado River	March 17-20	(106) \$270	1	\$	_____
7. Sierra El Mayor Metamorphic Core Complex	March 18-20	(107) \$237	1	\$	_____
8. Quaternary Stratigraphy and Dating Methods	March 17-20	(108) \$282	1	\$	_____
9. Peninsular Ranges Batholith, San Diego County	March 23-25	(109) \$211	1	\$	_____
10. Miocene Sedimentary Rocks, Whipple Mountains	March 23-26	(110) \$191	1	\$	_____
11. Landers: Earthquakes and Aftershocks	March 24-25	(111) \$113	1	\$	_____
12a. Mesozoic Structure of the Maria Belt (camping)	March 23-26	(112) \$167	1	\$	_____
12b. Mesozoic Structure of the Maria Belt (with motel)	March 23-26	(113) \$198	1	\$	_____
13. Miocene Volcanic Complex, Naval Air Weapons Station	March 23-26	(114) \$287	1	\$	_____
14. Miocene Supradetachment Basin, Shadow Valley	March 23-26	(115) \$196	1	\$	_____
15. Stratigraphy/Deformational History, Mecca Hills	March 23-25	(116) \$148	1	\$	_____
16. Neogene History of Garlock Fault	March 24-25	(117) \$166	1	\$	_____
17a. Earth Science Education: San Bernardino Mtns. — K-12 Teachers	March 20	(118) \$ 15	1	\$	_____
17b. Earth Science Education: San Bernardino Mtns. — Professionals	March 20	(119) \$ 30	1	\$	_____

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

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

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

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

Signature \_\_\_\_\_

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

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can be seen along the hike. During the second day we visit the Painted Canyon, Skeleton Canyon, and San Andreas fault zones. The trip culminates in Painted Canyon, where observations are compared to the classic model of transpression of Sylvester and Smith (1976). Key structural issues addressed include (1) the kinematic relations among oblique, normal, and reverse structures, (2) vergence of low-angle faults and folds, and (3) the role of bedding-plane slip in the upward flow of material within the transpressive zone.

**16. Neogene History of the Central Part of the Garlock Fault.** Thursday, March 24 (8:00 a.m.) through Friday, March 25 (5:00 p.m.). Bruce Carter, Dept. of Physical Sciences, Pasadena City College, Pasadena, CA 91106 (818) 585-7140; Sally McGill, California State University, San Bernardino. Cost: \$166 (2 L, 1 D, 1 ON). Limit: 30.

Because one stop will be in the Naval Air Weapons Station at China Lake, this trip is limited to U.S. citizens.

Please send full name, address, phone number, and social security number to Sally McGill, Dept. of Geological Sciences, California State University, 5500 University Parkway, San Bernardino, CA 92407, (909) 880-5347 at the time of preregistration.

The Garlock fault is a 250-km-long, active, left-lateral fault that separates the Mojave block from the Sierra Nevada and Basin and Range provinces. We will traverse the central part of the fault, looking at evidence for Holocene activity as well as older offsets. We will examine geomorphic features that record up to 7 m of lateral slip in the most recent earthquake. We will also visit three sites where the Holocene slip rate has been determined, including an offset channel near Mojave, an offset gravel bar in Fremont Valley, and an offset shoreline of Searles Lake. Excavations have been conducted at two of these sites, but they will not be open at the time of the trip. We will also look at Neogene sedimentary rocks in the Fremont Valley, Summit Range,

and Lava Mountains that have been offset tens of kilometres from their source areas in the El Paso Mountains. These older offsets, of several different ages, are consistent with the Holocene slip rate of 5-10 mm/yr.

**17. Earth Science Education Field Trip: Geology of the San Bernardino Mountains.** Sunday, March 20, all day. James M. Mehegan, Dept. of Geological Sciences, California State University, San Bernardino, CA 92407-2397, (909) 880-5337. Cost: \$15 for teachers; \$30 for professionals (1 L, includes field guide for this trip and sample bags). Bring cameras and rock hammers. Limit: 60.

**Field Trips Canceled since initial meeting announcement:**

- Growth Fault Basin near Lake Mead.
- Geology of the San Gorgonio Pass and the San Bernardino Mountains. (Trip #9 has been expanded to cover this area.)

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- Peninsular Ranges in the Riverside Area.
- Tectonics and Sedimentation, Southern Death Valley.
- Hydrogeology in the Los Angeles Basin.
- Neoproterozoic-Cambrian Boundary Interval in the Southern Great Basin:

## SYMPOSIA

Scheduled symposia and their conveners are as follows.

1. **Paleoseismology.** Glenn Roquemore, Dept. of Geological Sciences, Irvine Valley College, 5500 Irvine Center Dr., Irvine, CA 92720, (714) 559-3438; and Robert S. Yeats, Oregon State University. Cosponsored by the International Commission on the Lithosphere, Task Group II-3.
2. **Phanerozoic Cordilleran Metamorphism: Distribution and Tectonic Implications.** Phyllis A. Camilleri, Dept. of Geology and Geophysics, University of Wyoming, P.O. Box 3006, Laramie, WY 82071, (307) 766-2914; and David M. Miller, U.S. Geological Survey.
3. **Neoproterozoic-Cambrian of the Great Basin: New Developments in Stratigraphy, Sedimentology, Paleontology, and Related Fields.** Frank Corsetti, Dept. of Geological Sciences, University of California, Santa Barbara, CA 93106, (805) 893-3471; Anthony R. Prave, City University of New York; and John D. Cooper, California State University, Fullerton.
4. **Tertiary Basins and Volcanism in the Death Valley Region: Their Tectonic Significance. Part A: Sedimentary Basins.** B. W. Troxel, 2961 Redwood Rd., Napa, CA 94558, and Lauren A. Wright, Pennsylvania State University. **Part B: Volcanic Fields.** James P. Calzia, U.S. Geological Survey, Menlo Park, CA 94025; and B.W. Troxel.
5. **Sequence Stratigraphy of the Great Basin: Facies Patterns and Sequence Boundaries.** Mark Harris, Dept. of Geosciences, University of Wisconsin—Milwaukee, P.O. Box 413, Milwaukee, WI 53201, (414) 229-5777; and Kathy Nichols, U.S. Geological Survey.
6. **Poster Symposium: Recent Contributions to the Southern California Areal Mapping Project.** Douglas M. Morton, U.S. Geological Survey, c/o Dept. of Earth Sciences, University of California, Riverside, CA 92521, (909) 276-6397.
7. **Hydrogeology of Southern California.** Prem K. Saint, Dept. of Geological Sciences, P.O. Box 34080, California State University, Fullerton, CA 92634-9480, (909) 773-2154.
8. **Tectonic Evolution of Baja California.** Rebecca J. Dorsey, Dept. of Geology, Box 6030, Northern Arizona University, Flagstaff, AZ 86011, (602) 523-4561; and Arturo Martin, Ensenada.
9. **Accommodation Zones and Transfer Zones: The Significance and Nature of the Large-Scale Segmentation of the Basin and Range.** James Faulds, Dept. of Geology, University of Iowa, Iowa City, IA 52242, (319) 335-1097; and Jack Stewart, U.S. Geological Survey.
10. **Effects of the 1992-1993 Winter Storms on the Southwestern Cordillera.** Robert A. Larson, 6416 Woodley Ave., #5, Van Nuys, CA 91406, (818) 458-4923. Cosponsored by the Engineering Geology Division of GSA.

11. **Episodic Mesozoic and Cenozoic Extension in the Basin and Range.** Wanda J. Taylor, Dept. of Geoscience, University of Nevada, Las Vegas, NV 89154, (702) 597-4615; and David M. Miller, U.S. Geological Survey.
12. **The Uses of Vertebrate Fossils in Solving Biostratigraphic Problems.** Stuart Sumida, Dept. of Biology, California State University, San Bernardino, CA 92407-2397, (909) 880-5346. Cosponsored by the Paleon-

13. **Earth Science in the Public Arena: Strengthening Environmental Decisions with the Geological Approach to Critical Inquiry.** Cosponsored by the Institute for Environmental Education. W. Gary Ernst, School of Earth Sciences, 101 Mitchell Bldg., Stanford University, Stanford, CA 94305, (415) 723-2750; Vic Baker, University of Arizona; and Pat Abbott, San Diego State University. Abstracts for this session only will be accepted through December 15. Send abstracts to Joan Fryxell (see general information).

tological Society and by the Society of Vertebrate Paleontology.

14. **Geology in the City, as Told by Engineering Geologists, University Geologists, and K-12 Earth Science Teachers.** Wendy Van Norden, Harvard-Westlake School, 3700 Coldwater Canyon, North Hollywood, CA 91604, (818) 980-6692. Cosponsored by the National Association of Geology Teachers.
15. **Poster Symposium: Perspectives on Teaching K-12 Earth Science.** Janet J. Woerner, Dept. of Elementary/Bilingual Education, California State University, San Bernardino, CA 92407, (909) 880-5623, fax 909-880-5988, E-mail: jwoerner@wiley.csusb.edu.; and Ellen P. Metzger, San Jose State University. Cosponsored by the California Earth Science Academy.
16. **Women and Minorities—Developing New Leaders from Underrepresented Groups.** Marilyn Suiter, American Geological Institute, 4220 King St., Alexandria, VA 22302-1507, (703) 379-2480, fax 703-379-7563; and James M. Mehegan and Louis A. Fernandez, California State University, San Bernardino.
17. **Poster Symposium for Undergraduate Research.** Jim Woodhead, Dept. of Geology, Occidental College, Los Angeles, CA 90041, (213) 259-2556. Cosponsored by the Geology Division of the Council on Undergraduate Research.

## THEME SESSIONS

1. **Mesozoic Deformation Southwest of the Colorado Plateau, the Cordilleran-Chihuahuan Linkage.**
2. **Geologic and Paleogeographic Influences on Mesozoic Vertebrate Community Dynamics.**

## POSTER SESSIONS

Poster sessions will be located adjacent to the Exhibits and coffee service. Each poster booth will provide three rectangular horizontal tack boards arranged at table height. Posters will be available for viewing for one-half day.

## PROJECTION EQUIPMENT

All slides must be 2" x 2" and fit standard 35 mm carousel trays. Two projectors and two screens will be available for all oral sessions. Overhead projectors will not be available. Please bring loaded carousel trays, if possible.

## EARTH SCIENCE EDUCATION PROGRAMS

1. **Field Trip #23: Geology of the San Bernardino Mountains.** Sunday, March 20, all day. James M. Mehegan, Dept. of Geological Sciences, California State University, San Bernardino, CA 92407-2397, (909) 880-5337. Cost: \$15 for teachers; \$30 for professionals (1 L, includes field guide for this trip and sample bags). Bring cameras and rock hammers. Limit: 60.
2. **Symposium #13: Earth Science in the Public Arena: Strengthening Environmental Decisions with the Geological Approach to Critical Inquiry.** W. Gary Ernst, School of Earth Sciences, 101 Mitchell Bldg., Stanford University, Stanford, CA 94305, (415) 723-2750; Vic Baker, University of Arizona; and Pat Abbott, San Diego State University. Cosponsored by the Institute for Environmental Education.
3. **Symposium #14: Geology in the City, as Told by Engineering Geologists, University Geologists, and K-12 Earth Science Teachers.** Monday, March 21, from 6:00 to 7:30 p.m. Wendy Van Norden, Harvard-Westlake School, 3700 Coldwater Canyon, North Hollywood, CA 91604, (818) 980-6692. Cosponsored by the National Association of Geology Teachers.
4. **Poster Symposium #15: Perspectives on Teaching K-12 Earth Science.** Janet J. Woerner, Dept. of Elementary/Bilingual Education, California State University, San Bernardino, CA, 92407, (909) 880-5623, fax 909-880-5988, E-mail: jwoerner@wiley.csusb.edu., and Ellen P. Metzger, San Jose State University. Cosponsored by the California Earth Science Academy.
5. **Social Hour.** Monday, March 21, following the symposium. Free hors d'oeuvres and a cash bar.

Talks throughout the technical sessions that may be of interest to earth science teachers will be listed on a flyer available at the information center next to the meeting registration area. For information on any of the earth science education programs, contact James M. Mehegan, Dept. of Geological Sciences, California State University, San Bernardino, CA 92407-2397, (909) 880-5337, fax 909-880-7007, E-mail: jmehegan@wiley.csusb.edu.

## EXHIBITS

Exhibits will be located adjacent to the poster sessions. The cost of exhibits is \$300 for commercial exhibitors and \$150 for educational and nonprofit institutions. For further information and space reservations, please contact Timothy M. Ross, Exhibits Coordinator, Dept. of Geological Sciences, California State University, San Bernardino, CA 92407-2397, (909) 880-5311, fax 909-880-7005, E-mail: tross@gallium.csusb.edu.

## STUDENT SUPPORT

The GSA Cordilleran Section has funds available for grants to support GSA Student Associates of the section who are presenting papers at the meeting. Students are strongly encouraged to apply for these grants, and we anticipate that most students who qualify will be funded to some degree. Apply to Cordilleran Section Secretary Bruce A. Blackerby, Dept. of Geology, California State University, Fresno, CA 93740, (209) 278-2955 (direct) or 278-3086 (dept.). Applications should include certification that the student is presenting a paper and is a GSA Student Associate of the Cordilleran Section. *All letters must be received by January 15, 1994.*

## GUEST PROGRAM

**An Afternoon at the San Bernardino County Museum.** Tuesday, March 22, 1:00 to 5:00 p.m. The San Bernardino County Museum, located at 2024 Orange Tree Lane, Redlands, specializes in the cultural and natural history of San Bernardino County and the surrounding region. Exhibits are drawn from collections in archaeology, biology, geology, and history. A special exhibit titled "Treasures of the Tar Pits" will be featured during the meeting. The museum has a hands-on Discovery Hall for children. Shuttle service and admission are included. Cost: \$6.

**Additional Information on the San Bernardino County Museum.** On Saturday, March 19, the museum is hosting the Mineral Locality Symposium, from 9:00 a.m. to 9:00 p.m. Admission is \$5 at the door. Also on Saturday, the Discovery Hall is holding a "Make a Sloth" Craft Day, 1:00 to 4:00 p.m. Reduced admission is available throughout our meeting for GSA badge holders. Museum hours are 9:00 a.m. to 5:00 p.m. Tuesday through Saturday. Call the museum at (909) 798-8570 for more information.

## GENERAL INFORMATION

Inquiries, additional information, special requests, and suggestions should be addressed to Joan E. Fryxell, Meeting Chair, Dept. of Geological Sciences, California State University, San Bernardino, CA 92407-2397, (909) 880-5311, fax 909-880-7005, E-mail: jfryxell@wiley.csusb.edu. ■

## 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.

### Cordilleran

Bruce A. Blackerby, (209) 278-2955

### Rocky Mountain

Kenneth E. Kolm, (303) 273-3932

### North-Central

George R. Hallberg, (319) 335-1575

### South-Central

Rena M. Bonem, (817) 755-2361

### Northeastern

Kenneth N. Weaver, (410) 554-5534

### Southeastern

Michael J. Neilson, (205) 934-5102

## 1994

## Abstract Form Request

GSA Abstracts Coordinator,  
P.O. Box 9140, Boulder, CO 80301

Please send \_\_\_\_\_ copies of the 1994 GSA Abstract form. I understand that the same form may be used for all 1994 GSA meetings—the six Section Meetings and the GSA Annual Meeting in Seattle.

Name \_\_\_\_\_  
Address \_\_\_\_\_  
City \_\_\_\_\_  
State/ZIP \_\_\_\_\_

## NEW GSA MEMBERS

The following 325 Members were elected to membership by council action during the period from February 1993 through September 1993 (\* indicates transfer from Student Associate to Member).

Gregory C. Aebischer	*Kathryn E. Cook	Tony G. Guiang
Kevin P. Allen	*Nicholas D. Cook	Michael P. Gutmann
Mark K. Allex	William J. Cook	Frances M. Hagey
*H. Elizabeth Anderson	Catherine M. Cooney	Richard J. Hamrick
*Kevin M. Ansdell	Helen P. Corley	*Bryan C. Hann
*Antonio M. Arribas, Jr.	Luis G. Corretge	*Peter J. Harries
*John C. Ayers	Andres Crespo	*Stanley H. Harts
Rahul Bahadur	Kenneth L. Crider	*Terry J. Hayden
Ronald F. Balazik	Lucy M. Curran	*Joseph E. Hazel, Jr.
Wayne A. Ballard	Kirsten A. Cyr	*Dianne M. Henrich
Michael R. Banks	*Jill K. Darin	*Anne E. Henry
*Marc V. Bardoux	*Andrew J. Davidoff	Paul M. Hess
Paul R. Bartz	*John W. S. Davis, Jr.	*Virginia S. Hill
Geoffrey A. Bates	Ralph K. Davis	*Marc M. Hirschmann
Bernard B. Beegle	James W. DeMaagd	Jefferson P. Hoffer
*Barbara M. Bekken	Daniel Dicker	*John M. Holbrook
Kenneth Belitz	*Ronald S. Dietz	*Helena M. Hollauer
Russell B. Bender, Jr.	*Gregory M. Dipple	*Robert C. Horner
Bjorn Bjornstad	Jill L. Domeier	Timothy J. Horscroft
*Charles A. Blalock	*Donald T. Donley	*Kevin P. Hoyle
Mark C. Bowers	*Joseph J. Donovan	Patrick B. Hubbard
Kenneth R. Bradbury	Martin Doyon	Terry Huffington
*Susan Carol Bradford	Robert W. Durham	*B. Lynn Ingram
Michael A. Brady	Harry M. Edenborn	Manual A. Iturralde-Vinent
Heather C. Brainerd	Mark W. Ellis	*Dawn M. Johnson
Susan E. Brink	*Erika R. Elswick	Michal L. Jones
Douglas B. Brown	*Donna S. Erickson	James M. Joyce
Andrew L. Browne	*Richard M. Essex	Wolfgang Kalkreuth
Jeffrey D. Bryan	John D. Ferguson	Carl E. Kamp
Bjorn Buchardt	*Jonathan K. Filer	John A. Karachewski
*David C. Buesch	*Kinardo Flores-Castro	Tom J. Karnuta
Rhonda F. Buhl	Sam R. Forkner	Brian G. Katz
*Beverly A. Burns	Richard N. Foster	Mark G. Kick
Leo P. Burns	Joel A. Frisch	Raymond C. Kimbrough
Brittan K. Byerly	Catherine I. Gabis	Gregory A. Kirby
Steven F. Caldwell	Mark A. Garman	Jeffrey L. Kirkwood
*William R. Callender	William M. B. Gavin	Richard L. Kittel
Oswaldo R. Campanella	*George J. Gerhold	Catherine L. Kling
*Antonio M. Carrillo	George M. Gibson	Urs S. Kloetzi
Joseph A. Cartwright	*Richard D. Gillespie	Louis H. Klotz
Susan E. Celestian	*Robert G. Gillson III	Benjamin C. Kneller
Dane R. Chance	*Robert M. Goering	John J. Knight
Allen Cichanski	Lori M. Goetsch	*Diane Clemens Knott
Kevin B. Clahan	Robert C. Graham	Kent S. Koptiuch
*Scott H. Clark	Joseph R. Grant	Karen M. Kraft
Timothy W. Clark	*Miles W. Gray	Mark T. Kuncir
Edward L. Coffey III	Russell W. Graymer	Bruno D. LaFrance
Dwight F. Coleman	Daniel A. Gregori	Donna M. Lake
Robert K. Conery	Jeffrey L. Gromny	

*Lance L. Lambert	*Iain A. Olness	*Susan M. Skirvin
*Roberta C. Lamons	*Atsushi Oshida	Elena A. Skovorodnikova
Bonnie L. Latiolais	Frederik C. Paauwe	Derek A. Sloop
Jong-ik Lee	Nicole M. Pagano	Deborah K. Smith
Mike R. Leeder	Jack C. Pashin	*Young K. Sohn
Dirk W. Leemkuil	Alvin J. Patrick	Raul G. Solis
William E. Leever, Jr.	*William S. Pendexter	Rasoul B. Sorkhari
*Michael B. Leite	Mark A. Perry	David D. Sparks
*Andrew C. Leith	Tadeusz M. Peryt	David A. Spencer
*David L. LePain	Marcio M. Pimentel	Lee A. Spencer
*J. H. Leutscher	*Jeffrey G. Pittman	Mark Springett
Martin E. Lieurance	Roger W. Portell	*Steve A. Stadelman
Mian Liu	Neal H. Potts	Allison B. Stern
Shumin Liu	*K. S. Pound	Robert D. Stewart
Thomas D. Lorenson	*Aaron L. Pugh	Frank M. Stieger
David C. Lorthioir	George P. Puvvada	Mary W. Stoertz
Joyce E. Lucas-Clark	T. J. Quesnel	Frederick Stumm
George M. Lukert	*Frank R. Rack	*Robert J. Sullivan, Jr.
*John J. Lund	Seiyed N. Raisassadat	Carol S. Sutherland
*Scott C. Lundstrom	Geoffrey J. Rait	Keith J. Swett
*Barbara Ann Lusardi	Susan D. Rankin	Carrie Szot
*Michael W. MacDonald	*M. Akbarian Rashvanlu	Winston C. Tao
Jinichirou Maeda	*Anthony E. Rathburn	Barbara J. Tewksbury
William J. Marks	*Robert A. Ratliff	*Jennifer A. Thomson
Christopher T. Martin	Henry Rauche	Morton K. Thoresen
Roberto D. Martino	Stewart D. Redwood	*Derek J. Thorkelson
Guy Masson	Peter T. Regan	*Owen T. Thornberry III
*Allyson C. Mathis	Victoria H. Remenda	Christiana A. Tickle
*Stephen R. Mattox	*Graciela Rendon-Coke	Jeffrey G. Timmons
Gerald F. McArthur	Paul R. Renne	Noel Tyler
*Dave L. McCarthy	J. Bruno Risatti	*Russell B. Urban-Mead
*David S. McCormick	*James K. Roche	Rick Van Nieuwenhuysse
*Sally F. McGill	Ronald W. Rogers	Jeffrey D. Vervoort
Robert McKibbin	Gary D. Rosenberg	Gonzalo Vidal
*Carol J. McKillip	Stephen H. Rowley	Martin F. Vidal
Frank K. McKinney	Tracy A. Rushmer	David A. Wardell
*David J. McLean	Michael P. Ryan	Jonathan C. Warren
G. Tarcilo Medina Araujo	Waclaw Ryka	Ernest R. P. Waterman
*Andres Meglioli	Roberto L. Sanchez	*Jesse D. Wellman
*Rebecca K. Mellinger	Peter E. Schaaf	*David P. West
Douglas C. Menzies	*Linda M. Schieber	*Brian M. Whiting
Sarah P. Merchant	Susan C. Schock	Mark G. Whittle
Gero W. Michel	Gregor Schoenborn	*Raymond P. Wiggers
*Martin G. Miller	*David L. Schwarz	John B. Williams
Francis C. Monastero	Susan C. Seaber	Robert R. Williams
Lee E. Monnens	Maile L. Seeger	Matthew G. Willis
Donald H. Monteverde	*C. Michael Seidensticker	Jeffrey T. Wilson
Christopher R. K. Moore	*Amy Semrasedu	*Paula N. Wilson
William R. Moore	*Lisa A. Senior	*Jacqueline Windh
D. Scott Moors	Brian N. Shaffer	*Kathleen Woida
Raymond R. Moreno	*John H. Shaw	*Cynthia M. Wurm
*Ellen Morris	Antony L. Shepherd	Brett G. Wyckoff
Edward C. Mosevich	Barbara L. Sherriff	Atsushi Yamaji
*Karl J. Mueller	*Cynthia S. Shroba	*Kenn-Ming Yang
Nelson G. Munoz	*Martin E. Siem	Peter Z. Yang
*Rodrick D. Myers	William G. Siesser	Victor John Yannacone, Jr.
*Karen L. Nesbit	Elisabeth S. Silver	*Gene M. Yogodzinski
Ewa M. Newman	Eric R. Silvers	*Sidney A. Young, Jr. ■
*John J. O'Rourke	Richard N. Simpson	
Yoshihide Ogasawara	Manuel M. Sintubin	

## 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: 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: 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: 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: January 13, 1994.*

### About People

SEPM (Society for Sedimentary Geology) awardees for 1993 include GSA Fellow **John E. Warne**, Colorado School of Mines, Golden, honorary membership; GSA Honorary Fellow **Maria Bianca Cita**, University of Milan, the Francis P. Shepard Medal; and GSA Member **Gerard V. Middleton**, McMaster University, Hamilton, Ontario, the Francis J. Pettijohn Medal.

GSA Fellow **Richard E. Gray**, G.A.I. Consultants, Inc., Monroeville, Pennsylvania, was recently elected national Vice President of the Association of Engineering Geologists.

## Bravo Boston GSA Chorale

### AUDIO CASSETTE TAPES AVAILABLE

The Bravo Boston GSA Chorale performed the melodic and moving Mozart Requiem, popularized in the film *Amadeus*, on Tuesday evening, October 26 as part of the 1993 GSA Annual Meeting. The chorale was assembled from your geological colleagues and was accompanied by a professional orchestra. In addition, the performance featured two concerto works by Vivaldi and Purcell, featuring geologists as soloists. The chorale was conducted by John Finney at Jordan Recital Hall on the campus of the New England Conservatory of Music.



Purcell: *Sonata in D for Trumpet and Strings and Trumpet Tune in D*

Vivaldi: *Concerto in G minor for Two Violoncellos*

Mozart: *Requiem, K. 626*

THE BRAVO BOSTON GSA CHORALE

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Address \_\_\_\_\_

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Payable to: GSA 1993 Annual Meeting

Mail to: Meetings Department—Chorale, P.O. Box 9140, Boulder, CO 80301

## NEW GSA STUDENT ASSOCIATES

The following 617 Student Associates became affiliated with the Society during the period from February 1993 through September 1993.

Andrew K. Adams  
Stephen D. Adams  
Dina Adimey  
Randall J. Adsit  
Kerry L. Aggen  
Anna M. Agustsdottir  
Maureen Alai  
Joseph T. Alex  
David M. Alexander  
Patrick M. Allen  
Michael L. Alter  
Carlos A. Alvarez  
John A. Anderson  
Kirk C. Anderson  
Pamela J. Anderson  
Tammera Anderson  
Vassilia Angelaki  
Robert M. Appelt  
Sandy M. Archibald  
Audrey Aronowsky  
Stuart G. Ashbaugh  
Katherine N. Ashley  
Hassan A. Awlia  
Hwanjo Baek  
Vaughn G. Balzer  
Laura A. Banfield  
David J. Barclay  
Sharon L. Barker  
Christopher M. Barletta  
Lisa K. Barlow  
Michelle L. Barnes  
Julie K. Bartley  
Graham M. Bates  
Jeffrey K. Bates  
Gerald W. Bawden  
Gregory P. Beatrice  
James V. Beck  
Ulf Becker  
Joanne B. Beltran  
Elisa T. Bergslien  
Wendy S. Berk  
Djuna M. Bewley  
Adrian D. Bilger  
Thomas D. Billard  
Michael R. Blaes  
Douglas R. Blake  
George C. Blatsos  
Troy A. Blodgett  
Katherine W. Bock  
Pamela M. Bodnar  
Robert D. Bolger  
Janice L. Bolton  
Florenzo Bordignon  
Gilles Borel  
Karl W. Bornhoeft  
Renee L. Bourgeois  
R. Larry Bowman  
Timothy K. Boyle  
Kim A. Bracchi  
Rebecca M. Bradshaw  
Cortney C. Brand  
Margaret C. Brewer  
Benjamin A. Brooks  
David L. Brown  
Renata M. Brunner  
Erin J. Bryant  
John M. Bukowski  
Michael G. Burgess  
Timothy S. Burke  
William J. Burnett  
Laura M. Burriss  
Ilya V. Buynovich  
Robert B. Cain  
John B. Calhoun  
Thomas J. Callahan  
Eric K. Cann  
Brenda D. Canup  
Melanie R. Carpenter  
Vicki L. Carpenter  
John J. Casey  
Devin N. Castendyk  
Monty L. Cervelli  
Baolong Chai  
Damon A. Chaky  
John R. Chambers  
Byunguck Chang  
Alejandro Chavez  
Hernandez  
Singfoong Cheah  
Chang S. Cheong  
David S. Cherry  
Jonathan K. Child  
Catherine A. Chmidling  
Suk-Joo Choh  
Ching-Yen Chu  
Frank C. Chuang  
Young H. Chung  
Samantha G. Churgin  
Marek A. Cichanski  
Cindy A. Clark  
Heather L. Clark  
Donald J. Colby  
DeNeice M. Collerain  
Nancy E. Collins  
Ronald G. Colyer  
Rebekah K. Condon

Michelle M. Connolly  
Enzo M. Conti  
Lawrence B. Conyers  
Michelle L. Coombs  
Florence E. Cooper  
Frances G. Cooper  
Matthias V. Cord  
Daniel J. Cordier  
Richard L. Corley  
Peter T. Cowdin  
Richard E. Cowles  
Walter K. Crawford III  
Michael S. Cronin  
Valerie N. Croup  
Joanna C. Crowe  
Michella C. Crown  
Margery S. Crweson  
Joseph J. Cudney  
Steven J. Cuellar  
Bryce E. Currie  
Lisa A. Cyphers  
Reginald G. Dawkins, Jr.  
Reynald R. De Castro  
Pamela J. De Groat  
Carol M. Dehler  
Rhawn F. Denniston  
David C. DeYoung  
James Diaz  
Jennifer R. Diaz  
Margaret A. Diffenderffer  
David A. Dinter  
Joshua N. Distler  
James L. DiVietro  
Terry W. Dixon  
Timothy A. Dodd  
Simon Doerling  
Frances K. Donaldson  
Alton C. Dooley, Jr.  
Tracy H. Dorgan  
L. Curtis Doyle II  
Patrick E. Drouin  
Patrick L. Drumm  
Genet I. Duke  
Christopher C. Duncan  
Karlyn H. Duncan  
Anna M. Duzs-Moore  
Michael A. Edwards  
Rebecca M. Edwards  
Eric C. Eines  
William W. Elinski  
Claire L. Elkington  
Henry K. Elliott, Jr.  
Amy L. Ellwein  
James A. Embry  
Susan A. Erickson  
Daniel C. Erni  
Paul M. Evins  
Inge Ewing  
Lucile A. Ezell  
Brian D. Fairchild  
Bobby J. Fanning  
Riccardo Fantini  
Mohammad A. Farooqui  
Gretchen M. Feiss  
Rodney B. Feller  
Thomas W. Ferguson  
Nelson F. Fernandes  
Lynne W. Fielding  
Edward M. Fincke  
Sue A. Finstick  
Wendy L. Fissel  
Ann M. Fleming  
Keith A. Fleming  
Patricia J. Fleming  
Arnim Fluegge  
Godlove T. Fonjweng  
Lane P. Fowler  
Amy D. Fox  
Anthony M. Foyle  
Paul M. Freeman  
Amy K. Friends  
Dawn M. Fry  
David L. Fugate  
Travis H. Fuller  
Andrew C. Fulton  
Kenneth G. Galli  
Diane L. Gallion  
Tanwi Gangopadhyay  
Waleed A. Garatli  
Horst H. L. Gawlik  
Gregory A. Gelhar  
Timothy R. Gere  
Timothy R. Gerlach  
Frank Gerullis  
John M. Godfrey  
Francisco G. Gomez  
Edward J. Gona  
Randall J. Gould  
Cathy A. Grace  
Hilary C. Granados  
Charles M. Graves  
Brian E. Green  
Julie C. Greenleaf  
Wendy R. Greisinger  
John E. Griffin  
Robert P. Griffith

Chifeng Gu  
Michael E. Guebert  
Antonio Guerrero, Jr.  
Lisa R. Guertin  
Nora J. Gunnels  
Chad E. Gunter  
Claudia J. Gutierrez  
Rafael A. Gutierrez  
Brian M. Gwinn  
Laura M. Habig  
Paul C. Hackley  
Bob E. Hall  
Lauren A. Hammack  
Anthony C. Hamric  
David S. Hansen  
Douglas W. Hanson  
Valerie J. Harbaugh  
Jan Harken  
Brent N. Harris  
Kevin G. Harrison  
Michael J. Harrison  
James E. Hay  
Timothy J. Hazlett  
Randall F. Hedegaard  
Georg A. Heiss  
Michael D. Hewitt  
Christi A. Hill  
Heather K. Hill  
Jaime O. Hincapie-Duque  
Nicole L. Hindal  
Marc J. Hinton  
Gregory M. Hitz  
Meghan L. Hodgins  
Edith K. Hollister  
Todd A. Holsman  
Timothy J. Hopkins  
Erinn K. Horrigan  
Patrick R. Houle  
Laura K. Howe  
Kimberly A. Howell  
Robert B. Hughes  
Michael L. Hulver  
Kelly Hunter  
Jennifer M. Husek  
Bryan L. F. Hutchinson  
Ingrid L. Hutter  
Hue-Hwa Hwang  
Matthew G. Jager  
Joerk Jarick  
James L. Jerden  
Caren H. Jewett  
Roger E. Johnson  
Scott A. Johnson  
Dennis H. Johnston  
Gretchen L. Johnston  
Darren M. Jolley  
Gary W. Jones  
Clark E. Jorgensen  
Lori J. Juergens  
Kayode S. Kadiri  
Michael S. Kahle  
Christopher L. Kaminski  
Michael R. Kaplan  
Simon A. Kattenhorn  
Nancy L. Katyl  
Shelley J. Kauffman  
Susan E. Kay  
Carter E. Keairns  
Susan M. Keay  
Tammy E. Keim  
Alysa M. Keller  
Fernando H. Keller  
Tristania M. Kibbey  
Nicholas B. Kidd  
Denise E. King  
Andrew G. Klein  
Elizabeth P. Knapp  
Kurt M. Knesel  
Joseph J. Knezevic  
David A. Knobloch  
Robert B. Knowles  
Carol M. Kok  
Jonathan J. Kolak  
Christine E. Koltermann  
Karl J. Kreutz  
Robbin Krystal  
Peter R. Kuglstatler  
Carla M. Kuhn  
Andrew J. Kulp  
Ching-Huei Kuo  
Craig L. Kurtz  
Walter Kurz  
Matthew J. La Force  
Martin O. Lai  
A. Christopher Lambert  
Jean Frances Lambert  
Brian A. Landau  
Elizabeth M. Landrigan  
Jeffrey M. Langevin  
Alfred Y. Lanphier  
Alma C. Larsen  
Alison S. Lathrop  
Luc Lavier  
David Lazorchak  
Hermann Lebit  
Sang H. Lee

## NEW GSA FELLOWS

The following seven Members were advanced to Fellowship in October 1993:

Richard P. Major  
James M. McLelland  
Waite R. Osterkamp

Steven Schamel  
Paul Stone

Philip R. Whitney  
Don E. Wilhelms

Mary L. Leech  
Marvin R. Leedy  
Oren D. Leff  
Varner L. Leggett  
David R. Lemons  
Edward F. Lener  
Robert E. Lennox III  
Paul D. Levin  
Richard H. Levy  
Shing-Tzong Lin  
Mike K. Liguori  
Brian J. G. Lobb  
Lila M. Lohr  
Linda M. Lortz  
Yi Lu  
Shane A. Lyle  
Donna A. Lynch  
Robert E. Mace  
Sean R. Machovoe  
William S. Mah  
Ravidya N. Maharaj  
Margaret M. Maher  
Scott G. Maher  
Petra C. Maissenbacher  
Susan M. Majersky  
Paul E. Malmquist  
Natalia Malyk-Selivanova  
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Jeffrey T. Zenker  
Michael J. Zyllich



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.

1993 Meetings

December

**American Geophysical Union Fall Meeting**, December 6–10, 1993, San Francisco, California. Information: AGU—Meetings Dept., 2000 Florida Avenue, N.W., Washington, DC 20009, (202) 462-6900, fax 202-328-0566, E-mail: dsolomon@kosmos.agu.org.

**World Organization of Volcano Observatories—IAVCEI Commission**, December 13–17, 1993, Guadeloupe Island, West Indies. Information: Catherine Netter, Observatoires Volcanologiques, IGP, phone 33-1-44-27-24-00, fax 33-1-44-27-24-01.

1994 Meetings

January

**Remote Sensing and GIS International Symposium**, January 27–28, 1994, location to be determined. Information: Vern Singhroy, Canada Centre for Remote Sensing, 588 Booth Street, Ottawa, Ontario K1A 0Y7, Canada, (613) 947-1215, fax 613-947-1385; or Ivan Johnson, 7474 Upham Court, Ar-

vada, CO 80003, (303) 425-5610; and Doug Nebert, Water Resources Division, USGS National Centre, MS 445, Reston, VA 22092, (703) 648-5691, fax 703-959-5691.

**Remote Sensing for Marine and Coastal Environments, 2nd Thematic Conference**, January 31–February 2, 1994, New Orleans, Louisiana. Information: Robert Rogers, ERIM, Box 134001, Ann Arbor, MI 48113-4001, (313) 994-1200, ext. 3234, fax 313-994-5123.

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 Planetary 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,

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.

**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. (Abstract deadline: January 7, 1994.)

**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.

**GSA South-Central Section Meeting**, March 21–22, 1994, Little Rock, Arkansas. Information: Philip L. Kehler, Dept. of Earth Sciences, University of Arkansas, 2801 S. University Ave., Little Rock, AR 72204, (501) 569-3546, fax 501-569-8020.

Meetings continued on p. 318

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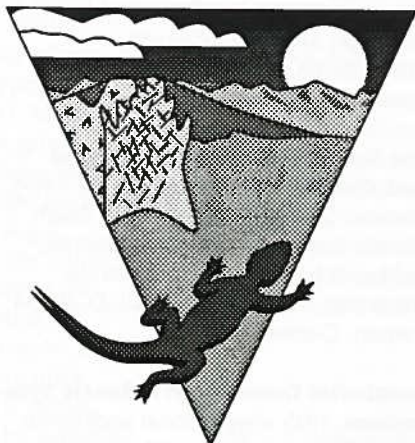
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**GSA Cordilleran Section Meeting**, March 21–23, 1994, San Bernardino, California. Information: Joan Fryxell, Dept. of Geological Sciences, California State University, 5500 University Parkway, San Bernardino, CA 92407-2397, (909) 880-5311, fax 909-880-7005.

**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. (Abstract deadline: December 2, 1993.)

**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. (Abstract deadline: December 1, 1993.)

**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: 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.

**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 Rossendale 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.

■ **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. Lowan, 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. (Abstract deadline: January 4, 1994.)

**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. (Abstract deadline: January 13, 1994.)

**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.

**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.

**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 Serezze (BS), Italy.

**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.

**Basement Tectonics 11th International Conference**, July 25–29, 1994, Potsdam, Germany. Information: Onno Oncken, Conference Chairman, Geoforschungs 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. (Abstract deadline: January 24, 1994.)

**August**  
**Clay Minerals Society 31st Annual Meeting**, August 14–19, 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.

**The South Atlantic: Present and Past Circulation**, August 15–18, 1994, Bremen, Germany. Information: South Atlantic Symposium, Barbara Donner, Fachbereich Geowissenschaften der Universität, Postfach 33 04 40, D-28334 Bremen, Germany.

**Equatorial Gateway in Atlantic Symposium**, 14th International Sedimentological Congress, 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. Informa-

tion: 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

**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**  
**Cyclicity 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.

**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. 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.

■ **Fifth International Mine Water Congress**, September 18–23, 1994, Nottingham, U.K. Information: Conference Secretary, IMWA Conference, c/o Department of Mineral Resources Engineering, University of Nottingham, University Park, Nottingham NG7 2RD, U.K. (Abstract deadline: December 31, 1993)

**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. (Abstract deadline: January 14, 1994.)

**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 x250, fax 55-123-21-8543 or 22-9325.

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International Joint Commission, 1988). Concerns have also been expressed that because of the explosive growth of satellite communities within the Metropolitan Toronto and Region Watershed (Fig. 1), continued road salting as now practiced may have serious implications for ground-water quality in major aquifers such as the Oak Ridges Moraine (Howard and Beck, 1986).

In recent years, the Groundwater Research Group at the University of Toronto has focused considerable attention on the issue of road de-icing chemicals as a source of sodium and chloride in ground-water. The primary aims of this work have been (1) to determine the degree to which primary and trace constituents of road de-icing chemicals and other urban sources of chloride contamination may ultimately threaten the quality of ground water; (2) to determine the chemical behavior of the contaminants and identify inorganic chemical constituents that could assist in labeling the source of contamination; (3) to predict the extent to which continued deployment of road de-icing chemicals will eventually degrade the inorganic quality of ground water; and (4) to develop models that will enable the rates of ground-water degradation to be estimated. In this paper we review the major findings of this research and, in particular, examine the value of models for predicting regional changes in water quality with time.

## HYDROGEOCHEMISTRY AND WATER QUALITY

Road de-icing chemicals take several different forms, but NaCl is the cheapest and most commonly used. It is particularly cost-effective at temperatures above  $-12^{\circ}\text{C}$ . In practice, NaCl is normally applied in pure mineral form, but it is also used in conjunction with abrasives such as sand. In Metropolitan Toronto, the preferred practice is to apply pure NaCl to main urban roads, highways, and freeways, whereas mixtures of sand and 5%–95% NaCl are used on side streets. Mixtures of sand and 5% NaCl are also used on gravel roads, because pure NaCl tends to damage the road surface during a thaw. Calcium chloride ( $\text{CaCl}_2$ ) is more effective than NaCl at temperatures in the range  $-12$  to  $-34^{\circ}\text{C}$  but is less commonly used because it is two to four times more expensive and is known to make the road surface slippery when wet (Hanley, 1979).

Environmental damage due to NaCl road de-icing chemicals is well documented (Jones et al., 1986; Scott and Wylie, 1980), but most accounts concern visible impacts such as vehicle corrosion, dying vegetation, and disintegration of concrete. When NaCl is dissolved in water, the most common concern is an increase in salinity to levels that would make the water unsuitable for consumption and some industrial applications. Table 1 lists water-quality guidelines for sodium and chloride in drinking water as defined by various interested agencies. In most cases the guideline for chloride is set at 250 mg/L in recognition of a taste threshold that for most people exists between 200 and 300 mg/L. The guideline for sodium is more contentious, because the ion has been strongly linked with the development of hypertension, a condition affecting perhaps 20% of the U.S. population (Moses, 1980; Craun, 1984; Tuthill and Calabrese, 1979). Raised sodium intake has also been associated indirectly with hypernatraemia (World Health Organization, 1984). Most agencies retain a guideline of 200 mg/L for purely aesthetic purposes. However, other agencies have been more cautious, the European Economic Community, for example, setting a guideline of just 20 mg/L.

During the hydrogeochemical part of the study, major ion, minor ion, and trace-metal analysis was performed on solutions of road salt and other suspected sources of chloride in the Toronto region. These sources include fertilizers and manure piles (Hill, 1982; Poinke and Urban, 1985), septic tanks, landfill leachates, and saline waters from the underlying Palaeozoic bedrock formations. The primary purposes of this work were to screen the chloride sources for potentially hazardous major, minor, and trace inorganic pollutants and to identify inorganic chemical parameters that could provide a diagnostic indication of the chloride source. In total, chemical analysis was performed on 37 chloride source samples, including five samples of road de-icing chemical from four different suppliers. Details of the geochemical investigation are described in Howard and Beck (1993).

Analysis of 5% solutions of NaCl (30 000 mg/L chloride) revealed an unexpectedly high degree of

TABLE 1. WATER-QUALITY GUIDELINES FOR SODIUM AND CHLORIDE IN DRINKING WATER

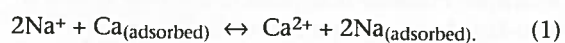
Agency	Limit	Type	Chloride (mg/L)	Sodium (mg/L)
U.S. Environmental Protection Agency (USEPA)	Secondary maximum contaminant level	Aesthetic	250	-
Health and Welfare Canada	Aesthetic objective	Aesthetic	250	200
Ontario Ministry of the Environment (MOE)	Maximum desirable concentration	Aesthetic	250	-
"	Aesthetic objective	Aesthetic	-	200
State of New York	Maximum contaminant level	Health	250	-
State of Florida	Maximum contaminant level	Health	-	160
World Health Organization (WHO)	Guideline value	Aesthetic	250	200
European Economic Community (EEC)	Guideline level	Aesthetic	-	20
"	Maximum admissible concentration	Aesthetic	-	150

Note: Data after Ontario Ministry of the Environment (1991). Dashes indicate no guideline given.

chemical purity. Sulfate and nitrate were found to be the most important secondary constituents, but they contributed less than 0.4% each to the solutions' total dissolved solids. Of the trace metals, only iron, aluminum, copper, and barium were detected, normally at concentrations in the range 0.1% to 0.3%. From a water-quality perspective, it is apparent that only sodium and chloride, the primary inorganic components, constitute a serious threat to ground-water potability.

A comparison to the chemical characteristics of all potential chloride sources revealed that it is the absence rather than the presence of certain ions that offers greatest potential for distinguishing NaCl road salt from other sources of chloride contamination. For example, NaCl road de-icing salts are characterized by extremely low levels of iodide and fluoride ( $\sim 20$   $\mu\text{g/L}$  and  $100$   $\mu\text{g/L}$ , respectively, in a 5% solution). In contrast, most natural sources of saline ground water are considerably more enriched in iodide and fluoride, commonly by several orders of magnitude.

When minor ion data are unavailable, the depletion of sodium with respect to chloride is a common characteristic of recent, active contamination by NaCl road salt. The depletion is attributed to an ion exchange reaction that has been observed during seawater invasion of coastal aquifers (Howard and Lloyd, 1983). The reaction takes the form:



Although this reaction has been responsible for lowering sodium concentrations in aquifers on the fringe of Metropolitan Toronto (Howard and Falck, 1986), the capacity of soils and sediments to perform ion exchange appears to have been exceeded in heavily urbanized areas that have received large influxes of NaCl over extended periods of time. As a result, saline ground waters from the central area rarely show a depletion of sodium.

## SALT BALANCE

A prerequisite for modeling subsurface salt transport is an understanding of the rate at which the applied salt is retained in the subsurface on an annual basis. This was achieved using a catchment-mass-balance approach, in which chloride input, represented by the mass of chloride applied to the catchment during a specified time frame, is budgeted against chloride output in the form of chloride loading in the

exiting stream. The net difference represents the mass of salt that is stored (retained) within the catchment.

A chloride mass balance was determined for the highly urbanized Highland Creek basin of the Metropolitan Toronto and Region Watershed (Fig. 1). Full details of the balance are given by Howard and Haynes, (1993). The basin is  $104 \text{ km}^2$  in area, and it is receiving approximately 17 000 Mg of NaCl road de-icing chemicals each year. This represents approximately 200 g of NaCl for every square metre of the catchment. Chloride leaving the basin was determined from stream flow and electrical conductivity measurements recorded at 15-minute intervals over a two-year period. The amount of chloride leaving the basin through stream sediment load was assumed to be negligible. The results are summarized in Table 2. They reveal that only 45% of the salt applied is being removed annually from the catchment by surface water runoff, the remainder entering temporary storage in shallow subsurface waters.

While the total mass of chloride entering the subsurface exceeds the mass of chloride leaving as baseflow to the stream, chloride will accumulate in the ground water, and chloride concentrations in the ground water will increase. Eventually, chloride in the ground water will reach a level at which the mass lost in base flow will match the mass of chloride entering the subsurface. At this stage, steady state will be reached, and no further deterioration of ground-water or stream-water quality will occur. Aquifer recharge in the basin is approximately 162 mm per annum. If present rates of salt application are maintained and 45% of this salt enters the subsurface, chloride concentrations in ground waters discharging as base flow will eventually reach a steady state concentration of  $>400$  mg/L, according to the data. This value represents a threefold increase over present average baseflow concentrations and well exceeds guidelines for drinking-water quality. The impact of sodium will be delayed locally by ion exchange, but similar calculations suggest that steady-state sodium concentrations will reach an equally unacceptable 250 mg/L.

## TRANSPORT MODELS

Although the salt balance calculations are useful in determining the average concentrations of sodium and chloride in base-flow discharge when steady-state

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TABLE 2. SUMMARY OF CHLORIDE BALANCE FOR THE PERIOD NOVEMBER 1, 1988 TO OCTOBER 31, 1991

Season	Total chloride applied (Mg)	Chloride loading in surface runoff		
		Winter months (% of total applied)	Summer months (% of total applied)	Surface runoff (% of total applied)
1988–1989	10 486	$>15^*$	19	$>34$
1989–1990	11 228	31	14	45
1990–1991	9 173	26	-	$>26$

Note: Data summarized after Howard and Haynes (1993). Dash indicates not determined.

\* Data available for only March and April.

conditions are reached, contaminant transport models are required to investigate spatial and temporal changes in ground-water quality. During the study, three types of model were developed, each designed to meet specific applications.

### "FLOWPATH"

FLOWPATH (Franz and Guiguer, 1990) is a two-dimensional, finite-difference model that can simulate horizontal, steady-state ground-water flow and perform particle tracking in heterogeneous, anisotropic, confined or unconfined and leaky aquifers. The model was applied to a representative 460 km<sup>2</sup> region of the Greater Toronto area. As shown by Figure 1, the area is bounded by a major urban river to the west, an urban catchment divide in the east, and by Lake Ontario and the Oak Ridges moraine to the south and north, respectively. Model data were supplied by 8000 water-well records, 800 of which were used to estimate variations in aquifer transmissivity. Static water levels from all 8000 records were used to generate the potentiometric surface and thereby permit model calibration.

To estimate contaminant travel times in the aquifer, a reverse particle tracking routine was invoked that, in effect, releases particles along the discharge boundary (i.e., terminal streams and Lake Ontario) and measures their rate of progress as they move upgradient along flow lines. By plotting travel times on each of the flow paths, isochrones can be drawn that represent lines of equal travel time to the discharge points.

The value of this approach is demonstrated by Figure 2, which shows isochrones calculated for the southern third of the modeled area. Chemically conservative contaminants released within a few kilometres of the rivers and Lake Ontario will discharge within a 5 yr period. Contaminants released more centrally will take more than 100 yr to leave the system. Assuming that road salt is distributed evenly within the area, an analysis of the cumulative area contained within each isochrone will indicate the time required for steady state to be achieved. For the study area in Figure 1, results are given in Figure 3. The data suggest that average chloride concentrations at discharge points will reach steady-state value within 200 yr of initial salt application.

### Analytical Solutions

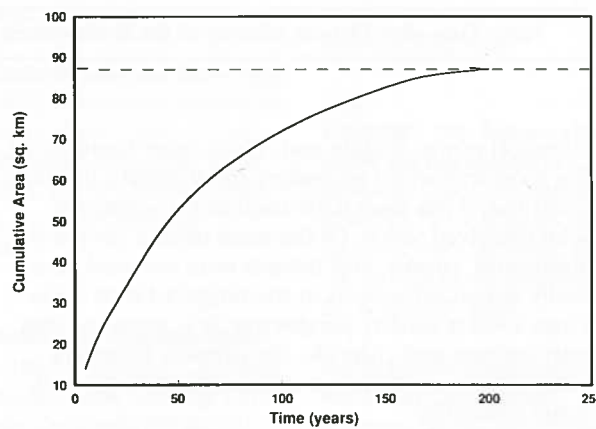
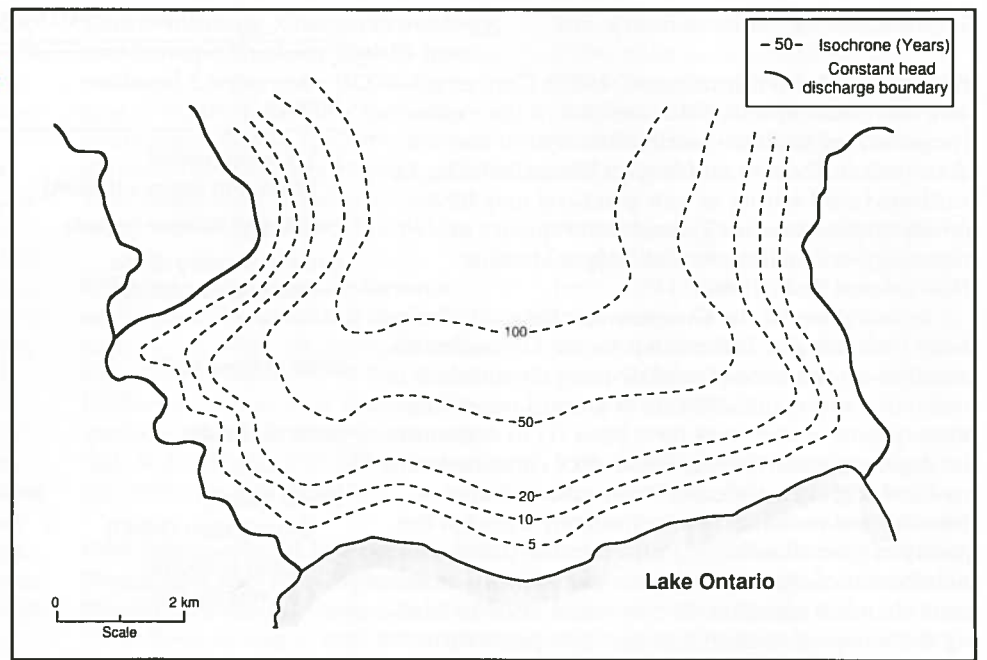
Although FLOWPATH offers a relatively quick and easy-to-use tool for estimating rates of ground-water quality degradation and stream contaminant loadings, it is less suitable for estimating contaminant concentrations within time and space. This type of problem can be approached in many ways, but the simplest and perhaps most useful involves the application of three-dimensional analytical solutions. In most cases, two solutions proved most valuable. The first is designed for single releases of a "slug" and models the transport of finite contaminant sources of dimension X, Y, Z, initial concentration C<sub>0</sub> instantly introduced into a steady-state, uniform flow field (flow in the x-direction). Modified after Taylor and Howard (1988), it takes the form:

$$C(x,y,z,t) = (C_0/8) \cdot \{ \text{erf}[(x + X/2 - vt)/2(a_x vt)^{0.5}] - \text{erf}[(x - X/2 - vt)/2(a_x vt)^{0.5}] \} \cdot \{ \text{erf}[(y + Y/2)/2(a_y x)^{0.5}] - \text{erf}[(y - Y/2)/2(a_y x)^{0.5}] \} \cdot \{ \text{erf}[(z + Z/2)/2(a_z x)^{0.5}] - \text{erf}[(z - Z/2)/2(a_z x)^{0.5}] \}, \quad (2)$$

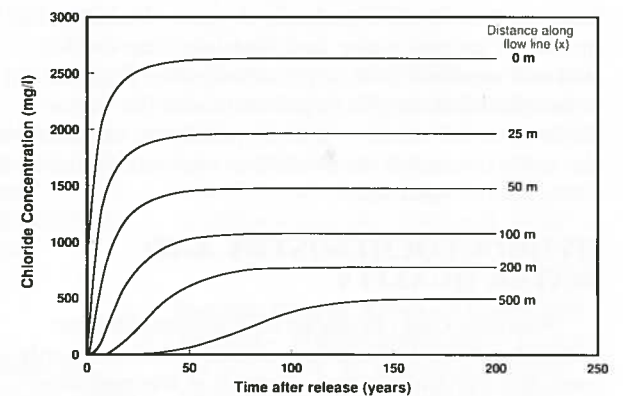
where: x, y, z are distances measured from the center of the source, a<sub>x</sub> is the dispersivity in the x direction, a<sub>y</sub> is the dispersivity in the y direction, a<sub>z</sub> is the dispersivity in the z direction, v is the contaminant velocity, and t is time. The other solution is for a source, concentration C<sub>0</sub> and dimensions Y by Z (in the y and z directions, respectively), introduced continuously into a one-dimensional steady-state flow field (flow in the x direction) (Domenico and Schwartz, 1990). In this solution, the continuous source is considered to approximate the situation where salt applied to a highway of length Y moves vertically downward to the water table and mixes with water moving in the aquifer to a depth of Z. The solution takes the form:

$$C(x,y,z,t) = (C_0/8) \cdot \text{erfc}[(x - vt)/2(a_x vt)^{0.5}] \cdot \{ \text{erf}[(y + Y/2)/2(a_y x)^{0.5}] - \text{erf}[(y - Y/2)/2(a_y x)^{0.5}] \} \cdot \{ \text{erf}[(z + Z/2)/2(a_z x)^{0.5}] - \text{erf}[(z - Z/2)/2(a_z x)^{0.5}] \}. \quad (3)$$

**Figure 2.** Contaminant discharge isochrones for the southern third of the FLOWPATH study area. Isochrones are shown for chemically conservative parameters (retardation factor: 1).



**Figure 3.** Cumulative area curve for contaminant discharge isochrones, showing approximate time to steady-state conditions as predicted by FLOWPATH.



**Figure 4.** Variation of steady-state chloride concentration with time as a function of various distances along the flowline.

Whereas the finite source solution (equation 2) is most appropriate for single isolated releases of a chemical (e.g., the use of a snow-salt dump for one season), the continuous-source solution (equation 3) is more effective in situations where salt is applied over an extended period of time. If a series solution is used to calculate the error functions erf and erfc (Walton, 1989), both equations are easily programmed into spreadsheets such as LOTUS 123.

The benefits of the analytical solution spreadsheet approach are illustrated here by an example drawn from the downtown Toronto area. In this example, chloride is applied to a 300 m length of two-lane highway at a rate of 21.5 kg·m<sup>-1</sup>·yr<sup>-1</sup>. Almost half (45%) of the chloride is lost in surface runoff, and the remainder enters the subsurface beneath the road where it mixes with ground water to form a contaminant plume. The initial dimensions, initial concentration, and subsequent behavior of the plume are dictated by local aquifer conditions. In downtown Toronto the aquifer materials can be broadly classified as silty sands with a hydraulic conductivity of 6 x 10<sup>-6</sup> m/s and an effective porosity of 30%. Dispersivities in the x, y, and z directions are estimated to be 20 m, 1 m, and 0.1 m, respectively. The hydraulic gradient is 1%, and this results in an average linear flow velocity of 6.3 m/yr and an aquifer flux of 1.9 m<sup>3</sup>·m<sup>-2</sup>·yr<sup>-1</sup>. If it is assumed that ground water flows perpendicular to the highway, then the initial dimensions of the plume will be the length of the salted section (300 m) by the depth of mixing beneath the highway. The mixing depth (Z) is likely to be somewhere in the range 1 to 5 m. The greater the mixing depth, the lower the concentration at the source. For a mixing depth of 2 m used in the example, initial source concentration is 3120 mg/L. Although errors in the choice of mixing depth can generate errors in plume concentration close to the source, the effects become negligible at distances beyond approximately 20 Z (i.e., >40 m).

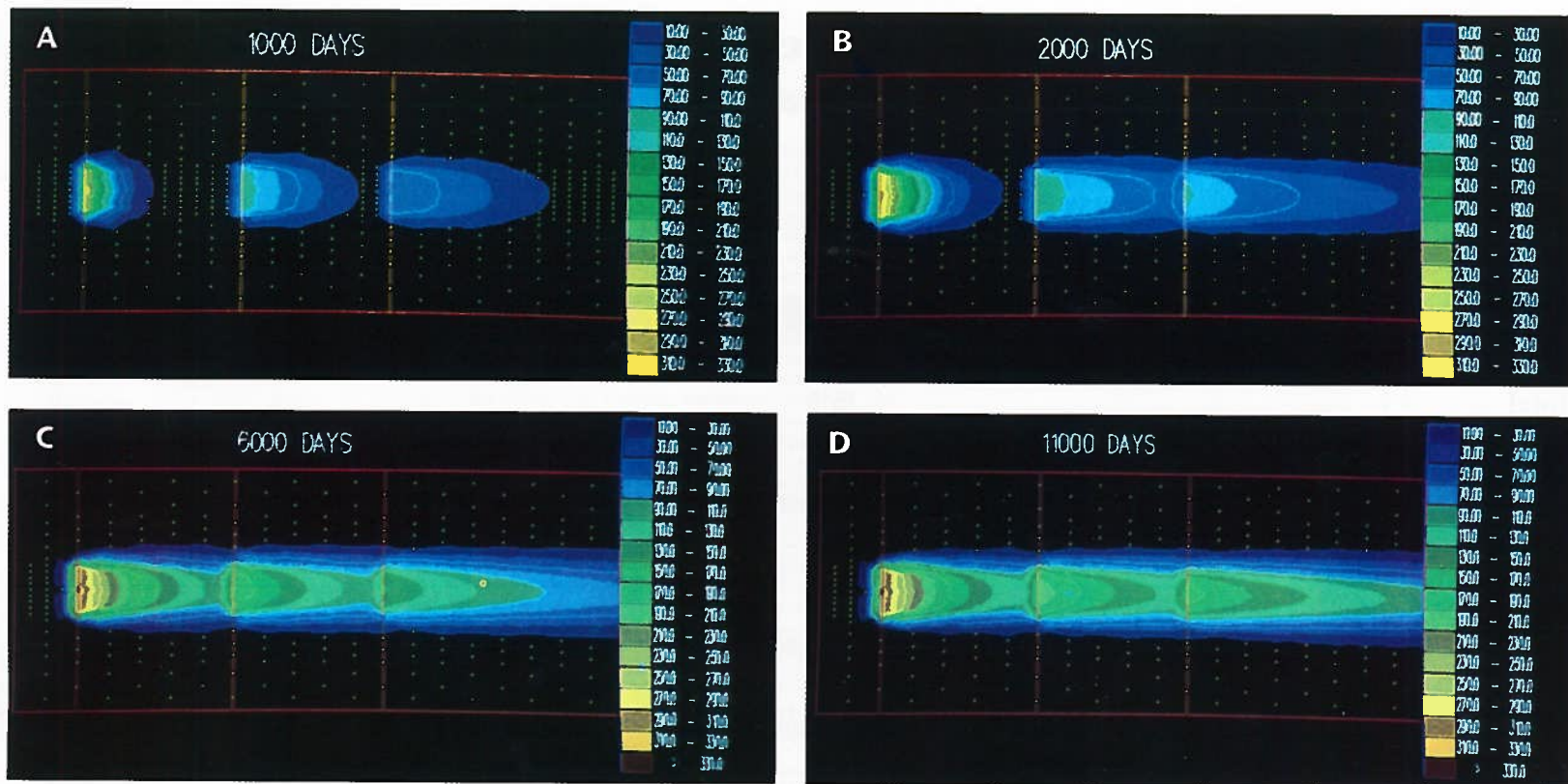
The results, shown in Figure 4, show how chloride concentrations at the top of the aquifer (z = 0 m) and in the center of the plume (y = 0 m) vary with time as a function of distance (x) along the ground-water flow line. Highest concentrations (1000–3000 mg/L) are within a few tens of metres of the highway, but thereafter fall rapidly due to dispersive processes. Steady state occurs within a very short time frame (<10 yr). More distant sites do not see the effects of salting for tens of years and are less seriously affected.

Furthermore, these sites may not reach steady state for 100 yr or more.

The spreadsheet analytical solutions are useful for providing quick answers to relatively simple problems. They are especially valuable for performing sensitivity analyses on the large number of input variables. Simplicity of approach, however, brings limitations, the most important of which include the assumptions of steady-state flow at constant velocity and of aquifer homogeneity. For example, changes in steady-state chloride concentration with distance seen in Figure 4 are almost entirely due to chemical dispersion, or "spreading" in a vertically downward direction. While this is likely to be the major mechanism for dilution at relatively short distances from the highway (typically <500 m) its importance will diminish at greater distances where the underlying aquitard will begin to impose a spreading boundary. At large distances, aquifer recharge can become the most important consideration. Recharge increases aquifer flow velocity and also dilutes the plume with uncontaminated water. To some extent these effects can be incorporated into the spreadsheet by modifying the transport equations. It is often more convenient, however, to approach such situations with finite element models such as AQUA.

### "AQUA"

The importance of recharge as a diluting mechanism for road salt was investigated using AQUA, a two-dimensional finite element model. This model can simulate ground-water flow and mass transport in heterogeneous and anisotropic, confined or unconfined aquifer systems under steady state and transient flow conditions. AQUA was used to simulate ground-water flow conditions in part of a small subcatchment in the Highland Creek basin. The model domain is a 2 km by 1 km rectangular area containing three 10-m-wide roadways. These are spaced at 500 m intervals and are oriented perpendicular to the direction of flow. Highland Creek is represented by a fixed head boundary; the ground-water divide and limiting flow lines are represented by no-flow boundaries. The aquifer is 5 m thick and is recharged everywhere at a rate of 160 mm/yr. The hydraulic conductivity averages 1.2 x 10<sup>-4</sup> m/s, and the effective porosity is approximately 30%.



**Figure 5.** AQUA simulation of chloride plume development, showing rates of migration away from salted roads. Contours range from 10 to 300 mg/L, with a contour interval of 20 mg/L.

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Figure 5 shows plume behavior when salt is applied to 220 m sections of each highway. Concentrations shown are average values over the depth of the aquifer. Highest chloride concentrations are always in the plume nearest the ground-water divide, where Darcy velocities are low and little water is available to dilute the infiltrating salt. At early times plume concentrations are relatively low, but they increase slowly with time as more salt is added to the system. Eventually, steady state is reached at which time salt inputs are balanced by salt output. This occurs after just 30 yr, a period shorter than indicated by FLOWPATH, but reasonable given the relatively small size of the modeled area. At steady state, concentrations of chloride within 200 m of the salted highway are typically two to three times the concentration observed in the discharging base flow.

## CONCLUSIONS

During the past 40 yr, highway departments in snow-belt regions of the world have come to recognize NaCl de-icing chemicals as the most convenient, cost-effective means of maintaining safe winter driving conditions. The environmental damage to vegetation, surface water, and ground water is commonly regarded as acceptable, given the benefits derived. Unfortunately, in "accepting" the observed environmental damage, the commonly held perception is that the system is in equilibrium, and the observed damage is as bad as it is likely to get under the present level of salt application. This is apparently not so. A salt budget determined in the Toronto area suggests that only 45% of the salt applied is being flushed into surface water bodies each year; its environmental damage is readily apparent. The remainder is entering shallow subsurface waters with the result that most will not reemerge for more than 50 yr. If present rates of salt application are maintained, chloride and sodium concentrations in ground waters discharging as stream base flow will eventually reach steady-state concentrations of >400 mg/L and >250 mg/L, respectively. These values represent a threefold increase over present average base-flow concentrations and exceed guidelines for drinking-water quality. The time to steady state will depend on local hydrogeological conditions, including the size of the catchment. Model studies indicate that steady state in the Toronto area may take 200 yr from the time of initial salting of the roads, by which time average concentrations of sodium and chloride in ground water will be similar to predicted base-flow concentrations. Locally, particularly within a few hundred metres of highways, concentrations three to four times the base-flow concentrations can be anticipated.

## ACKNOWLEDGMENTS

This work was supported by research grants from the Great Lakes University Research Fund (sponsored by Environment Canada and the Natural Sciences and Engineering Research Council) and the Ontario Ministry of the Environment. We thank numerous University of Toronto students and colleagues who

assisted in the collection and interpretation of the results presented, and especially the Ontario Ministry of Transport and the local municipalities for their cooperation in providing salt-application data.

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Manuscript received April 5, 1993; revision received June 25, 1993; accepted July 12, 1993.

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For information call the GSA Meetings Department,  
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## 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,  
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## 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 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 Edi-  
tors 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 recom-  
mendations 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 empha-  
sis 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.

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The Geological Society of America

**BULLETIN**

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## DEPARTMENT OF GEOLOGICAL SCIENCES UNIVERSITY OF TEXAS AT AUSTIN

The Department of Geological Sciences invites applications for a tenure-track faculty position, starting fall 1994. We are seeking candidates in the area of structure/tectonics who specialize in brittle deformation at any scale and/or on the relationships between sedimentation and tectonics. The successful candidate will be expected to teach undergraduate and graduate courses, supervise M.A. and Ph.D. students, and develop a strong research program which will complement our existing structure/tectonics program.

Applicants should provide a resume, list of research publications, and names of three references prior to the closing date of January 31, 1994. Mail to: Structure Search Committee Chairman, Department of Geological Sciences, University of Texas at Austin, Austin, TX 78712.

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## UNIVERSITY OF FLORIDA LOW TEMPERATURE GEOCHEMISTRY

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ance with all applicable EOE, ADA, and Affirmative Action guidelines.

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Position as Professor and Chairperson available September 1994 in Geosciences Department with strengths in petrology, structure, sedimentology/paleontology, surficial processes, physical and resource geography, and spatial analysis. The department has 19 tenured faculty, 90 graduate students, and 135 undergraduate majors. Long-term department goals are in earth and environmental geosciences. Geosciences, housed with other basic sciences in the College of Science, has strong collaborative ties with the Colleges of Forestry, Agricultural Sciences, and Oceanic and Atmospheric Sciences, the Center for Analysis of Environmental Change, the U.S. Forest Service Research Lab, the U.S. Geological Survey, and the U.S. EPA Environmental Research Laboratory located on or near the OSU campus. Oregon State University is a Land Grant, Sea Grant, Space Grant, and Carnegie Class I Research University.

Candidates must have a Ph.D. or equivalent in the physical geosciences and a distinguished record of academic achievement commensurate with full-professorial appointment.

Send resume, including evidence of administrative, research, and teaching experience; publications; external recognition awards; and names of three references to Professor A. Jon Kimerling, Chairman, Geosciences Search Committee, Department of Geosciences, Oregon State University, Corvallis, OR 97331-5506. Candidates should also submit a statement on their views of the future of geosciences teaching and research. Candidates will be notified before letters of reference are requested. Applications will be reviewed starting January 1, 1994, until the position is filled.

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## TENURE-TRACK POSITION IN METAMORPHIC PETROLOGY THE UNIVERSITY OF NEW MEXICO

The Department of Earth and Planetary Sciences is accepting applications for a tenure-track faculty position in metamorphic petrology beginning August, 1994. We anticipate hiring at the Assistant Professor level, but Associate level applicants can be considered. Minimum qualifications: Ph.D. with specialty in metamorphic petrology, completed by the time of appointment. Preferred qualifications include: research expertise with a strong field emphasis, petrographic analysis, analytical work used for quantitative P-T and P-T path determinations, thermal modeling, analysis of metamorphic and deformational textures, and interest in the tectonic evolution of orogenic belts. The successful candidate is expected to develop and maintain strong research and teaching programs in metamorphic petrology and to contribute to a collaborative effort to study the interaction of deformational and metamorphic processes. Undergraduate teaching responsibilities include metamorphic petrology and participation with the undergraduate mineralogy-petrology sequence and physical geology. Graduate teaching will include courses in the applicant's field of specialization. The Department of Earth and Planetary Sciences has 19 full-time faculty and excellent analytical facilities, including a JEOL 733 superprobe with Oxford Link automation system, two electron microscopes (JEOL 2000 FX and JEOL 2010) and an ion microprobe (Cameca 4f). New Mexico, with its spectacular geologic setting and proximity to the National Laboratories, provides an exceptional location for teaching and research related to the interaction of deformation and metamorphism.

Applicants should submit a resume, transcripts, copies of publications, a brief statement of research

and teaching experience and interests, and the names, addresses, and telephone (and fax) numbers of four referees to: Dr. K. E. Karlstrom, Chair of Metamorphic Petrology Search Committee, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131. To ensure full consideration, applications should be received by January 15, 1994.

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## UNIVERSITY OF PITTSBURGH LOW TEMPERATURE GEOCHEMISTRY

The Department of Geology and Planetary Science invites applications for a tenure-track faculty appointment at the assistant professor level in low-temperature laboratory-based geochemistry. Exceptionally qualified, experienced candidates may be considered for appointment at higher rank. This position is expected to be available, subject to budgetary approval, with a starting date of September, 1994.

We seek an individual who is a competent teacher, has a strong research commitment, and can develop a successful research program that is competitive for external funding. Responsibilities will include teaching introductory level geology courses (both for majors and non-majors) as well as upper level and graduate offerings in the individual's area of expertise.

Applicants should submit a statement of research interests, curriculum vitae, reprints of recently published articles, and names of at least three references to Professor Thomas H. Anderson, Chairman, Department of Geology and Planetary Science, University of Pittsburgh, Pittsburgh, PA 15260 before January 15, 1994.

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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.

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Required by 49 U.S.C. 3685			
1a. Title of Publication	1b. PUBLICATION NO.	2. Date of Filing	
GSA Today	1 0 5 2 5 1 7 3	7/16/93	
3. Frequency of Issue	3a. No. of Issues Published Annually	3b. Annual Subscription Price	
Monthly	12	Member \$7.00 Nonmember \$40.00	
4. Complete Mailing Address of Known Office of Publication (Not printer, publisher, or distributor) (Street, city, county, state and ZIP+4 code)			
The Geological Society of America, Inc., P.O. Box 9140, Boulder, Colorado 80301 U.S.A.			
5. Complete Mailing Address of Headquarters or General Business Office of Publisher (Not printer)			
Same as above			
6. Full Names and Complete Mailing Addresses of Publisher, Editor, and Managing Editor (Full name, title, street, city, state and ZIP+4 code)			
Publisher: F. Michael Wahl, P.O. Box 9140, Boulder, Colorado 80301 U.S.A.			
Editor: Faith E. Rogers, P.O. Box 9140, Boulder, Colorado 80301 U.S.A.			
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Limited supplies of the following continuing education manuals/notes remain available from the Boston Annual Meeting. These may be ordered, while supplies last, from GSA Publication Sales.

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Candidates sought for tenure track position in Geology and Geophysics department to develop active research programs directed towards understanding development, structure, sedimentation, stratigraphy of continental shelves/margins. Considerable latitude exists for focus of research; opportunities available for cooperative programs with other institution research staff.

Ph.D. required; must be willing/able to secure funding to support their programs from appropriate federal and/or private sources. Ability/willingness to go to sea required.

The Department staff of about 100 includes 30 tenured or tenure-track scientists and 25 Ph.D. candidates in the WHOI/MIT Joint Graduate Program. WHOI operates three ocean-going research vessels, the deep submersible ALVIN state-of-the-art experimental facilities and analytical instrumentation.

Application review begins December 1993. Send a statement of research interests, curriculum vitae and names and addresses for 3 references to Human Resources Office, Box 54PE, Woods Hole, MA 02543.



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## 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. Kottlowski, 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

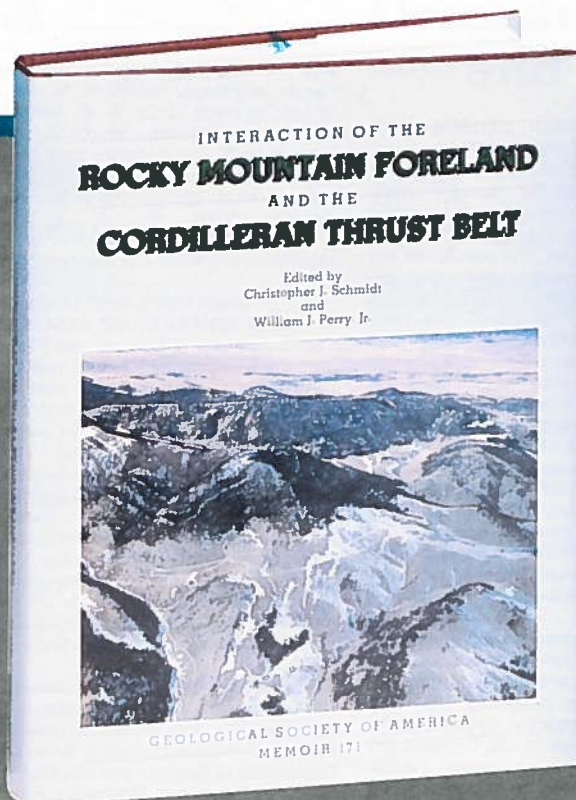
Nominations can be made by anyone, based on the following criteria: (1) paper must be selected from GSA or state geological survey publications, (2) paper must be selected from those published during the preceding three full calendar years, (3) nomination must include a paragraph stating the pertinence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

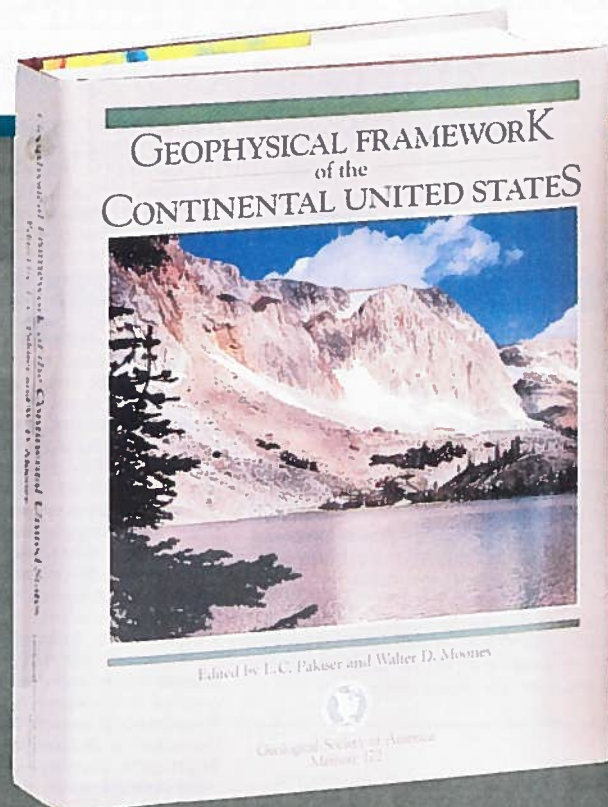


#### Interaction of the Rocky Mountain Foreland and the Cordilleran Thrust Belt

edited by Christopher J. Schmidt and William J. Perry, Jr., 1989

Focuses on the interaction of structures of Cordilleran thrust belt origin with those of the adjacent or subadjacent Rocky Mountain foreland. The first five chapters summarize the tectonic styles of the Rocky Mountain (Wyoming) foreland, primarily in terms of Laramide crustal shortening. The next five chapters focus on general or comparative studies of interaction and/or overlap between Laramide-style (thick-skin, crustal-scale) deformation of the foreland and dominantly thin-skin, Sevier-style deformation of the Cordilleran thrust belt. Seventeen following chapters chiefly look at interaction and overlap geometries: nine deal entirely with areas and regions north of the Snake River downwarp; seven with areas within the Wyoming salient of the thrust belt; one looks at the paleomagnetic evidence of thrust-sheet rotations both north and south of the downwarp around both margins of the southwestern Montana recess of the Cordilleran thrust belt; and one looks at the complex tectonic styles near the U.S.-Mexican border. The last five chapters are on sedimentologic and stratigraphic studies related to foreland/ thrust belt interaction and foreland-basin evolution. Profusely illustrated and includes three pocket-plates and a microfiche card.

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edited by L. C. Pakiser and W. D. Mooney, 1990

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ISSN 1052-5173

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