Vol. 12, No. 5 A Publication of the Geological Society of America May 2002

GSA TODAY

Persistent Holocene Outflow from the Black Sea to the Eastern Mediterranean Contradicts Noah's Flood Hypothesis

INSIDE:

Persistent Holocene Outflow from the Black Sea to the Eastern Mediterranean Contradicts Noah's Flood Hypothesis Ali E. Aksu, Richard N. Hiscott, Peta J. Mudie, André Rochon, Michael A. Kaminski, Teofilo Abrajano, and Doğan Yaşar, p. 4

GSA Foundation Penrose Circle, p. 18

GSA TODAY

GSA TODAY publishes news and information for more than 17,000 GSA members and subscribing libraries. *GSA Today* lead science articles should present the results of exciting new research or summarize and synthesize important problems or issues, and they must be understandable to all in the earth science community. Submit manuscripts to science editor Karl Karlstrom, kek1@unm.edu.

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. Periodicals postage paid at Boulder, Colorado, and at additional mailing offices. Postmaster: Send address changes to *GSA Today*, Member Services, P.O. Box 9140, Boulder, CO 80301-9140.

SUBSCRIPTIONS for 2002 calendar year: Society Members: *GSA Today* is provided as part of membership dues. Contact Member Services at 1-888-443-4472, (303) 447-2020, or member@geosociety.org for membership information. Nonmembers & Institutions: Free with paid subscription to both *GSA Bulletin* and *Geology*, otherwise $65 for U.S., Canada, and Mexico; $75 elsewhere. Contact Subscription Services at (800) 627-0629 or gsa@allenpress.com. Also available on an annual CD-ROM (together with *GSA Bulletin*, *Geology*, GSA Data Repository, and an Electronic Retrospective Index to journal articles from 1972); $94 to GSA Members, others call GSA Subscription Services for prices and details. Claims: For nonreceipt or for damaged copies, members contact Member Services; all others contact Subscription Services. Claims are honored for one year; please allow sufficient delivery time for overseas copies, up to six months.

STAFF

Executive Director: John W. Hess
Science Editor: Karl E. Karlstrom, Department of Earth and Planetary Science, University of New Mexico, Albuquerque, NM 87131-1116, kek1@unm.edu
Director of Publications: Jon Olsen
Managing Editor: Jeanette Hammann, jhammann@geosociety.org
Editorial Assistant: Christina Alba
Production Manager: Diane C. Lorenz
Production Coordinator: Margo Y. Good
Graphics Production: Margo Y. Good

ADVERTISING

Classifieds and display: Contact Ann Crawford, 1-800-472-1988, ext. 1053, (303) 357-1053, fax 303-357-1070; acrawford@geosociety.org.
GSA ONLINE: www.geosociety.org
Printed in U.S.A. using pure soy inks.

THE GEOLOGICAL SOCIETY OF AMERICA

50% Total Recovered Fiber
10% Postconsumer

CONTENTS

Vol. 12, No. 5 | **May 2002**

science article

Persistent Holocene Outflow from the Black Sea to the Eastern Mediterranean Contradicts Noah's Flood Hypothesis
Ali E. Aksu, Richard N. Hiscott, Peta J. Mudie, André Rochon, Michael A. Kaminski, Teofilo Abrajano, and Doğan Yaşar 4

Dialogue 10

Emergency Management: Roles for Geoscientists 11

Book Reviews 12

2002 Section Meetings 12

Announcements 14

Journal Highlights 17

GSA Foundation Update: Penrose Circle 18

GeoTrip Memories: New Year's at the End of the World 20

GeoVentures: Iceland 21

Classified advertising 22

On the cover: Image shows Landsat thematic mapper data using the short-wave infrared, infrared, and visible (green) channels (TM bands 5, 4, and 2) of Istanbul. See "Persistent Holocene Outflow from the Black Sea to the Eastern Mediterranean Contradicts Noah's Flood Hypothesis," by A.E. Aksu, et al., p. 4–9. Images courtesy of NASA—Goddard Space Flight Center, Scientific Visualization Studio.

Persistent Holocene Outflow from the Black Sea to the Eastern Mediterranean Contradicts Noah's Flood Hypothesis

***Ali E. Aksu**, aaksu@sparky2.esd.mun.ca, and **Richard N. Hiscott**, Department of Earth Sciences, Memorial University of Newfoundland, St. John's, Newfoundland A1B 3X5, Canada*

***Peta J. Mudie** and **André Rochon**, Geological Survey of Canada—Atlantic, P.O. Box 1006, Dartmouth, Nova Scotia B2Y 4A2, Canada*

***Michael A. Kaminski**, Research School of Geological and Geophysical Sciences, University College London, Gower Street, London WCIE 6BT, UK, and KLFR, 3 Boyne Avenue, Hendon NW4 2JL, UK*

***Teofilo Abrajano**, Department of Earth and Environmental Sciences, Rensselaer Polytechnic Institute, Troy, New York 12180, USA*

***Doğan Yaşar**, Institute of Marine Sciences and Technology (IMST), Dokuz Eylül University, Haydar Aliyev Caddesi No. 10, Inciraltı, Izmir, Turkey 35340*

ABSTRACT

Controversy surrounds reconnection of the Black Sea and Mediterranean during Holocene sea-level rise. This reconnection and its causes have implications for European and Middle Eastern archaeology, paleoclimate, and marine sedimentation; e.g., genesis of organic-rich muds (sapropels). Bill Ryan, Walter Pitman, and co-workers propose reconnection via a catastrophic flood of Mediterranean water into the Black Sea at ca. 7.5 ka, with speculation that this was the historical basis for the biblical story of Noah's Flood. In contrast, this paper suggests a more complex and progressive reconnection over the past 12 k.y. Today, the Black Sea exports considerably more brackish water than the saline inflow it receives from the Mediterranean. There is a stratified, two-layer flow that has a strong effect on aquatic life and seabed sediments. The "Marmara Sea Gateway" (narrow straits of Dardanelles and Bosphorus, and deep intervening Marmara Sea) provides a set of natural flow valves (and sediment traps) that in principle should contain a record of the reconnection. Using ~7500 line-km of seismic profiles, 65 soft-sediment cores, and 43 radiocarbon dates, we recognize a 10–11 k.y. history of low surface-water salinities in the Marmara Sea and northern Aegean Sea. The low-density surface layer promoted uninterrupted water-column stratification and depleted oxygen concentrations at depth and is attributed to persistent Black Sea outflow across the Bosphorus Strait. Seismic data reveal a climbing delta on the middle shelf south of the Bosphorus exit, active only from ca. 10 to 9 ka based on radiocarbon dating of its distal prodelta. The strength of the early outflow is confirmed by the progradation of this delta, and contemporaneous severe water-column stratification leading to deposition of sapropels in basinal areas. Ryan and Pitman's argument for a catastrophic Black Sea flood hinges on the rapid first appearance of euryhaline (Mediterranean) mollusks on Black Sea shelves at ca. 7.5 ka. In our view, this colonization was not a consequence of catastrophic flooding but rather the outcome of a slow establishment of two-way flow in the Bosphorus and a time lag during which the fresher waters of the deep Black Sea were replaced by more saline inflow, eventually allowing marine organisms to colonize the Black Sea shelves.

INTRODUCTION

The "Marmara Sea Gateway" connects the Black Sea and eastern Mediterranean (Fig. 1A and 1B) and consists of a linked set of narrow straits with shallow bedrock sills (Bosphorus Strait—sills ~40 m deep; Dardanelles Strait—sills ~70 m deep) and the inland Marmara Sea, locally deeper than 1200 m. The gateway provides a natural laboratory in which to study evolution of the Quaternary climate of central and northern Europe. Today, the Black Sea is swollen by the discharge of major European rivers (Danube, Don, Dnieper, Dniester, Southern Bug) and exports ~300 km^3/yr of brackish water through the gateway. This is 50 times the cumulative annual discharge of the small rivers entering the Marmara Sea. Satellite altimetry shows that the surface of the Black Sea is ~30 cm above the level of the Marmara Sea, which, in turn, is ~5–27 cm above the level of the northern Aegean Sea (Polat and Tuğrul, 1996). These elevation differences drive the net outflow across the gateway. The present water exchange across the Bosphorus Strait is a two-layer flow. A cooler, lower salinity (17‰–20‰) surface layer exits the Black Sea and warmer, higher salinity (38‰–39‰) Mediterranean water flows northward through the strait, at depth (Polat and Tuğrul, 1996). Except for the open Aegean Sea, the upper tens of meters of the water column in the gateway area are strikingly fresher than the deep water because of the Black Sea outflow (Fig. 1C). The low-density surface layer prevents ventilation of the deeper water column and promotes organic-matter preservation and benthic communities adapted to suboxic to dysoxic conditions (0.1–1.3 ml/l O_2). Organic-rich sapropels (muds with >2% total organic carbon, or TOC) punctuate the Pliocene-Quaternary record of the

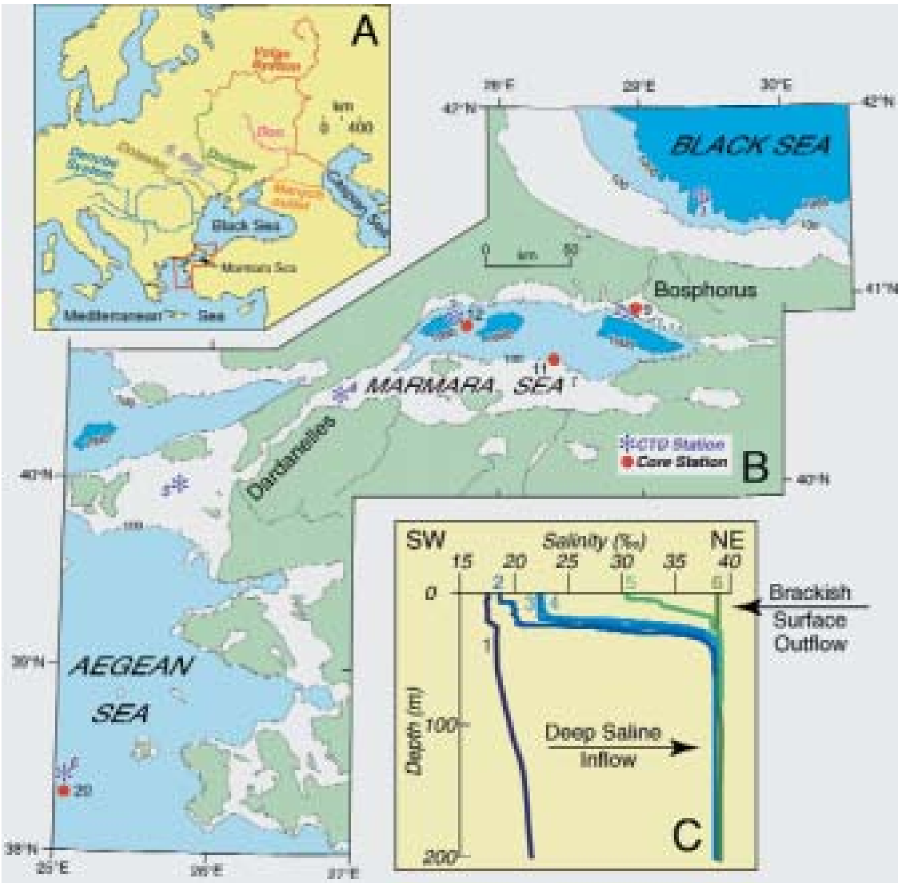


Figure 1. A: Location of the Marmara Sea, major European rivers entering the Black Sea, and part B. During deglaciation, the Volga system was connected to the Black Sea through the Manych outlet (Mamedov, 1997) and a link to the Don River. **B:** Simplified bathymetry in meters (Aksu et al., 1999b); location of cores, and conductivity-temperature-depth (CTD) stations 1–6, plotted in part C. Full core names: 20—AEG91-20; 11—MAR97-11; 9—MAR98-09; 12—MAR98-12. **C:** Salinity versus water depth in the upper 200 m (stations 1, 3, 6) or to the seabed (stations 2, 4, 5), showing sharp salinity-controlled pycnocline at ~20–25 m except in the Black Sea (subtle pycnocline at ~130 m) and the southern Aegean Sea (no low-salinity layer). The low-salinity surface lid originates from Black Sea outflow and promotes permanent stratification, which in turn promotes sub-pycnocline oxygen depletion. Salinity (CTD) data from archives of Institute of Marine Sciences and Technology.

eastern Mediterranean area, in part as a result of particularly strong periods of water-column stratification associated with Black Sea outflow (Aksu et al., 1995).

During Quaternary glaciations of the past 150 k.y. (oxygen isotopic stages 6, 4, 2), the straits were subaerially exposed (Yaltırak et al., 2002) and the present Marmara and Black seas were lakes. The reconnection of the Black Sea to the Mediterranean following the last glaciation has become an issue of intense controversy. Ryan et al. (1997) proposed the "Flood Hypothesis": a catastrophic refilling of the Black Sea basin at ca. 7.5 ka that took place in <2 yr. Before this event, the water level stood ~150 m below modern sea level (Fig. 2A). They link this deluge with the biblical account of Noah's Flood and explain a low Black Sea (Lake) well into the Holocene by advocating a dry central European climate. Because the Mediterranean and Marmara water levels had already risen to –15 m by ca. 7.5 ka, well above the present bedrock sills in the Bosphorus Strait, Ryan et al. (1997) require a hypothetical sediment dam to hold back the global ocean. At the time of reconnection, they propose that "The soil and debris that had once dammed the [Bosphorus Strait] were quickly swept away.… Ten cubic miles of [Mediterranean] water poured through each day, two hundred times what flows over Niagara Falls," (Ryan and Pitman, 1999, p. 234). Radiocarbon dates of ca. 7.5 ka for the first euryhaline mollusks (salinity tolerance ~20‰–40‰; Knox, 1986) to populate the drowned shelves of the northern Black Sea are used to date the flood. Many readers will be familiar with the Flood Hypothesis from articles in *National Geographic* (May 2001), *Scientific American* (February 1999), *New Scientist* (October 4, 1997), *Earth* (August 1998), and other media (e.g., BBC documentary, "Horizon," December 16, 1996).

The controversy triggered by the widespread publication of the Flood Hypothesis has catalyzed new interest in the paleoceanography of this region and has forced a thorough reexamination of diverse data sets. We began to study the gateway area in 1995 and have acquired ~7500 line-km of airgun, sparker, and Huntec boomer profiles (vertical resolution ~10–20 cm), 65 short cores, and 43 radiocarbon dates from cores (Aksu et al., 1999b, 2002a, 2002b; Hiscott et al., 2002; Mudie et al., 2001, 2002a, 2002b; Kaminski et al., 2002; Abrajano et al., 2002). The essential observations that can be used to resolve the controversy surrounding reconnection are summarized for the first time in this paper and point to persistent southward export of low-salinity water from the Black Sea since at least 10 ka (Fig. 2A). Seismic, geochemical, sediment, microfossil, and palynological data provide no support whatsoever for a catastrophic northward flow of saline Mediterranean water.

Instead, we explain the reconnection by an "Outflow Hypothesis" (Fig. 2B) in which the Black Sea rose to the Bosphorus sill depth by ca. 11–10 ka, when the Marmara Sea was ~20 m lower. The burgeoning Black Sea fed a brackish-water torrent that deposited a delta at the southern end of the Bosphorus Strait and that strongly influenced microfossil communities and sediment characteristics across the gateway. The Black Sea was refilled by the Danube, Dniester, Southern Bug, Dnieper, and Don Rivers, augmented at times by the Volga discharge through the Manych outlet (Mamedov, 1997) and connection to the Don valley (Fig. 1A). The combined drainage area of these six rivers equals that of the Mississippi-Missouri

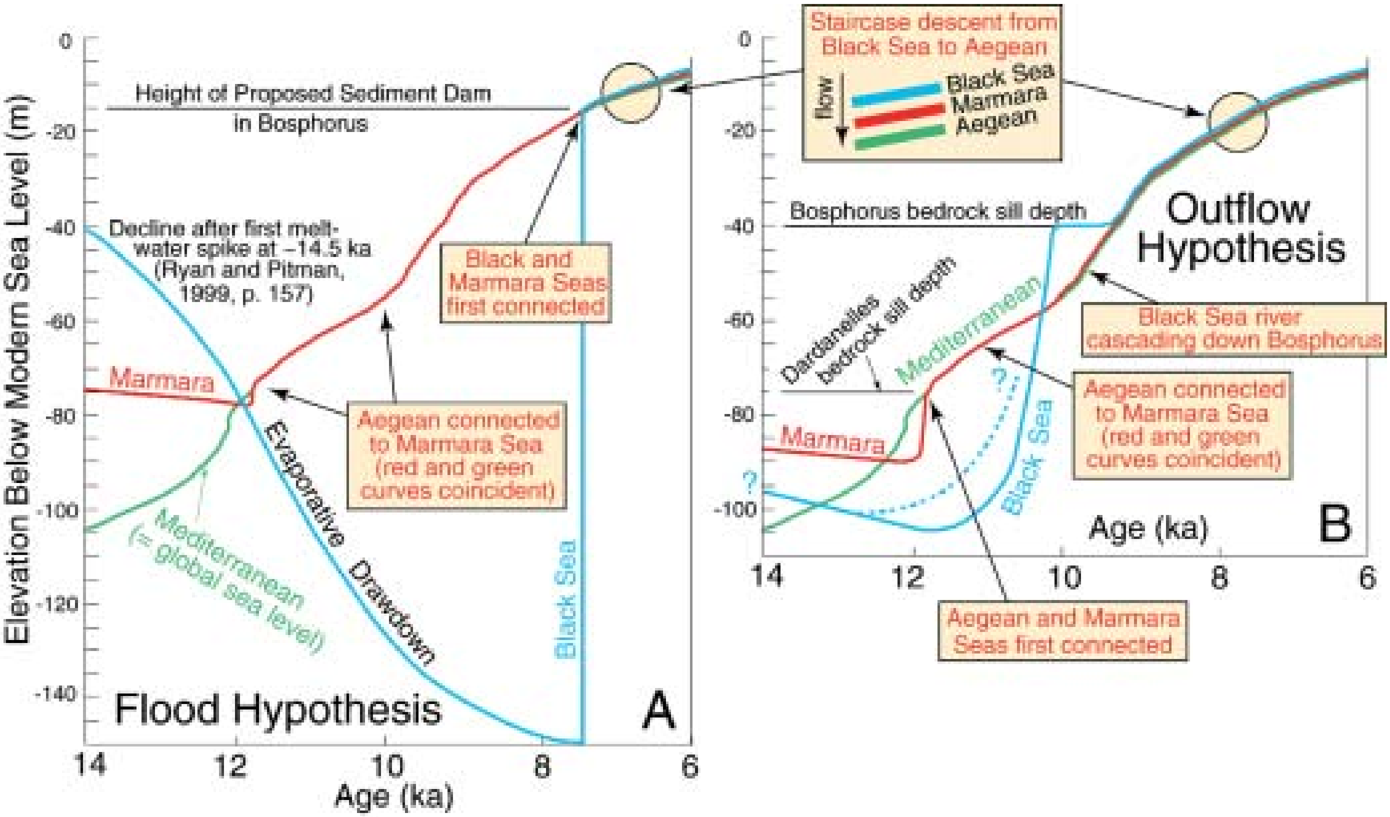


Figure 2. Schematic water-level histories of the Black Sea, Marmara Sea, and Mediterranean (Aegean) Sea according to the Flood Hypothesis (**A**; Ryan and Pitman, 1999) and the Outflow Hypothesis (**B**; Aksu et al., 1999b; Aksu et al., 2002b; Hiscott et al., 2002). In both plots, the Mediterranean curve is the Barbados (global) curve of Fairbanks (1989). When Mediterranean and Marmara curves are superimposed (from ca. 12 to 10 ka), the Marmara Sea was an embayment of the Mediterranean. According to the Flood Hypothesis, the Marmara and Mediterranean catastrophically flooded into the depressed Black Sea basin when a hypothetical sediment dam in the Bosphorus channel was scoured away; subsequently, the Black Sea began to flow outward across the gateway. The Flood Hypothesis predicts thorough mixing of the Marmara Sea water column until ca. 7.5 ka with a final turbulent stirring and flushing in of Mediterranean fauna and flora. According to the Outflow Hypothesis, the Black Sea reached a –40 m bedrock sill depth in the Bosphorus Strait first, initiating a cascade downslope into the rising Marmara Sea and building the delta of Figure 4. This hypothesis does not involve a catastrophic flood. The Outflow Hypothesis predicts stratification and low oxygen conditions in the Marmara Sea since ca. 10 ka, similar to today (Figure 1C).

system. Although the Flood Hypothesis requires that eastern Europe was dry prior to ca. 7.5 ka, a large body of palynological data from lakes in the region and marine studies document increased precipitation and a wetter climate starting earlier, at ca. 12 ka (Harrison et al., 1996; Mudie et al., 2002b).

CORE DATA

Four 125–235 cm-long cores—three in the Marmara Sea and one in the Aegean—clarify the history of the gateway area since ca. 15 ka (Figs. 1B and 3). Black Sea cores are discussed elsewhere (Aksu et al., 2002b) because they do not constrain the reconnection as well as gateway cores. Sediments are mainly burrowed muds with scattered shells, except for sand below 95 cm in Core 9 and laminated muds in sapropels. Downcore plots were recast into the time dimension using 13 radiocarbon dates and, for Aegean Core 20, additional age picks for Santorini ash Z-2 and the oxygen isotopic stage 2/1 transition.

Benthic foraminifera allow estimation of bottom water oxygenation, using the benthic foraminiferal oxygen index (BFOI) of Kaiho (1994). Low values indicate dysoxic conditions at the seabed below a stratified water column (Kaminski et al., 2002). In the central Marmara Sea and northern Aegean Sea (Cores 12 and 20), values are lowest and hence greatest stratification occurred during deposition of organic-rich sapropels from ca. 10 to 6.5 ka. In contrast, off active southern-shelf deltas in the Marmara Sea and at the southern exit of the Bosphorus Strait (Cores 11 and 9; Figs. 1B and 4A), stratification has persisted since postglacial inundation (ca. 12 ka at core site 11 and ca. 9 ka at core site 9).

We measured the carbon isotopic composition, $\delta^{13}C$, of a number of fatty acids like the dominant n-hexadecanoic acid (C_{16}) and n-octadecanoic acid (C_{18}). In Cores 20 and 12, the highest TOC occurs in sediments deposited from 10–6.5 ka, at or just above an interval with the most negative $\delta^{13}C_{16}$ and $\delta^{13}C_{18}$ (Fig. 3; Aksu et al., 1999a, Abrajano et al., 2002). $\delta^{13}C$ in the carbon fixed by photosynthesizers reflects the $\delta^{13}C$ in the dissolved inorganic carbon (DIC) used by these organisms. An effective way to deplete

^{13}C in the water column DIC and lower δ^{13}C is to increase the contribution of respired carbon relative to atmospheric abundances. This is exactly what would occur in an unventilated (stratified) water column, whereas enhanced net primary production would create the opposite fatty-acid δ^{13}C trend. Black Sea outflow was the probable cause of the stratification.

Dinoflagellate cysts *Brigantedinium simplex* (Fig. 3A) and *Spiniferites cruciformis* (Fig. 3B, 3C, and 3D) are sensitive indicators of low-salinity marine, and fresh and/or brackish water conditions, respectively, and can be used to trace water masses. Mildly brackish water conditions prevailed in the Marmara Sea before its reconnection with the Aegean at ca. 12 ka (Cores 11 and 12), continued until ca. 9 ka off river deltas of the southern Marmara shelf (Core 11), and accompanied the development of sapropel in the Aegean Sea from ca. 10 to 6.5 ka (Core 20). The only realistic source of significant brackish water in the northern Aegean Sea is outflow from the Black Sea, because small rivers in the region have insufficient catchments and discharges. The ouflow is confirmed in Core 12 by a broad peak in *Peridinium ponticum* (endemic to the Black Sea) from ca. 11 to 6 ka (Mudie et al., 2002b). Thus Black Sea overflow began prior to the hypothesized flood.

Pollen abundance indicates increased terrigenous supply from rivers beginning at ca. 11–10 ka and declining in the

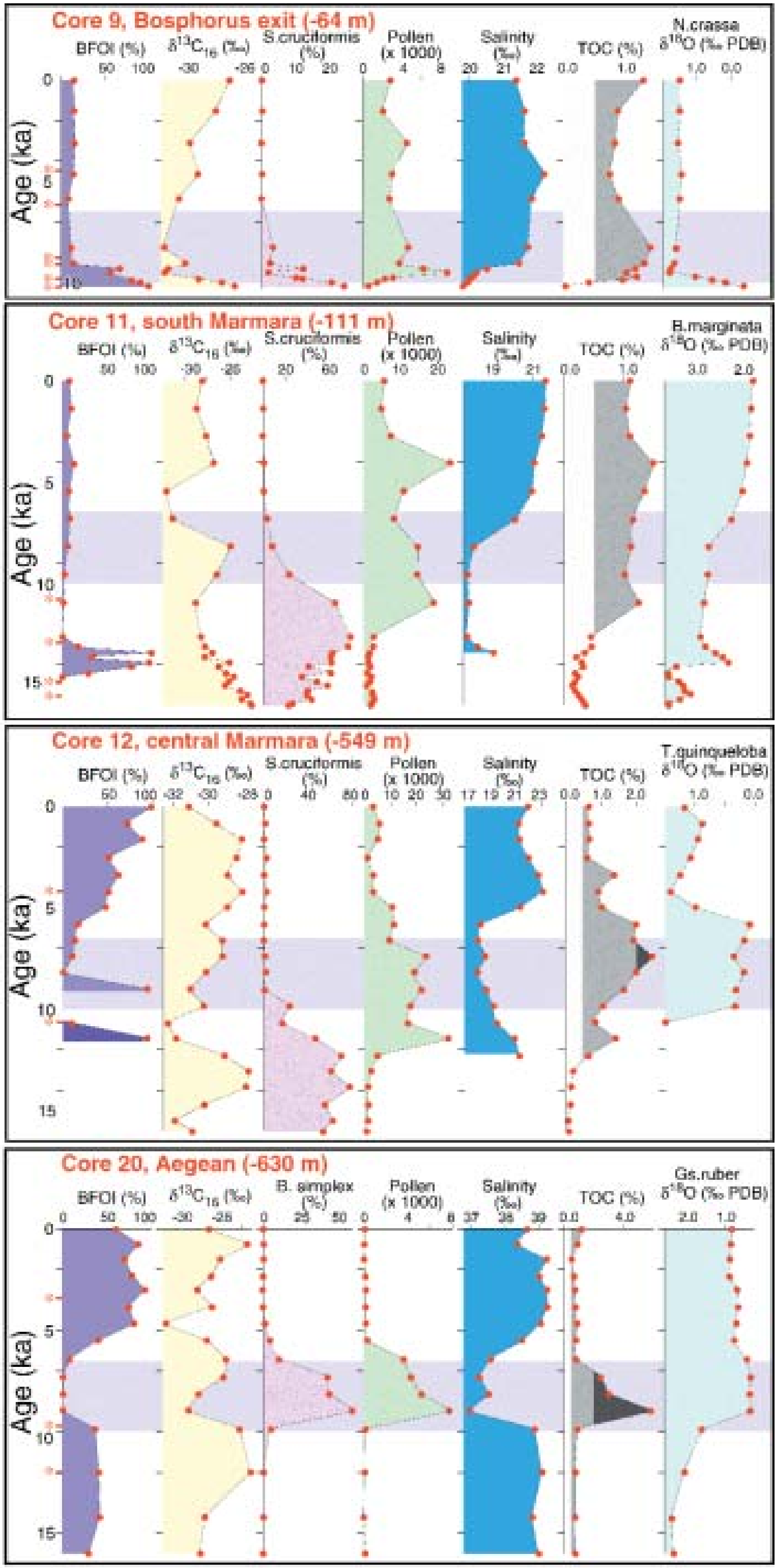


Figure 3. Downcore plots of key proxy variables, explained in text. Core locations in Figure 1B. The water depth at each site is indicated (e.g., –630 m). Samples have been transposed into a time domain using radiocarbon dates tabulated in Aksu et al. (2002a), and the oxygen-isotope and ash record in Core 20. Control points are marked by red * symbols along the age scale. Where red dots (sample positions) cluster, the accumulation rate was highest (e.g., deltaic strata at the base of Cores 11 and 9). Where red dots are missing for some variables, the species required for determinations were absent (e.g., *Turborotalita quinqueloba* before ca. 10 ka for Core 12). The mauve-colored band from ca. 10–6.5 ka coincides with sapropel deposition and significant changes in several proxy variables.

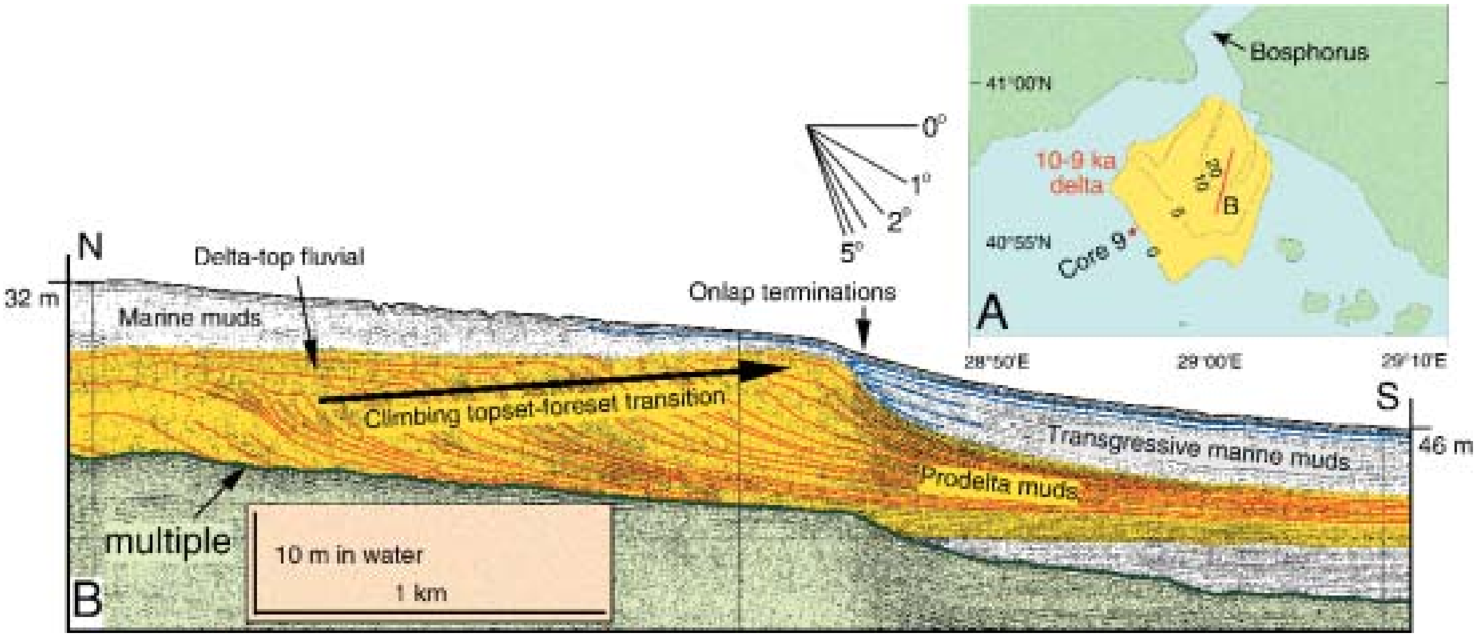


Figure 4. Outflow delta lobe in plan (**A:** sediment thicknesses in milliseconds of two-way traveltime where 10 ms ≈ 7.5 m) and cross section (**B:** Huntec deep-towed boomer profile). The topset-foreset transition (offlap break) climbs consistently from north to south, indicating progradation during a relative sea-level rise. Foresets dip ~2°. Core 9 (Fig. 3) was raised from the distal prodelta fringe.

central Marmara and Aegean seas by ca. 6 ka (Cores 12 and 20). The persistent moderate pollen abundances at the southern exit from the Bosphorus Strait (Core 9) since ca. 9.5 ka are ascribed to pollen input into the Black Sea from major European rivers. Pollen profiles of southern Black Sea cores show no evidence of human settlement (deforestation or agriculture) before ca. 4 ka (Mudie et al., 2002b). This conflicts with the Ryan and Pitman (1999) hypothesis of widespread agricultural activity on Black Sea shelves before their proposed catastrophic flood.

Paleo–sea-surface salinity (SSS) was calculated as explained in Aksu et al. (1995) using a Mediterranean-based transfer function to determine sea-surface temperatures, the paleotemperature equation of Shackleton (1974) to determine $\delta^{18}O$ of the ancient surface waters, and empirical data to relate these latter values to salinity. In the Aegean and central Marmara seas, SSS dropped dramatically during sapropel deposition (Cores 20 and 12). SSS at the southern exit from the Bosphorus Strait was depressed from ca. 10 to 9 ka, consistent with high abundances of the fresh and/or brackish-water indicator, dinocyst *S. cruciformis*.

Elevated TOC in Aegean Sea sediments coincides with lowered SSS, increased terrigenous supply of pollen, and increased stratification of the water column (low BFOI). In the Marmara Sea, TOC has been persistently high since ca. 11–10 ka, with a moderate decrease since ca. 5–3 ka away from the Bosphorus exit (Cores 12 and 11). Pollen abundance mimics these trends, confirming the terrestrial origin of the organic matter (Mudie et al., 2002b; Abrajano et al., 2002). The core data indicate development of a brackish-water surface layer in the Marmara Sea by ca. 11–10 ka, with strongest water-column stratification from ca. 10 to 6.5 ka when widespread sapropel developed in the gateway area. Today, the brackish-water surface layer originates entirely from Black Sea outflow. There is no interruption in the degree of stratification at ca. 7.5 ka, as would surely have accompanied a catastrophic flood. Similarly, the failure of open-marine foraminifera to colonize the Marmara Sea at ca. 7.5 ka is inconsistent with a major flood (Aksu et al., 2002b; Kaminski et al., 2002).

OUTFLOW DELTA AT THE SOUTHERN BOSPHORUS EXIT

Perhaps the best physical evidence for early and strong Black Sea outflow is a 10–9 ka delta lobe at the southern exit of the Bosphorus Strait (Fig. 4). Its age is constrained by radiocarbon dates in the distal prodelta (Core 9, Fig. 4A). The only source for the deltaic sediment is the strait itself. There is no shelf-edge delta here, only a mid-shelf delta with a topset-to-foreset transition that climbs in the seaward direction, indicating delta progradation into a rising water body. We compared the elevation of the topset-to-foreset transition to the Holocene global sea-level curve (Fig. 2). Global sea level is only compatible with a delta at this elevation during a narrow window of time, from ca. 10 to 9 ka. Before ca. 10 ka, this part of the shelf was subaerially exposed; after ca. 9 ka, the delta would have been drowned by rising sea level. Abandonment of the delta lobe at ca. 9 ka coincided with an increase in SSS at core site 9 (Fig. 3), presumably because of diminished brackish-water outflow through the strait and northward penetration of a saline wedge under the surface-water layer (Hiscott et al., 2002). Subsequently, a drape of transgressive-to-highstand mud accumulated here and throughout the Marmara Sea (Hiscott and Aksu, 2002). The resultant water-column stratification (estuarine circulation) promoted dysoxic bottom conditions that have persisted to the present (Fig. 3, BFOI).

THE RECONNECTION PROCESS, WITH IMPLICATIONS FOR PIONEERING MOLLUSKS

When the Aegean Sea first flooded across the Dardanelles Strait at ca. 12 ka, the surface of the Marmara Sea had an elevation of ~–90 m. Coastal areas were quickly flooded to an elevation of –75 m, drowning a lowstand unconformity and barrier islands (Fig. 2B; Hiscott and Aksu, 2002). The effects of the Mediterranean incursion are best seen in Core 12 (Fig. 3; SSS of 20‰–21‰, falling *S. cruciformis*, sudden arrival of planktonic foraminifera *Turborotalita quinqueloba*). Away from deltas of the southern shelf and Bosphorus exit, a widespread mud drape quickly began to accumulate even in the narrow Dardanelles entrance and continues to accumulate today. There is no evidence for erosion of this drape by strong currents at ca. 7.5 ka. The Marmara Sea then continued to rise with the global ocean. By ca. 11–10 ka, the Black Sea had risen to the Bosphorus bedrock sill depth of –40 m and began to spill into the Marmara Sea, producing a climbing delta at the southern end of the strait and initiating a period of uninterrupted outflow and water-column stratification. For the first ~1000 yr, the Black Sea was likely significantly higher than the Marmara Sea (Fig. 2B), so that the Bosphorus channel may have been occupied by a south-flowing river supplied entirely by Black Sea outflow. Later, by ca. 9 ka, the Marmara Sea rose to the level of the sills in the Bosphorus, and perhaps 500–1000 yr later a saline wedge had penetrated well into the strait, leading ultimately to the initiation of a two-layer flow by perhaps ca. 8 ka (Lane-Serff et al., 1997; Kaminski et al., 2002).

On the southwestern Black Sea shelf, a set of back-stepping barrier islands convince us that the transgression was not geologically instantaneous (Aksu et al., 2002a). We infer, based on extrapolated core dates, that lowstand shelf-edge deltas in the Black Sea were inundated by ca. 12–11 ka as a consequence of increased precipitation over Europe (Harrison et al., 1996). Black Sea outflow was initially quite strong, filling the entire cross section of the Bosphorus. Only when the outflow became weaker and the global ocean matched the Black Sea height did the first saline Mediterranean deep water begin to cross the Bosphorus Strait. We estimate that this first true reconnection of the Black Sea and the Mediterranean Sea took place at ca. 8 ka, delayed because of the time lag involved with developing two-layer flow (Lane-Serff et al., 1997). Once initiated, protracted filling of the deeper central regions of the Black Sea with more dense saline water would have been a prerequisite to the successful colonization of shallow shelf areas by euryhaline mollusks. The radiocarbon dates of ca. 7.5 ka reported by Ryan et al. (1997) record, in our view, the rising of the Black Sea pycnocline (density interface above the saline deep water) to shelf depths, allowing open-marine fauna to live in these areas. Previously, the surface 100–200 m was too fresh and the salinity was likely too rapidly changing to permit even opportunist species to colonize the seabed.

CONCLUSIONS

We are convinced that the Outflow Hypothesis provides the best explanation for seismic, sediment, and fossil data in the Marmara Sea Gateway. Many of our observations are entirely incompatible with a late catastrophic flooding of the Black Sea, a circumstance that provides sufficient grounds to discard this hypothesis, following accepted scientific methodology. Nevertheless, there are new intriguing issues that demonstrate a need to more systematically evaluate the late Quaternary history of the gateway. The pre-Holocene sea-level history in the Black Sea is still poorly constrained. Sea-level rise may have started as early as ca. 17 ka as postulated by Pirazzoli (1996), or may have been delayed until ca. 11 ka as inferred by Aksu et al. (2002a). The pace of saltwater flow into the Black Sea basin, and the manner in which invertebrate organisms adapt and migrate into new and changing environments are central to a full understanding of the significance of the 7.5 ka date for the arrival of pioneering euryhaline mollusks. More generally, many lessons can be learned in the gateway area regarding the oceanography of marginal seas, lags in the establishment of water-mass and biotic linkages across narrow straits, and controls on the accumulation of organic-rich muds. Many of these issues can only be addressed in the Marmara Sea Gateway—nowhere else on Earth is there a comparable naturally regulated link between a large inland sea and the global ocean.

ACKNOWLEDGMENTS

We thank Erol Izdar and Orhan Uslu (former directors, Institute of Marine Sciences and Technology) and the officers and crew of the R/V *Koca Piri Reis*. Funding and in-kind support were provided by the Natural Sciences and Engineering Research Council of Canada, the *Piri Reis* Foundation, and the Geological Survey of Canada. We thank Marc De Batist, David Piper, and Karl Karlstrom for their reviews of the manuscript.

REFERENCES CITED

Abrajano, T., Aksu, A.E., Hiscott, R.N., and Mudie, P.J., 2002, Aspects of carbon isotope biogeochemistry of late Quaternary sediments from the Marmara Sea and Black Sea: Marine Geology (in press).

Aksu, A.E., Yaşar, D., and Mudie, P.J., 1995, Paleoclimatic and paleoceanographic circumstances leading to the development of sapropel layer S1 in the Aegean Sea basins: Palaeogeography Palaeoclimatology Palaeoecology, v. 116, p. 71–101.

Aksu, A.E., Abrajano, T., Mudie, P.J., and Yaşar, D., 1999a, Organic geochemical and palynological evidence for the Aegean Sea sapropel S1: Marine Geology, v. 153, p. 303–318.

Aksu, A.E., Hiscott, R.N., and Yaşar, D., 1999b, Oscillating Quaternary water levels of the Marmara Sea and vigorous outflow into the Aegean Sea from the Marmara Sea–Black Sea drainage corridor: Marine Geology, v. 153, p. 275–302.

Aksu, A.E., Hiscott, R.N., Kaminski, M.A., Mudie, P.J., Gillespie, H., Abrajano, T., and Yaşar, D., 2002a, Last glacial–Holocene paleoceanography of the Black Sea and Marmara Sea: Stable isotopic, foraminiferal, and coccolith evidence: Marine Geology (in press).

Aksu, A.E., Hiscott, R.N., Yaşar, D., Işler, F.I., and Marsh, S., 2002b, Seismic stratigraphy of late Quaternary deposits from the southwestern Black Sea shelf: Evidence for non-catastrophic variations in sea level during the last 10,000 years: Marine Geology (in press).

Fairbanks, R.G., 1989, A 17,000 year glacio-eustatic sea-level record: Influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation: Nature, v. 342, p. 637–642.

Harrison, S.P., Yu, G., and Tarasov, P., 1996, Late Quaternary lake-level record from northern Eurasia: Quaternary Research, v. 45, p. 138–159.

Hiscott, R.N., and Aksu, A.E., 2002, Late Quaternary history of the Marmara Sea and Black Sea from high-resolution seismic and gravity core studies: Marine Geology (in press).

Hiscott, R.N., Aksu, A.E., Yaşar, D., Kaminski, M.A., Mudie, P.J., Kostylev, V., MacDonald, J., Işler, F.I., and Lord, A.R., 2002, Deltas south of the Bosphorus Strait record persistent Black Sea outflow to the Marmara Sea since ~10 ka: Marine Geology (in press).

Kaiho, K., 1994, Benthic foraminiferal dissolved-oxygen index and dissolved-oxygen levels in the modern ocean: Geology, v. 22, p. 719–722.

Kaminski, M.A., Aksu, A.E., Hiscott, R.N., Box, M., Al-Salameen, M., and Filipescu, S., 2002, Late glacial to Holocene benthic foraminifera in the Marmara Sea: Marine Geology (in press).

Knox, G.A., 1986, Estuarine Ecosystems: A systems approach, volume 1: Boca Raton, Florida, USA, CRC Press, 289 p.

Lane-Serff, G., Rohling, E.J., Bryden, H.L., and Charnock, H., 1997, Postglacial connection of the Black Sea to the Mediterranean and its relation to the timing of sapropel formation: Paleoceanography, v. 12, p. 169–174.

Mamedov, A.V., 1997, The late Pleistocene–Holocene history of the Caspian Sea: Quaternary International, v. 41–42, p. 161–166.

Mudie, P.J., Aksu, A.E., and Yaşar, D., 2001, Late Quaternary dinocysts from the Black, Marmara, and Aegean Seas: Variations in assemblages, morphology, and paleosalinity: Marine Micropaleontology, v. 43, p. 155–178.

Mudie, P.J., Rochon, A., and Aksu, A.E., 2002a, Pollen stratigraphy of late Quaternary cores from Marmara Sea: Land-sea correlation and paleoclimatic history: Marine Geology (in press).

Mudie, P.J., Rochon, A., Aksu, A.E., and Gillespie, H., 2002b, Dinoflagellate cysts and freshwater algae and fungal spores as salinity indicators in late Quaternary cores from Marmara and Black Seas: Marine Geology (in press).

Pirazzoli, P.A., 1996, Sea-level changes: The last 20000 years: New York, John Wiley & Sons, 211 p.

Polat, Ç., and Tuğrul, S., 1996, Chemical exchange between the Mediterranean and Black Sea via the Turkish Straits, *in* Briand, F., ed., Dynamics of Mediterranean straits and channels: Bulletin de l'Institut Océanographique, Monaco, Special No. 17, CIESME Science Series No. 2, p. 167–186.

Ryan, W.B.F., and Pitman, III, W.C., 1999, Noah's Flood: The new scientific discoveries about the event that changed history: New York, Simon & Schuster, 319 p.

Ryan, W.B.F., Pitman, III, W.C., Major, C.O., Shimkus, K., Maskalenko, V., Jones, G.A., Dimitrov, P., Görür, N., Sakınç, M., and Yüce, H., 1997, An abrupt drowning of the Black Sea shelf: Marine Geology, v. 138, p. 119–126.

Shackleton, N.J., 1974, Attainment of isotopic equilibrium between ocean water and benthonic foraminifera genus *Uvigerina*: Isotopic changes in the ocean during the last glacial: Centre National de Recherche Scientifique et Colloques Internationales, v. 219, p. 203–209.

Yaltırak, C., Sakınç, M., Aksu, A.E., Hiscott, R.N., Galleb, B., and Ülgen, U.B., 2002, Global sea-level variations and raised coastal deposits along the southwestern Marmara Sea during the last 224,000 years: Marine Geology (in press).

Manuscript received January 14, 2002; accepted March 8, 2002. ▲

DIALOGUE

James "Bud" Alcock

Enthusiasm for Earth System Science Continues at GSA

***James "Bud" Alcock**, Pennsylvania State University, Abington College*

Many of my younger colleagues will not be familiar with the Whole Earth Catalogue, a wonderful '60s–'70s compilation of ideas and tools for alternative lifestyles. It was an attempt to bring many disparate areas of interest, knowledge, and technology together in a single integrated resource. The growing field of earth systems science reminds me of the catalog. In a world where science so often tends toward ever-greater fragmentation and specialization, earth systems science recognizes the complex connections that act within different realms of the geoscience and across disciplines. Much as the shift in biology to an ecology-based science in the late 1960s revolutionized our understanding of evolution and biological function, viewing Earth as a single complex system has the potential to allow us to develop a truly global view of our planet and its history.

My first exposure to earth systems science occurred shortly after I joined the Department of Environmental Sciences at Penn State Abington. Lee Kump, Jim Kasting, Rob Crane, Kate Freeman, and Eric Barron at University Park were developing an introductory course that used systems and graphical analysis to study Earth's physical environment. Asked to teach the course at the Abington Campus, I simply fell in love with its ideas, especially the intellectual power that can be obtained from systems analysis supported by simple models. The key is a recognition of the importance of feedback in controlling change within natural systems.

For example, I model the Amazon rainforest ecosystem and the effect of deforestation on system stability for my students. In the forest, there is positive feedback between levels of precipitation and the amount of area covered by healthy forest. Significant decreases in precipitation would be expected to cause losses within the forest. Loss of trees will reduce evapotranspiration in the area and so reduce overall humidity and precipitation. What I find interesting about the system is that this feedback has the potential to stabilize a healthy rainforest and to create a point of no return within the system after significant deforestation. If the point of no return were reached, runaway behavior would lead to collapse of the ecosystem. A simple analysis recognizing interconnections between forest, climate, and human behavior leads to a depressing but important prediction.

It is the ability of systems analysis to cut through the complexity of an earth system to identify its most important functions and components that makes it such a powerful tool. Obviously, a simple analysis, such as the one I describe above, may be wrong. However, even if proven incorrect, I would argue the analysis is important because it identifies questions that need to be answered and so is a valuable tool in directing research.

This past summer, GSA and the Geological Society of London sponsored a joint meeting, Earth Systems Processes. The meeting was full of ideas and intellectual energy based on a systems approach to the earth sciences. As Sharon Mosher said in an earlier "Dialogue" reporting on the event, "... it has been years since I have attended a meeting that had such scientific enthusiasm." Topics ranged from snowball Earth (both the why it could and why it couldn't happen), to changes in atmospheric carbon over time, to the effects of temperature of Venutian plate tectonics, among many others. This fall in Denver, Lee Kump and I hope to recapture a little of that meeting's magic in a technical session that explores the role of feedback in controlling earth systems. We encourage you to use this opportunity to learn more about earth systems science if you are not familiar with it or to share your ideas and research on earth systems if you are.

Ed. note: This is the third of three articles about emergency management and its relevance to earth scientists. Part 1 (November 2001) and Part 2 (February 2002) are available at www.geosociety.org/pubs/gsatoday.

"We can turn our passions for science into progress for both science and the public."

—Sharon Mosher

Emergency Management: Roles for Geoscientists

__Jeffrey N. Rubin,__ Tualatin Valley Fire & Rescue, Oregon City, Ore., Geologist and Emergency Manager

Of the four phases of emergency management (EM), geoscience carries benefits in mitigation but has applications to preparedness, response, and recovery as well. There are two principal—and related—routes for geoscientists to make significant contributions to EM, in what amounts to applications of scientific research: working partnerships with EM and public advocacy.

A broad range of geoscience disciplines lends itself to research with direct applications to natural hazard mitigation and preparedness: tectonics and structural geology, seismology, volcanology, tsunamis, landslides, meteorology and climate change, and remote sensing. Dissemination of research within the geoscience community is certainly valuable, but the primary utility for EM relies on effective communication of research interpretations for the nonscientific community, particularly in a manner that allows practical applications research.

Partnerships

Hazard vulnerability assessments and hazard mitigation plans are important components of state and local efforts to minimize occurrences and/or impacts of disasters, as well as implementing an effective post-disaster recovery phase. State EM agencies develop and update such documents periodically. Hazard vulnerability assessments combine hazard nature, likelihood of occurrence, and potential impact into a rating system. This helps define risk management parameters, enables distinction between high-frequency, low-acuity events (e.g., minor flash floods and ice storms) and low-frequency, high-acuity events (e.g., earthquakes and weapons of mass destruction), and allows for prioritization of mitigation and preparedness resources. Recent federal legislation requires a hazard mitigation plan for cities and counties to be eligible for mitigation grants and certain types of disaster recovery assistance. Many localities undertaking the process of vulnerability analysis and mitigation planning are doing so for the first time; others have existing assessments based on limited data. Geoscientists able to serve as advisors or reviewers for assessment and planning can fill an important role. Although the prediction capabilities that much of the public expects do not exist, geoscientists can try to provide probability boundaries and explain to emergency managers (and the public) what *can* be measured and what eruption warnings mean.

The core of antiterrorism is the combination of EM and public safety; specialized areas of earth science offer partnership opportunities in preparedness and response. The U.S. Geological Survey's National Mapping Division has long worked under a memorandum of understanding with the National Imagery and Mapping Agency and its predecessor, the Defense Mapping Agency. Much of this collaboration has had military applications outside the continental United States but is now playing an increasingly important role in homeland defense. Response to earthquakes includes the valuable establishment of a post-earthquake technical clearinghouse that incorporates a range of geoscience specialties. Instrumentation and field surveys examine earthquake mechanics, ground deformation, fault displacement, soil disturbance, and landslides, along with structural engineering investigation. Prompt establishment of technical clearinghouses can measure aftershocks and help predict landslides and structural failure, thus helping to guide further response as well as recovery and mitigation.

Public Advocacy

The most important step involved in bringing science to public education, advocacy, or policy is communication. Consider some typical questions on behalf of the general public: What is peak ground acceleration? Why is seismographic equipment used to monitor volcanic activity? How well can we predict earthquakes and eruptions? Am I at risk from a local fault system that hasn't moved in 8 Ma? How can I make my home safer? As long as I have insurance, won't I be OK? Why bother preparing for a catastrophic event? Public education provides information with the goal of changing behaviors, e.g., nonstructural mitigation, purchase of flood (or earthquake or other) insurance, and minimizing development in flood-plain policy making. Geoscientists may not be doing much of the actual public presentation, but we are essential in developing the factual basis for it. Being able to provide engaging, understandable, evidence-based material for public consumption is a rare and valuable skill. Some geoscientists already do this well, while others do not. Next time you see a geologist on TV providing information about an earthquake that has just occurred—or one that might—ask yourself if effective communication is taking place and whether you could do better. If the answer to the second question is "yes," it's up to you to take the next step.

Public education is also an essential component in the development of public policy. Policy is too important to be left to policy makers. As GSA and other scientific organizations have recognized, science must be a component of legislation involving natural hazards, whether federal mitigation laws or local land-use ordinances. As Sharon Mosher pointed out in her 2001 Presidential Address (See "Plate boundaries to politics: pursuing

continued on page 12

continued from page 11

passions in science," *GSA Today*, February 2002, p. 4–10), scientists can provide the information politicians need to make informed decisions. We can also provide information directly to the public—the same public that elects those who generate policy and may even vote directly on the policy itself. Results aren't guaranteed, but a lack of results is certain without action on our part.

Conclusion

Definitions, summaries, suggestions, and references in this series are intended to be comprehensive but not exhaustive; as with most specialized fields, there is an (over)abundance of information available to the casual seeker. This article and the series it concludes attempt to provide an overview of EM and the important roles available for geoscientists. The underlying goal is to provide an introduction —and possibly a hook—for those seeking a way to broaden their professional horizons and contribute their passions for science to the public good.

Useful Web Sites

FEMA Hazard Mitigation Planning: www.fema.gov/mit/planning.htm
GSA Geology and Public Policy: www.geosociety.org/science/govpolicy.htm
State emergency management agencies: www.fema.gov/fema/statedr.htm
State seismic policy boards: www.wsspc.org/links/ssabs.html

U.S. Dept. of Interior Center for Integration of Natural Disaster Information: http://cindi.usgs.gov/
Western States Seismic Policy Council Public Policy: www.wsspc.org/publicpolicy/Default.htm
WSSPC Post-Earthquake Technical Clearinghouse: www.wsspc.org/publicpolicy/policyrecs/policy013.html

BOOK REVIEWS

Origin of Igneous Rocks: The Isotopic Evidence

Gunter Faure, Springer, Berlin, 2001, 496 p., $74.95.

This book cannot be faulted on presentation. All the figures have been redrafted to a similar, legible style, and it is well copyedited, with almost no typographical errors. Based on these features alone, I wish I could recommend this book to a wide audience. Unfortunately, the book was designed for a limited audience; namely, for use in graduate courses on the isotopic constraints on the origin of igneous rocks.

Although the author includes neodymium, lead, oxygen, and even rhenium isotope data where available, the focus of this book is on strontium. This is not surprising, given the author's history of research on strontium isotopes, and from a graduate teaching perspective, is valuable in providing students with a summary of the importance and utility of strontium isotopes in constraining models for the evolution of igneous rocks. Chapter 1 is a superb review of the isotopic systems referred to in this book. The author's succinct summaries on the origin of each major igneous rock suite at the end of each chapter are also a highlight.

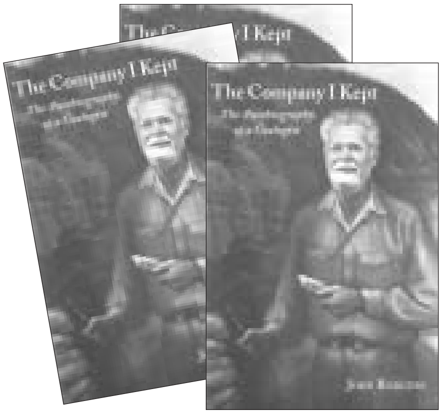
The emphasis on strontium is also the book's weakness. The igneous rock suites used in the book are chosen largely because of the abundance of strontium data on these suites, which does not always reflect their petrologic significance. For example, mid-ocean-ridge and oceanic-plateau basalts are poorly represented. The fact that most strontium data was obtained in the 1960s to 1980s also gives the misleading impression that the book is dated. The author includes many references from the 1990s; however, they are used far too selectively.

As someone who works with Precambrian rocks, I was disappointed in Chapters 7 and 8. The author has done an excellent job in the preceding chapters in summarizing rock suites from around the world, but I found the descriptions in Chapter 7 contained many errors or were too simplified. Also, both chapters rely on imprecise Rb-Sr rather than more precise U-Pb ages (e.g., Coldwell Complex, Nipissing Diabase).

Chapter 8 focuses on the implications of Archean rock suites on the evolution of igneous rocks through time. Unfortunately, it fails to discuss the wealth of neodymium and U-Pb geochronology that has accumulated in the past decade for the chosen examples, nor does it address the effects that a hotter mantle and thinner asthenosphere may have played in early crustal evolution. My disappointment with these two chapters, however, was more than offset by what I learned from reading the first six chapters.

Isotope geoscientists should buy it because it is an excellent compendium of isotopic data. If used in a graduate course, it will need to be supplemented with other material. For everyone else, make sure your library has a copy.

R. Michael Easton
Easton is a government geologist in Sudbury.



The Company I Kept: The Autobiography of a Geologist

John Rodgers, The Connecticut Academy of Arts and Sciences, New Haven, Connecticut, 2001, 224 p., $35.00.

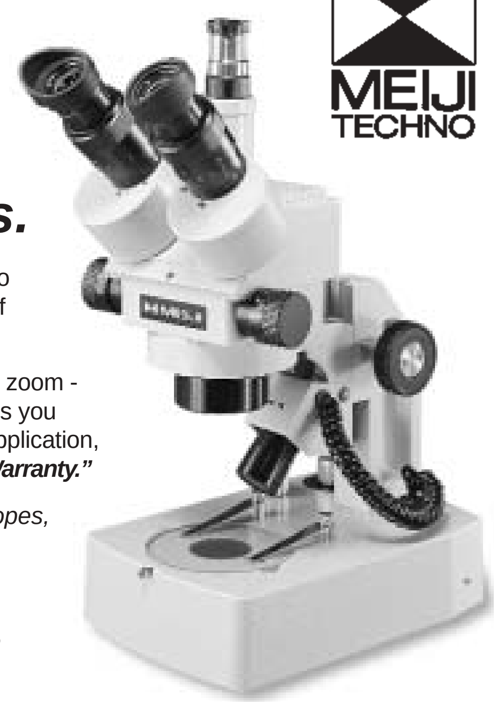
Rarely does one find a book so true to its title as is this autobiography by that seminal thinker about Appalachian tectonics and the formation of mountain ranges in general, John Rodgers. After several chapters detailing his family background and education, the book is a series of vignettes of his professors and associates in the context of Rodgers' interaction with them, covering the years from the 1930s well into the 1990s.

Rodgers decided early—in high school—that he wanted to be a geologist. A mentor at the New York State Museum in Albany, New York, where the Rodgers family lived, opened the way for him to learn from the museum collections. He decided to first attend Cornell and then Yale for the best of all scholars' reasons: namely, the amount that he could learn. As a student, he worked for the U.S. Geological Survey and noted how the field work helped change theoretical knowledge into practical knowledge (p. 62). After working in the west for three summers, as most young geologists preferred, he made the decision to focus on the east, resulting in his lifelong work in the Appalachians.

It is difficult to encapsulate the remaining sections of this book. They are titled by time period (for example, "The Later Fifties"). However, the sections don't stay within their time periods, sometimes tracing experiences within a country or with a colleague into the future. But within those pages is recorded the life, often the cultural life, the travels, and the associations of one of the premier geologists of our time. There is little actual science and much of movers, shakers, and connections, but a knowledgeable geologist can gain insight into where and how Rodgers' major ideas were formed and tested. One thing that comes through is Rodgers' love of field trips and his willingness to endure hardship for them. There are many personal reminiscences about the value of being able to ride a horse, as well as being able to pick up languages with a good bit of facility.

Many, if not most, of the seminal thinkers in geology during the twentieth century appear in these pages, including a number of GSA presidents and medalists. As a bonus, and perhaps displaying my ignorance, it was pleasing to discover the publications of The Connecticut Academy of Arts and Sciences, many with a Yale connection, and a number of which are concerned with American geology and geologists.

Sally Newcomb
Silver Spring, Maryland



ANNOUNCEMENTS

MEETINGS CALENDAR

2002

June 18–20	Solid-Liquid Separation '02, Falmouth, United Kingdom. Information: www.min-eng.com/sl02.html.
June 19	Third Rocky Mountain Association of Geologists Coalbed Methane Symposium, Denver, Colorado, USA. Information: www.rmag.org, (303) 573-8621.
June 30–July 5	GEOSCIENCE 2002: Expanding Horizons, Adelaide, South Australia. Information: www.16thagc.gsa.org.au.
September 8–11	American Association of Petroleum Geologists 2002 Rocky Mountain Section Meeting, Laramie, Wyoming, USA. Information: www.aapg.org/meetings/rms02.
September 25–27	Minerals Engineering '02, Perth, Australia. Information:www.min-eng.com/me02.html.
October 7–10	Sierra Nevada 2002: Science for Management and Conservation, Kings Beach, North Lake Tahoe, California, USA. Information: Joni Rippee, Wildland Resources Center, University of California, Berkeley, CA 94720, (510) 642-0095, fax 510-6423-3490, rippee@berkeley.edu, http://danr.ucop.edu/wrc/snssweb/snss.html. (*Poster abstracts deadline: June 1, 2002.*)

2003

March 17–18	Applied Mineralogy '03, Helsinki, Finland. Information: www.min-eng.com/appliedmineralogy03.
March 19–21	Flotation '03, Helsinki, Finland. Information: www.min-eng.com/flotation03/.
May 29–June 1	Geology Without Frontiers: Magmatic and Metamorphic Evolution of the Central European Variscides, Blansko, Czech Republic. Information: Jaromir Leichmann, No Frontiers, Dept. of Geology and Palaeontology, Masaryk University, Kotlarska 2, 611 37 Brno, Czech Republic, +420 (5) 41 12 92 61, fax +420 (5) 41 21 12 14, cgs@mail.natur.cuni.cz, www.natur.cuni.cz/~cgs/nofrontiers/. (*Abstract deadline: January 15, 2003.*)

In Memoriam

Franco Rasetti
Waremme, Belgium
December 5, 2001

Graham Ryder
Houston, Texas
January 6, 2002

Robert E. Stevenson
Princeville, Hawaii
August 2001

Robert C. Vorhis
Lithonia, Georgia
January 28, 2002

Malcolm P. Weiss
Santa Barbara, California
January 1, 2002

Please contact the GSA Foundation for information on contributing to the Memorial Fund.

About People

GSA Fellow **Charles O. Morgan** is the 2002 recipient of the A. Ivan Johnson Outstanding Achievement Award, recognizing his contributions to the work of ASTM Committee D18 on Soil and Rock. ASTM International is a standards development and delivery system for materials, products, systems, and services.

The 2002 National Science Board Public Service Award for increasing public understanding of science and engineering will go to 2001 GSA Public Service Award winner **Eugenie Scott**, an activist for teaching evolution in public schools. The annual award recognizes outstanding contributions to communicating, promoting, or helping to develop broad public policy in science and engineering. (Read the full story at www.nsf.gov/cgi-bin/getpub?pr0216.)

GSA member **Richard E. Wright** received the Emrich Service Award from the Pennsylvania Council of Professional Geologists (PCPG). This award is given to a geologist who represents the best ideals of the PCPG and who has had a distinguished career of meritorious service, dedication, and concern for the betterment of geology.

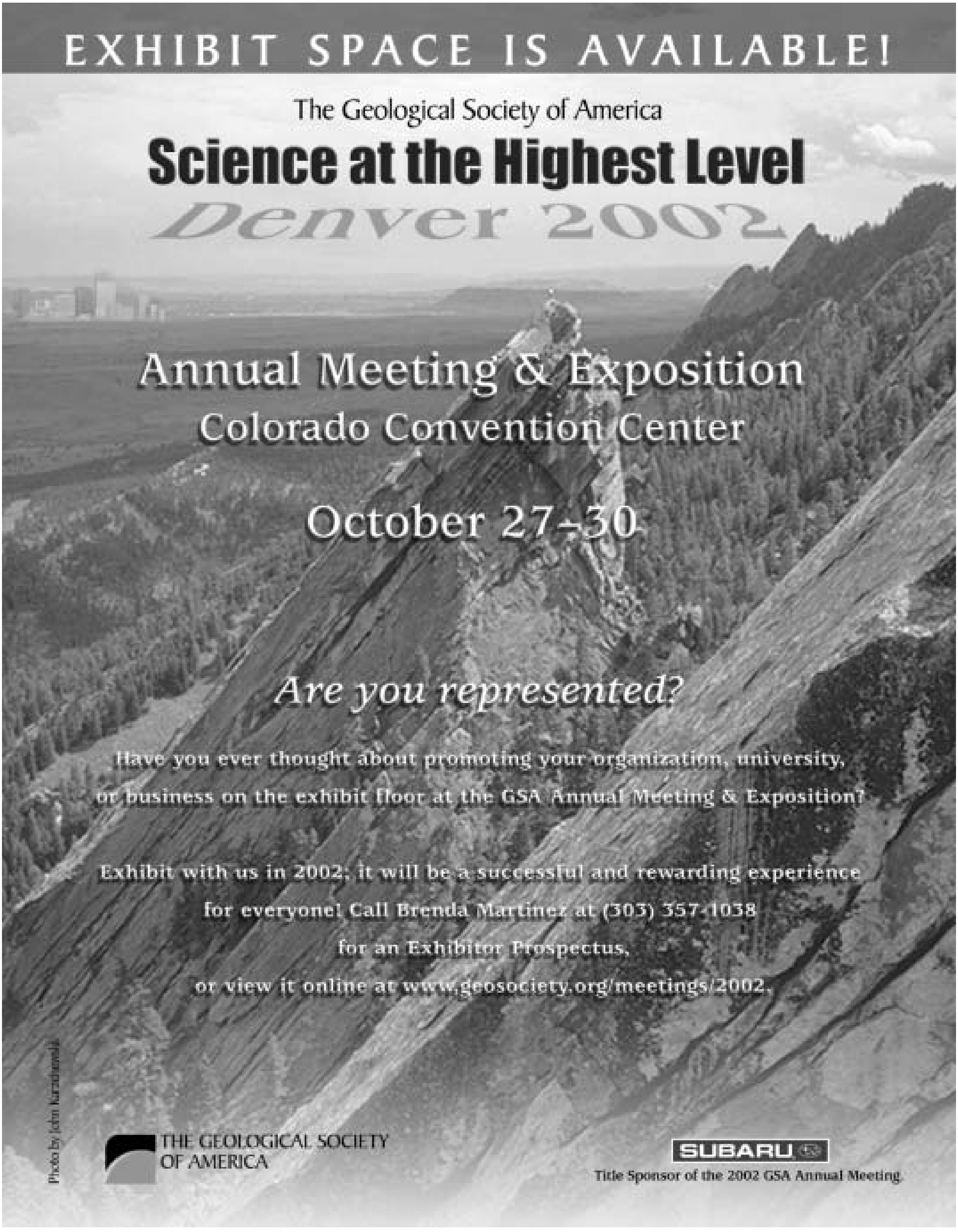


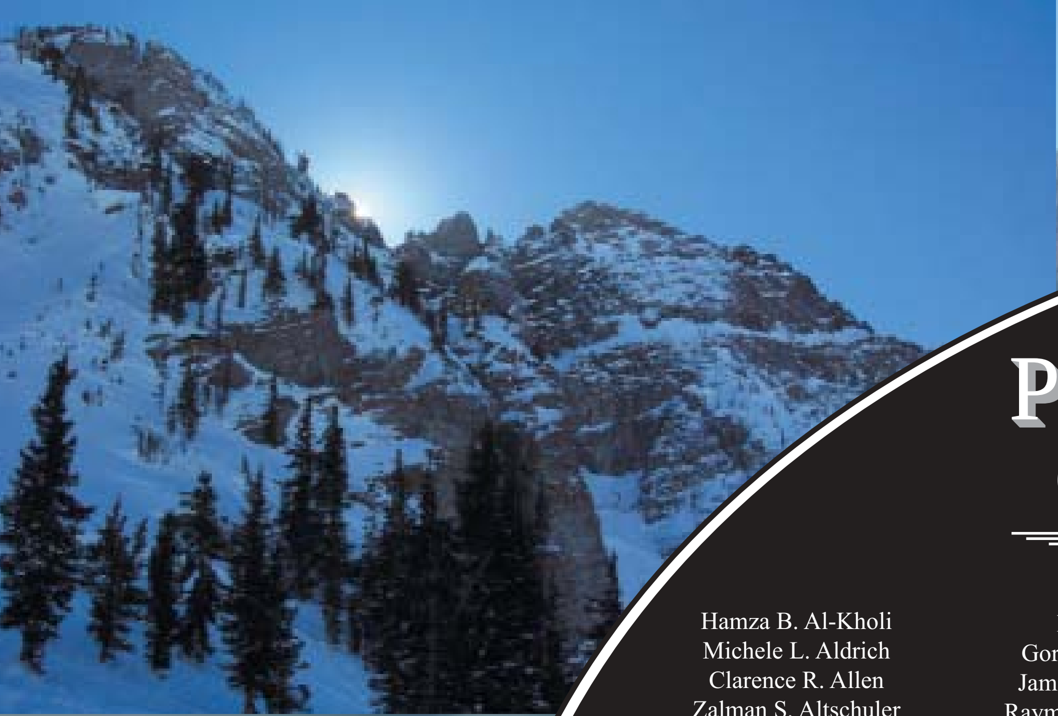
EXHIBIT SPACE IS AVAILABLE!
The Geological Society of America
Science at the Highest Level
Denver 2002
Annual Meeting & Exposition
Colorado Convention Center
October 27–30
Are you represented?
Have you ever thought about promoting your organization, university, or business on the exhibit floor at the GSA Annual Meeting & Exposition?
Exhibit with us in 2002; it will be a successful and rewarding experience for everyone! Call Brenda Martinez at (303) 357-1038 for an Exhibitor Prospectus, or view it online at www.geosociety.org/meetings/2002.
THE GEOLOGICAL SOCIETY OF AMERICA
SUBARU
Title Sponsor of the 2002 GSA Annual Meeting

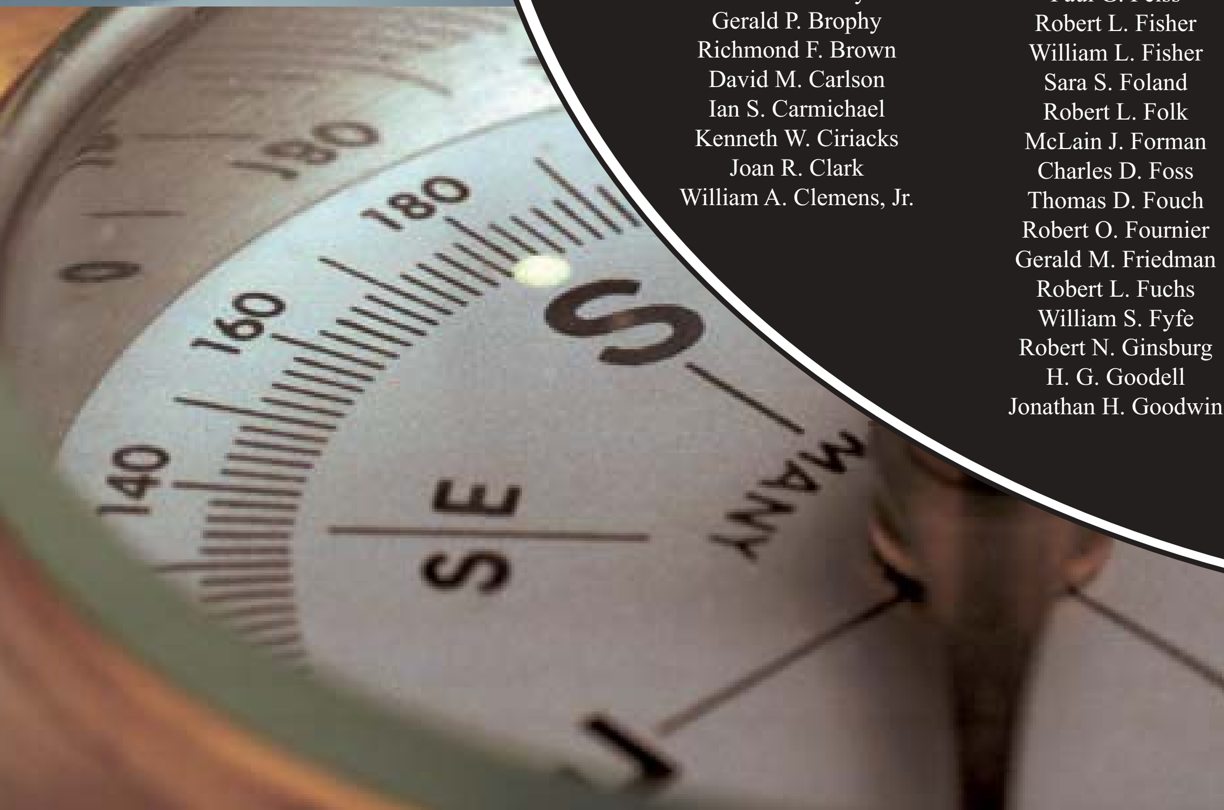
LOG ON FOR LETTERS

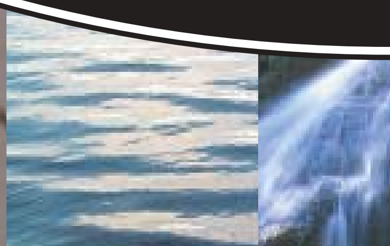
Letters to *GSA Today* on the following topic are posted at www.geosociety.org / pubs / gsatoday / letters.

— *GSA Evolution and Creationism Position Statement*

GSA has a new look on the Web!
We've improved speed and navigation, and,
as always, we welcome your comments.
www.geosociety.org







PENROSE CIRCLE

Gifts of $250 or more

Hamza B. Al-Kholi
Michele L. Aldrich
Clarence R. Allen
Zalman S. Altschuler
Robert J. Andres
Anonymous
Arthur B. Arnold
Brian F. Atwater
Hans G. Ave Lallemant
Jon C. Avent
Jean M. Bahr
Victor R. Baker
C. S. Barclay
Thomas D. Barrow
Paul C. Bateman
Edward S. Belt
William C. Berridge
Archie W. Berry, Jr.
Stanley S. Beus
Frederick B. Bodholt
Rena M. Bonem
Jon C. Boothroyd
Donald W. Boyd
Gerald P. Brophy
Richmond F. Brown
David M. Carlson
Ian S. Carmichael
Kenneth W. Ciriacks
Joan R. Clark
William A. Clemens, Jr.
Mark Cloos
Gordon A. Clopine
James W. Collinson
Raymond Coveney, Jr.
Darrel S. Cowan
Harmon Craig
Maria L. Crawford
William A. Crawford
John C. Crowell
Edward C. Dapples
James F. Davis
Virginia De Lima
Don U. Deere
William H. Dennen
Robert H. Dott, Jr.
H. E. Dregne
Bruce Dunkle
Gordon P. Eaton
Kenneth D. Ehman
W. G. Ernst
Russell C. Evarts
John L. Fauth
Paul G. Feiss
Robert L. Fisher
William L. Fisher
Sara S. Foland
Robert L. Folk
McLain J. Forman
Charles D. Foss
Thomas D. Fouch
Robert O. Fournier
Gerald M. Friedman
Robert L. Fuchs
William S. Fyfe
Robert N. Ginsburg
H. G. Goodell
Jonathan H. Goodwin
Ian R. Gordon
Howard R. Gould
Philip R. Grant, Jr.
Frank L. Greene
Edward S. Grew
Richard F. Hadley
Michel T. Halbouty
Susan D. Halsey
Gilmor S. Hamill IV
George F. Hanson
Pembroke J. Hart
Richard D. Harvey
Robert D. Hatcher, Jr.
James W. Hawkins, Jr.
John W. Hawley
Edward W. Hildreth
Melvin J. Hill
Lincoln S. Hollister
Richard A. Hoppin
Clifford A. Hopson
Donald M. Hoskins
Roy M. Huffington
C. S. Hurlbut, Jr.
Steven E. Ingebritsen
Roscoe G. Jackson II
Carl E. Jacobson
Kenneth S. Johnson
Suzanne M. Kay
Ralph O. Kehle
Susan M. Kidwell
M. D. Kleinkopf
William A. Kneller
Konrad B. Krauskopf
Jo Laird
Philip E. LaMoreaux
Susan M. Landon
Leo F. Laporte
Laurence H. Lattman
William N. Laval
Morris W. Leighton
Arthur L. Lerner-Lam

Here is a great big

THANK YOU

from the leadership of the GSA Foundation for the support from our Penrose circle donors. Your continuous and generous annual contributions are providing us the base to help GSA with it’s priorities for the year. We sincerely appreciate your support!

Alan E. Leviton
Helen T. Loeblich
J. D. Love
John S. Lowther
Robert L. Maby, Jr.
Robert P. MacDaniel
David B. MacKenzie
Richard H. Mahard
Harold E. Malde
Charles J. Mankin
Candace S. Martinez
John W. Mason
Christopher C. Mathewson
David S. McCormick
Thornton H. McElvain, Jr.
Leslie D. McFadden
Donald B. McIntyre
Judith A. McKenzie
Martha F. McRae
Andrew J. Meigs
Paul M. Merifield
Richard C. Mielenz
Robert C. Milici
Marcus E. Milling
Arthur Mirsky
Steven D. Mitchell
Sharon Mosher
William R. Muehlberger
Rosalind Munro
Anthony J. Naldrett
Sarah E. Newcomb
Richard L. Nielsen
Laurence H. Nobles
Robert M. Norris
J. M. O’Neill
Jack E. Oliver
William A. Oliver, Jr.
Jon Olsen
Carel Otte
A. T. Ovenshine
Elaine R. Padovani
Stavros S. Papadopulos
Elmer D. Patterson
Dallas L. Peck
Ralph B. Peck
David A. Phoenix
Donald B. Potter
Lloyd C. Pray
Mary C. Rabbitt
Douglas W. Rankin
George R. Rapp
Noel M. Ravneberg
Katherine M. Reed
Marshall J. Reed
Anthony Reso
Raymond C. Richter
Sarah M. Roeske
John L. Rosenfeld
Charles A. Ross
Jeffrey N. Rubin
Neilson Rudd
Mary E. Savina
Dwight L. Schmidt
Ruth A. Schmidt
B. C. Schreiber
Jane Selverstone
Kurt Servos
George C. Sharp, Jr.
Roy J. Shlemon
Charles H. Shultz
Leon T. Silver
Virginia B. Sisson
Brian J. Skinner
H. C. Skinner
James D. Smith
Robin L. Smith
Charles E. Stearns
Julie K. Stein
David A. Stephenson
John H. Stewart
Charles H. Summerson
Eric T. Sundquist
Lee J. Suttner
Donald A. Swanson
Wolfgang V. Swarzenski
Lawrence D. Taylor
Barbara J. Tewksbury
William A. Thomas
George A. Thompson
Hugh Torrens
Joshua I. Tracey, Jr.
Page C. Twiss
Rob Van der Voo
Newell F. Varney
Thomas A. Vogel
F. M. Wahl
Jane H. Wallace
Robert J. Weimer
John H. Weitz
Charles W. Welby
Stephen G. Wells
Donald E. White
Robert G. Wiese, Jr.
Frederic H. Wilson
John C. Wilson
M. G. Wolman
Leonard A. Wood
Herbert E. Wright, Jr.
E-an Zen
Herman B. Zimmerman

GSA FOUNDATION

GeoTrip Memories

New Year's at the End of the World: The Geology of Southern Patagonia, Including Tierra del Fuego

An Insider's Take on the Trip

Here's an excerpt from James Reynolds' notes on the trip. His journal is posted at http://tornado.brevard.edu/reynoljh/patagonia/calendar.htm.

December 30, 2001

… We then drove 70 km westward to the front of the Perito Moreno Glacier. Our guide, Soledad, told me of a new boat excursion that, for $20 per person, sails out to the glacier and stands just off of the 50–70 m wall of ice. Almost everyone went for it. It was fun to get that close to the ice. We saw one good calving. The boat ride lasted an hour. Just as impressive as the ice were all of the structures exposed on the shoreline of the lake. After returning to the dock, we went up to the overlooks on the east side of the glacier. I was focused in on a pretty blue ice block when it broke free and fell 50 m into the water. I got it all on video.

I was surprised how different the glacier is now from 1989. It has ceased surging so it no longer blocks the channel between the north and south arms of the lake. For that reason, there have been no jökulhlaups since 1988. Because the south side of the lake's level no longer fluctuates, there is significant exposure on the shoreline between the present lake level and the old high water level from the jökulhlaup days.

Everyone was very happy with the day. We returned to the hotel at 8:00 and had dinner at an all-you-can-eat restaurant called "El Chino." During dinner word came that Presidente Saá had resigned. All of the Argentines in the restaurant broke into applause. The comedy continues…

The Patagonia GeoTrip gang at Lago Pehoé, Parque Nacional Torres del Paine. James Reynolds of Brevard College, Brevard, North Carolina, led 36 participants on this GeoTrip through southern Argentina and Chile from December 26, 2001, to January 10, 2002. "It was a great trip," wrote Mary Dowse of Silver City, New Mexico. "It was a blast—great group!"

GeoVentures

GeoTrips

Iceland: Fire and Ice

August 1–15, 2002

Scientific leader: Haraldur Sigurdsson, Graduate School of Oceanography, University of Rhode Island. **Guest Lecturer:** Haukur Johannesson, Natural History Institute, Reykjavík, Iceland.

Description: This trip will reveal many unaltered and fresh geologic features that can be seen nowhere else on land. Expect to acquire an expanded understanding of volcanoes, hotspots, and rifts. View steep-walled and flat-topped hyaloclastite ridges derived from subglacial eruption, young hyaloclastite islands produced by submarine eruptions, great explosion craters, tephra cones, calderas, blocky obsidian flows, waterfalls descending into the rift valley and, of course, extraordinary glacial panoramas.

Fees and Payment: $3,400 for GSA members; $3,500 for nonmembers. A $400 deposit is due with your reservation and is refundable (less $100) through May 15. Fee is based on double occupancy. The single supplement, based on availability, is an additional $486. Total balance is due May 15. Min.: 20; max.: 40. Included: Classroom programs and materials; field trip transportation, lodging, all meals, guidebook and map. Not included: Airfare to and from Reykjavík, alcoholic beverages, and other expenses not specifically included.

Iceland: A Student Only–Oriented GeoTrip

New! Lower Fee

August 1–15, 2002

Scientific leader: James Reynolds, Brevard College, Brevard, North Carolina.

Description: Designed for students *only*, this trip will visit classical geological localities of Iceland on a low-frills budget. Participants will camp and prepare meals in a group kitchen tent. Eighty kilometers of hikes will take us through spectacular volcanic and glacial scenery. The trip begins in Baltimore and will fly to Reykjavík to make a 12-day loop around the country.

Fees and Payment: $2,395 for GSA student members; $2,445 for nonmembers. A $200 deposit is due with your reservation and is refundable (less $100) through May 15. Total balance is due May 15. Min. 20; max. 35. Included: Roundtrip airfare to Reykjavík from Baltimore (currently the gateway city), classroom programs and materials, field trip transportation, lodging, all meals, guidebook and map. Not included: Airfare to and from Baltimore, camping equipment (tent and sleeping bag), alcoholic beverages, and other expenses not specifically included.

REGISTER TODAY!

Send a deposit to hold your reservation; please pay by check or credit card. You will receive further information and a confirmation of your registration within two weeks after your reservation is received.

Name ____________________

Institution/Employer ____________________

Mailing Address ____________________

City/State/Country/ZIP ____________________

Phone (business/home) ____________________

Guest Name ____________________

GSA Member # ____________________

	Deposit Per Person	No. of Persons	Total Paid Deposit
Iceland	$400	____	$________
Iceland (students only)	$200	____	$________
	TOTAL DEPOSIT		$________

☐ VISA ☐ MasterCard ☐ American Express ☐ Discover

Credit Card # ____________________ Exp. Date ________

Signature ____________________

MAIL OR FAX REGISTRATION FORM AND CHECK OR CREDIT CARD INFORMATION TO:
2002 GSA GeoVentures, Member Services
P.O. Box 9140, Boulder, CO 80301
fax 303-357-1070 or 303-357-1071

MAKE CHECKS PAYABLE TO: GSA 2002 GeoVentures

CLASSIFIED Advertising

Ads (or cancellations) must reach the GSA Advertising office one month prior. Contact Advertising Department, (303) 357-1053, 1-800-472-1988, fax 303-357-1070, acrawford@geosociety.org. Please include address, phone number, and e-mail address with all correspondence.

Classification	Per Line for 1st month	Per line each addt'l month (same ad)
Situations Wanted	$1.75	$1.40
Positions Open	$6.50	$5.50
Consultants	$6.50	$5.50
Services & Supplies	$6.50	$5.50
Opportunities for Students		
first 25 lines	$0.00	$2.35
additional lines	$1.35	$2.35
Code number: $2.75 extra		

Agencies and organizations may submit purchase order or payment with copy. Individuals must send prepayment with copy. To estimate cost, count 54 characters per line, including all punctuation and blank spaces. Actual cost may differ if you use capitals, centered copy, or special characters.

Situations Wanted

Ph.D. in geology/paleontology w/ 5+ years exper in science research, oil industry, grad & undergrad teaching. Field experience in W. America, Europe, Greenland. Bilingual, published. Want to again be a geologist in USA. Willing to relocate. Contact @ (352) 278-3481.

Positions Open

TENURE TRACK POSITION
ENGINEERING GEOLOGY or SURFICIAL PROCESSES
SAN FRANCISCO STATE UNIVERSITY

The Department of Geosciences at SFSU invites applications for a tenure-track faculty position at the assistant professor level in Engineering Geology and/or Surficial Processes, beginning January or August 2003. The position requires a Ph.D. in geology, strong quantitative and field skills, and a commitment to excellence in teaching at graduate (M.S.) and undergraduate levels. We seek someone to teach advanced-level engineering geology and/or surficial processes courses, and general education courses in natural hazards or earth systems. The successful applicant will be expected to maintain an active research program that involves graduate and undergraduate students. Preference will be given to applicants who have applied experience with a geotechnical or environmental firm and experience in teaching and in applying GIS technologies.

The Department of Geosciences includes geology, meteorology, and oceanography and consists of 13 faculty members from these fields. The department offers B.S. and B.A. degrees in geology, a B.A. degree in meteorology, and a M.S. degree in applied geosciences. San Francisco State University, a member of the California State University system, serves a multi-cultural, ethnically diverse student body of 27,000 students, offering bachelor's degrees in 117 academic areas and master's degrees in 95 fields of study. Excellence in teaching is the University's primary mission, although SFSU faculty are expected to demonstrate continued professional achievement and growth through research, publications, and community involvement.

To apply, send a curriculum vitae, a statement of teaching and research interests, and names and addresses of three references to: Lisa White, Dept. of Geosciences, San Francisco State University, San Francisco, CA 94132. Applications should be received before September 30, 2002. San Francisco State University is an Equal Opportunity / Affirmative Action employer.

BELOIT COLLEGE
IGNEOUS AND METAMORPHIC PETROLOGY

Beloit College invites applications for a full-time one-year appointment at the assistant professor rank in igneous and metamorphic petrology, beginning fall 2002. (A national tenure-track search for a similar position will begin in fall 2002, pending final approval.) The successful candidate will teach the following four laboratory courses over the year: introductory physical geology and mineralogy (fall); petrology and an advanced course in the candidate's specialty, e.g., tectonics (spring). Supervision of undergraduate research projects expected. Additional expectations for the anticipated tenure-track position include teaching a six-week geologic field-methods course on a rotating basis, participating in the departmental field-trip program, and having a strong commitment to all-college offerings (e.g., first-year seminars, interdisciplinary courses).

Beloit College is a selective undergraduate liberal-arts college with an enrollment of 1,100 students. The college emphasizes excellence in teaching, breadth and versatility in its faculty, and student-faculty research. The city of Beloit is located in southern Wisconsin, close to Madison, Milwaukee, and Chicago.

Applicants should have a Ph.D. by the time of appointment. Send letter of application, statement of teaching and research interests, vita, college level transcripts, and three letters of reference to Carl Mendelson, Geology Search Committee, Beloit College, 700 College St., Beloit, WI 53511. This position will remain open until filled; to ensure full consideration, submit materials by 15 June 2002. Inquiries may be directed to Prof. Mendelson (608-363-2223 or mendelson@beloit.edu). More information about the department may be found at http://geology.beloit.edu/.

Beloit College is committed to cultural and ethnic diversity, and urges all interested individuals to apply. AA/EEO Employer.

INSTRUCTOR, HISTORICAL GEOLOGY
GEOLOGY AND GEOPHYSICS
LOUISIANA STATE UNIVERSITY

The Department of Geology and Geophysics at Louisiana State University invites applications for a non–tenure-track Instructor position to begin in the fall semester of 2002. Required Qualifications: Master's degree in geology or related field; college level teaching experience. Additional Qualification Desired: Ph.D. degree. Responsibilities: teaches sections of introductory historical geology; assists with other undergraduate programs when necessary, such as laboratory courses.

The Department consists of 19 faculty members covering a wide range of expertise. In support of our faculty and students, we have many well-equipped analytical and computational laboratories. Geology and Geophysics has strong support from the LSU administration as evidenced in our selection as one of the twelve priority departments at the University. For more information about our Department, see our Web site at http://www.geol.lsu.edu.

The review process will begin June 1, 2002, and will continue until candidate is selected. Interested persons should send a copy of their vita, a statement of their teaching background, teaching evaluations, and the names, addresses, and phone numbers of at least three references to: Chair, Department of Geology and Geophysics, Louisiana State University, Ref: Log #0955, Baton Rouge, LA 70803. LSU IS AN EQUAL OPPORTUNITY/EQUAL ACCESS EMPLOYER

APPLIED GEOMORPHOLOGIST
NORTHEN AND CENTRAL CALIFORNIA

Pacific Watershed Associates, a geologic consulting firm, is looking for a qualified applied geomorphologist to work throughout Northern and Central California. Requirements: B.S. and minimum of 3 yrs experience in relevant earth science. Job requires overnight and weekly travel. Strong writing and communication skills needed. Salary and benefits DOE. Contact PWA P.O. Box 4433 Arcata CA.95518 or 707-839-5130,pwa@northcoast.com.

OKLAHOMA STATE UNIVERSITY
SCHOOL OF GEOLOGY, RESEARCH ASSOCIATE

The School of Geology at Oklahoma State University invites applications for a Research Associate who will operate and maintain a JEOL JXA 733 electron microprobe. The appointment is currently funded for one year and we anticipate filling the position by August 2002.

We seek applicants with experience in electron microscopy, including performance, routine maintenance, and assisting users. The successful candidate will train Oklahoma State University faculty, research scientists, and students to use the electron microprobe, as well as collaborate and publish results in peer-reviewed journals and assist with writing grant proposals that support the instrument. Other responsibilities include management of the sample preparation laboratory.

The position is expected to be filled at the master's level, but applicants at other levels are invited to apply. Salary is commensurate with qualifications and experience.

Oklahoma State University is a comprehensive, land-grant, research university located 65 miles northeast of Oklahoma City and 65 miles west of Tulsa.

To apply, please send the following: (1) a detailed curriculum vita, (2) a personal statement of background and experience relevant to the position, and (3) the names and addresses, telephone numbers, and electronic mail addresses of three professional references.Review of applications begins by May 1, 2002, and continues until the position is filled.

Please send all materials to: Research Associate Search, School of Geology, Oklahoma State University, 105 Noble Research Center, Stillwater, OK 74078-3031.

For more information on the OSU School of Geology, please visit our website at www.okstate.edu/geology.

OSU is an Affirmative Action/Equal Employment Opportunity Employer, Committed to Multicultural Diversity.

FACULTY POSITIONS IN
EARTH AND ENVIRONMENTAL SCIENCES
NATIONAL CHUNG CHENG UNIVERSITY

The Department of Earth and Environmental Sciences at the National Chung Cheng University is inviting applicants for faculty positions, to begin August 1, 2002 or 2003. Preference will be given to the following research specialties: (1) Engineering geology, (2) Environmental geology, (3) Hydrogeology, (4) Geodesy (GPS), (5) Environmental geophysics, (6) Environmental sciences.

The successful candidates will be expected to develop outstanding programs in research and teaching at both undergraduate and graduate levels.

Application materials should include a curriculum vita, a summary of research interests, copies of important publications, teaching experience and plans, a list of three personal references with complete addresses and e-mail information. Application packages should be sent to: Dr. Chau-Huei Chen, Director, Institute of Seismology, National Chung Cheng University, 160 Shanshin, Minghsiung, Chiayi, Taiwan, R.O.C. Our search will commence immediately, but, the positions will remain open until outstanding candidates are appointed.

ASSISTANT PROGRAM DIRECTOR
JOINT OCEANOGRAPHIC INSTITUTIONS, INC. (JOI)

Seeking candidates for position of Assistant Program Director to help run the Ocean Drilling Program (ODP) and U.S. Science Support Program (USSSP), and to participate on a JOI team that will respond to National Science Foundation (NSF) program management solicitations associated with the incipient Integrated Ocean Drilling Program (IODP, see www.iodp.org).

Duties include assisting the Program Directors of USSSP and ODP in planning, coordinating, and managing program activities; preparing reports and publications; implementing new/revised policies; developing technical, fiscal, and administrative approaches to improve management of the programs; interacting with subcontractors; representing JOI within the scientific community; providing expert scientific and technical knowledge; and fostering communication/team work among program participants.

Incumbent will also assist in the preparation of JOI's response to anticipated NSF solicitations that seek U.S. management entity to: (1) provide a riserless drilling vessel to the international IODP, which is slated to begin October 1, 2003; and (2) administer a USSSP-successor program to support the participation of U.S. scientists in the IODP.

Applicants must possess a Ph.D. or equivalent experience in geosciences or oceanography. Three or more years of research, administration, and/or managerial experience are desirable, as is familiarity with the ODP and USSSP. The position requires excellent coordination and communication skills and requires travel. Salary is commensurate with experience. Generous benefits package.

Submit a curriculum vitae and contact information for three references to Director, Contracts & Administration, JOI, 1755 Massachusetts Ave. NW, Suite 700, Washington D.C. 20036-2102. Additional information is available at www.joiscience.org. Review of applications will begin May 1, 2002 and continue until position is filled. EOE/ MF/DV.

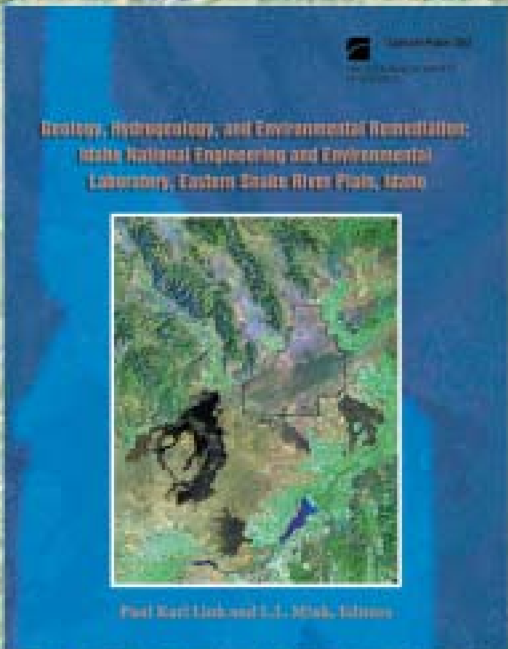
Services and Supplies

German-English translations. Specializing in Geology, Paleontology texts. Heidemarie.Johnson@nau.edu. (928) 779-1370.

TRAVEL MAPS—The world's largest online map catalog. Featuring city maps, topographic maps and digital maps worldwide. Call (336) 227-8300 or visit: www.omnimap.com.

Opportunities for Students

Research and Teaching Assistantships available for Fall Semester 2002 at Temple University: Research and Teaching Assistantships are available for the fall term (September 2002) in our Masters Program in Geology at Temple University. The 2-year Masters Program offers advanced courses and thesis research opportunities in environmental geology, hydrogeology, geochemistry, environmental geophysics, cyclic stratigraphy, soil science/paleosols, K/T boundary studies, and materials science. Financial support for every student includes stipend, book allowance and full tuition for 2 years. Research Assistantships and/or summer support are available for studies in karst hydrology and volcanology monitoring. Graduates of our program have an excellent record of employment and acceptance into doctoral programs. For information and applications please write, call or e-mail Edwin J. Anderson, Department of Geology, Temple University, Philadelphia, PA 19122 (Tel. (215) 204-8249, Fax (215) 204-3496, e-mail andy@astro.temple.edu). Applications will be accepted until these positions are filled. Please visit our Web site at www.temple.edu/geology for additional information.



SPE353, ISBN 0-8137-2353-1
softcover, 296 p., indexed
$135.00, member price $108.00

Geology, Hydrogeology, and Environmental Remediation: Idaho National Engineering and Environmental Laboratory, Eastern Snake River Plain, Idaho

Paul Karl Link and L.L. Mink, Editors

The Idaho National Environmental and Engineering Laboratory (INEEL), on the eastern Snake River Plain, occupies an arid geomorphic system that aggrades by closed-basin fluvial-lacustrine deposition and basaltic plains-volcanism. The area overlies the Snake River Aquifer, one of the largest and most dynamic bodies of subsurface freshwater in North America, and lies in the wake of the Yellowstone Hot Spot, within the Basin and Range province. This is the first peer-reviewed comprehensive volume dealing with multidisciplinary geoscience research at a U.S. Department of Energy facility. The volume contains 19 papers that deal with environmental issues, bioremediation, hydrogeology, and regional geology. The interdisciplinary coverage of this research is a bridge between pure and applied geoscience in an environmentally critical area. The research was funded by the U.S. Department of Energy, and performed by the Idaho Universities Consortium, Idaho Water Resources Research Institute, and the Idaho and U.S. Geological Surveys.

Topics covered by papers in this volume include Quaternary and Pliocene climate history preserved in lakebeds within a tectonically underfilled and volcanically silled basin, the Big Lost Trough; stochastic simulation of basalt flow heterogeneity, which allows greater precision of future Snake River Plain subsurface hydrologic models; state-of-the-art studies dealing with TCE degradation, tracer tests, and intrinsic bioremediation in layered basalt flows; modelling of thermal water beneath the eastern Snake River Plain; extensive drillhole information and subsurface data about the INEEL area, which allows an unusually precise calculation of recurrence and geometry of basaltic eruptions; a discussion of present aspects of petrogenesis of Snake River Plain basalts; and a modified view of Holocene paleoflood hydrogeology of the Big Lost River.

THE GEOLOGICAL SOCIETY OF AMERICA

P.O. Box 9140, Boulder, CO 80301-9140, USA
Toll-free: 888-443-4472
Fax: 303-357-1071, www.geosociety.org