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The Cambrian Substrate Revolution

David J. Bottjer, *Department of Earth Sciences, University of Southern California, Los Angeles, CA 90089-0740, dbottjer@usc.edu*
James W. Hagadorn, *Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125, hagadorn@caltech.edu*
Stephen Q. Dornbos, *Department of Earth Sciences, University of Southern California, Los Angeles, CA 90089-0740, sdornbos@usc.edu*

ABSTRACT

The broad marine ecological settings prevalent during the late Neoproterozoic–early Phanerozoic (600–500 Ma) interval of early metazoan body plan origination strongly impacted the subsequent evolution and development of benthic metazoans. Recent work demonstrates that late Neoproterozoic seafloor sediment had well-developed microbial mats and poorly developed, vertically oriented bioturbation, thus producing fairly stable, relatively low water content substrates and a sharp water-sediment interface. Later in the Cambrian, seafloors with microbial mats became increasingly scarce in shallow-marine environments, largely due to the evolution of burrowing organisms with an increasing vertically oriented component to their bioturbation. The evolutionary and ecological effects of these substrate changes on benthic metazoans, referred to as the Cambrian substrate revolution, are presented here for two major animal phyla, the Echinodermata and the Mollusca.

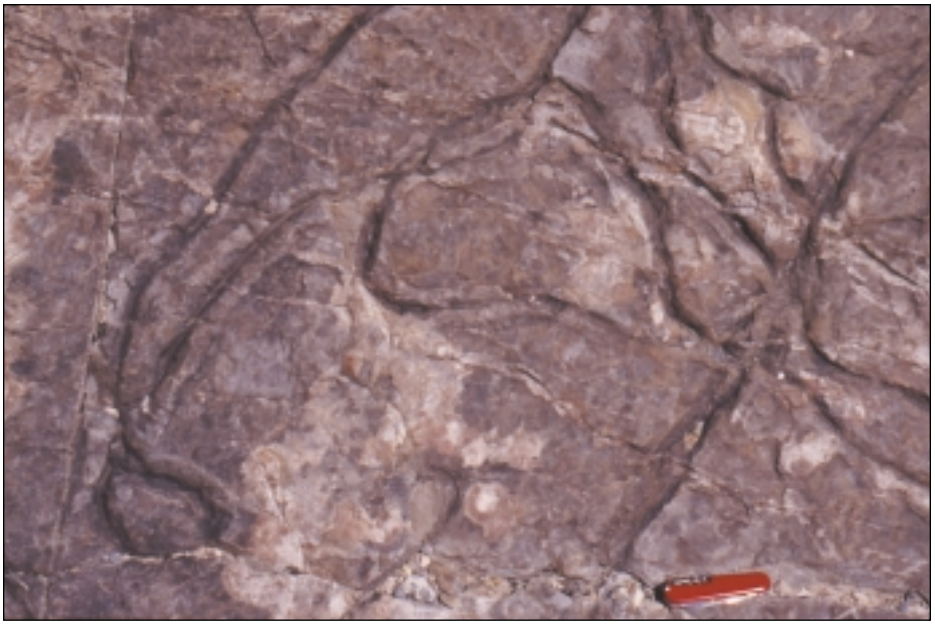

Figure 1. Looping and meandering trace fossil *Taphrhelminthopsis,* made by a large Early Cambrian bioturbator, on a bedding plane from Lower Cambrian Poleta Formation, White-Inyo Mountains, California. Such traces, consisting of a central trough between lateral ridges, occur in sandstones deposited in shallow-marine environments. Evidence indicating original presence of microbial mats is found in associated strata, and morphological features of these traces suggest they were produced on seafloor by active ingestion, or perhaps grazing, of underlying sediments (Hagadorn et al., 2000).

INTRODUCTION

Late Neoproterozoic and early Phanerozoic body and trace fossils commonly exhibit strange morphological adaptations and paleoenvironmental distributions (e.g., Fig. 1). At this time, the basic body plans of large metazoans were first evolving, and much research has been expended toward understanding the evolutionary relationships of these ancient animals. Of particular importance is that while this evolutionary play of metazoan body plan evolution was taking place, the ecological stage was shifting. Two changes in the biological dimensions of the marine ecological stage were especially important. First was the advent and development of predation, which, together with additional biological and geochemical factors, fostered the evolution of mineralized skeletons (e.g., Vermeij, 1989; Bengtson, 1994).

The second change in the biological dimensions of the ecological stage occurred in seafloor sediments, which act as the substrate on and in which benthic organisms live. This change was caused by increasing disturbance of sediments by bioturbation (e.g., Droser, 1987; Droser and Bottjer, 1989) (Fig. 2). Through analogy with the development of agriculture and its resulting effects upon soils, Seilacher and Pflüger (1994) have termed this change the agronomic revolution. Late Neoproterozoic seafloors were typically characterized by well-developed microbial mats (e.g., Gehling, 1986, 1996, 1999; Schieber, 1986; Hagadorn and Bottjer, 1997, 1999) and poor development of sediment mixing by vertically oriented burrowing (e.g., Droser et al., 1999; McIlroy and Logan, 1999) (Fig. 2). Sediment layers on the seafloor thus had relatively low water content and were characterized by a sharp water-sediment interface. Work on carbonates (e.g., Awramik, 1991) and more recently on siliciclastics (e.g., Hagadorn and Bottjer, 1997, 1999) has shown that in the Cambrian shallow marine environments characterized by seafloors covered with microbial mats became increasingly scarce, largely due to increasing vertically oriented bioturbation (Fig. 2). This change to a more Phanerozoic-style seafloor resulted in relatively greater water content of seafloor sediment and a blurry water-sediment interface, which led to the first appearance of a mixed layer. Mixed layers constitute the soupy upper few centimeters of the substrate that are homogenized by bioturbation and are characteristic of later Phanerozoic fine-grained substrates (e.g., Ekdale

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Cambrian Substrate *continued from p. 1*

et al., 1984). With near elimination of microbial mats in shallow-marine environments, microbial or mat-related food sources in sediment changed from being well layered to having a more homogeneously diffuse distribution in the sediment layers on the seafloor. Thus, this agronomic revolution led to the soft-sediment substrates we commonly see in shallow carbonate and siliciclastic marine environments today (Fig. 2). We term the effects this transition had on benthic organisms the Cambrian substrate revolution (Bottjer and Hagadorn, 1999). The Cambrian substrate revolution involved both evolutionary and ecological changes occurring at different time scales, including extinction, adaptation, and environmental restriction.

EVOLUTIONARY AND ECOLOGICAL IMPACTS

Paleobiologists have long been interested in the morphological features evolved by organisms that live on soft sediment seafloors (e.g., Thayer, 1975). Until recently such adaptations could only be adequately assessed for later Phanerozoic benthic organisms, due to an incomplete understanding of late Neoproterozoic and Cambrian paleobiology and paleoenvironments. New data from the Neoproterozoic-Phanerozoic transition have allowed paleobiologists to begin to address the adaptive morphology of these early animals. Environments of the Neoprotero-

Dialogue

Sara Foland, CEO

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Service at GSA: Programs for Students

Last month in "Dialogue," Jack May, Julie Williams May, and I discussed a few of the benefits GSA offers to students, especially those programs available at our Section Meetings. Last month's article was the first in our series on our third value—service. This month, I want to highlight several other GSA programs we offer to students.

Mentoring

Jack touched on one of the mentoring programs we offer that is made possible through the generosity of Roy Shlemon. With Roy's gift, GSA is able to arrange for applied geoscientists to meet with students at Section Meetings. For some students, this may be their first glimpse into the working life of an applied geoscientist. Roy envisioned a program that would facilitate bridging the gap between the applied and academic geology communities—with a special emphasis on providing information about potential career paths to students.

The John F. Mann Mentor Program in Applied Hydrogeology also works to provide guidance for students and help them prepare for careers. This one-on-one mentoring program brings geoscientists together with undergraduate and graduate students and faculty to foster relationships between the professional community and local colleges and universities, and to generate enthusiasm for career opportunities in applied hydrogeology.

Internships

GSA coordinates two intern programs with our partners, the National Park Service (NPS) and the Department of Agriculture U.S. Forest Service (USFS). Since 1996, GSA has placed 31 interns in national parks across the United States. These advanced undergraduate students spend a summer as geological interpreters or in resource management in the parks. Given the success of our NPS partnership and this intern program, GSA partnered with the USFS to place four undergraduates with Forest Service geologist mentors in the Pacific Southwest Region this summer. This Forest Service program is called Geology in the Forests.

Looking Ahead

In an upcoming issue of *GSA Today,* you'll read about GeoCorps America, a new program that will allow our sister societies to participate as partners in placing interns on public lands. Plans also include expanding the types of participants to allow career and retired professionals an opportunity to participate. This program's goal is to place 500 interns each year on America's public lands.

Service to students is one of the tenets of GSA. These two programs—mentoring and internships—are prime examples of how GSA helps students gain experience in geoscience careers and transition from the classroom. Neither program would be possible without partnerships, either with a donor or with the NPS and USFS. Partnering creates the link between the GSA, students, and hands-on geoscience experiences. Our ability to create effective partnerships stems directly from the generosity of donors to the GSA Foundation, such as the late John Mann, his wife Carol Mann, and our friend Roy Shlemon, all of whom believed in investing in the next generation of geoscientists.

Each of us can look back over our careers and see who or what helped us at each of the transition points—from undergraduate to graduate school, from school to career, and from research to applied geoscience. GSA programs provide an opportunity to learn about career choices and experience the life of a working geologist. GSA offers members and students an opportunity to make transitions as our careers evolve. ■

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zoic-Phanerozoic transition were different from those today, requiring the use of nonuniformitarian approaches to analyze the paleobiology and paleoecology of animals living at this time (e.g., Bottjer, 1998). For example, Seilacher (e.g., 1999) has postulated that lifestyles of organisms that lived on late Neoproterozoic sediments characterized by microbial mats, or matgrounds, would include: (1) mat encrusters, which were permanently attached to the mat; (2) mat scratchers, which grazed the surface of the mat without destroying it; (3) mat stickers, which were suspension feeders that were partially embedded in the mat, and comprise a subset of adaptations resulting in organisms broadly termed sediment stickers; and (4) undermat miners, which burrowed underneath the mat and fed on decomposing mat material.

The presence of metazoan fossils perhaps as old as 570 Ma (e.g., Fig. 1 in Martin et al., 2000), and molecular data indicating a possibly earlier origin of metazoans (e.g., Wray et al., 1996), suggests that there was an early stage of evolution for most benthic metazoan groups before they evolved mineralized skeletons (e.g., Fortey et al., 1996, 1997). This early stage of evolution for benthic organisms was within the environmental context of a Neoproterozoic-style minimally bioturbated seafloor covered with microbial mats. Thus, how did this late Neoproterozoic-Phanerozoic transition to more Phanerozoic-style seafloor conditions affect the evolution, dispersal, and paleoenvironmental distribution of metazoans, which were adapted to these Neoproterozoic seafloor sediments? Were there animals and perhaps entire communities that were adapted to these seafloor conditions, in the manner proposed by Seilacher (1999)?

We cannot yet fully answer these questions. However, mounting evidence suggests that many evolutionary and ecological changes, which took place during this time interval, were due to the transition in substrate style from the late Neoproterozoic marine environments and lifestyles described by Seilacher (e.g., 1999), to the bioturbated sedimentary environments and morphological adaptations documented for later Phanerozoic benthic organisms (e.g., Thayer, 1975).

Cambrian Substrate *continued on p. 4*

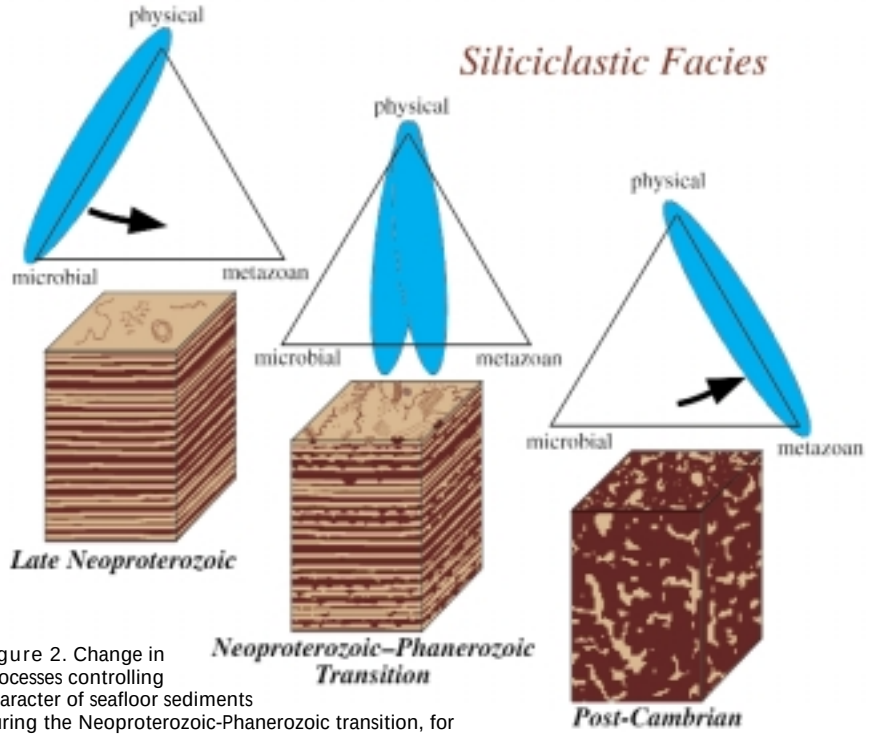

Figure 2. Change in processes controlling character of seafloor sediments during the Neoproterozoic-Phanerozoic transition, for siliciclastic neritic (below normal wave base to shelf edge) environments. These processes, indicated on the triangular diagrams, are physical (causing primary deposition of sediments), microbial (also producing primary structures), and subsequent bioturbation by metazoans. Changes in triangular diagram blue fields show change in relative dominance of these processes through this transition. Schematic seafloor cores indicate characteristic physical and biogenic sedimentary structures during this transition, from laminated and thin bedded (left), to partially bioturbated (center), to completely bioturbated (right). Derived from data in Droser (1987), Hagadorn and Bottjer (1997, 1999), Droser et al. (1999), and McIlroy and Logan (1999).

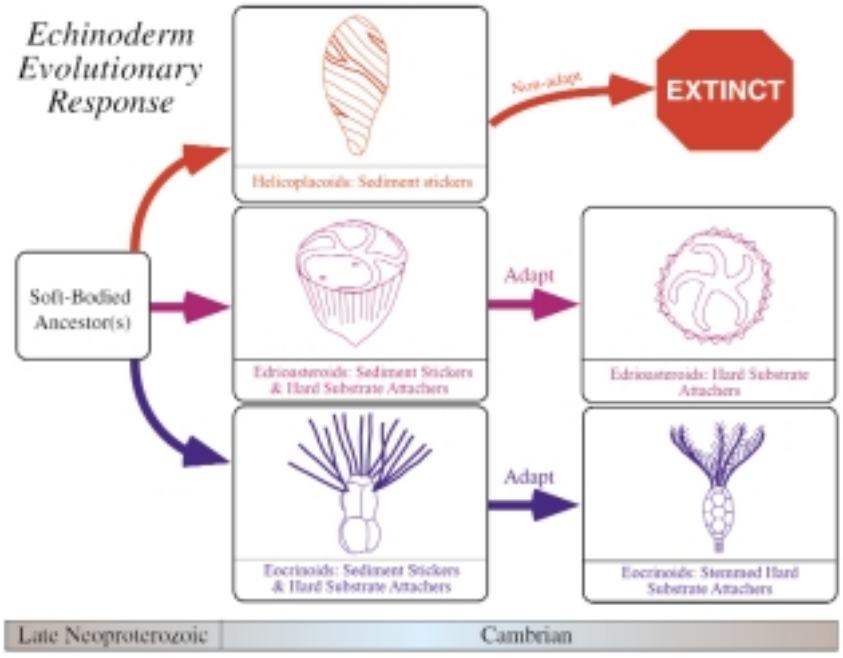

Figure 3. Evolutionary response of Cambrian sessile suspension-feeding echinoderms as part of the Cambrian substrate revolution. Arrows do not represent a direct evolutionary relationship between specific echinoderms shown, but imply a general evolutionary trend through the Cambrian within each of the groups examined, with these echinoderms serving as individual examples. Helicoplacoid drawing is modified from Paul and Smith (1984); specimen is 3 cm in height. For edrioasteroids, *Camptostroma* (left) is modified from Paul and Smith (1984); specimen is 5 cm in height. Edrioasteroid on right is a schematic of a typical attaching edrioasteroid, modified from Paul and Smith (1984); size is 5 cm in width. For eocrinoids, *Lichenoides* (left) is modified from Ubaghs (1967); specimen is approximately 2.5 cm in height. Eocrinoid on right is *Tatonkacystis,* modified from Sumrall et al. (1997); specimen is approximately 5 cm in height. Geological time not to scale and boxes do not represent the precise age range of the echinoderms they contain.

Cambrian Substrate *continued from p. 3*

Early suspension-feeding echinoderms and grazing polyplacophoran and monoplacophoran mollusks (and their likely soft-bodied ancestors) provide two examples of the effects of this change in substrate character.

SESSILE SUSPENSION-FEEDING ECHINODERMS

Evolution of Cambrian suspension-feeding echinoderms that had an immobile, or sessile, lifestyle provides strong evidence for the short-term impact of the Cambrian substrate revolution. For example, the unusual Early Cambrian helicoplacoid echinoderms were well adapted for survival on Neoproterozoic-style substrates. These small (1–5 cm) suspension-feeding echinoderms (Fig. 3) lived as sediment stickers on a substrate that underwent only low-to-moderate levels of horizontally directed bioturbation and did not have a mixed layer (Dornbos and Bottjer, 2000a). Helicoplacoids lacked typical Phanerozoic soft-substrate adaptations, such as the ability to attach to available hard substrates or presence of a root-like holdfast. Significant increase in depth and intensity of bioturbation in shallow-water muds and sands through the Cambrian (e.g., Droser, 1987) destroyed the stable substrates that these small echinoderms required and likely led to their extinction (Dornbos and Bottjer, 2000a) (Fig. 3).

In contrast, both edrioasteroids and eocrinoids, the other groups of undisputed Cambrian sessile suspension-feeding echinoderms, were able to adapt to the change in substrates created by increased bioturbation. The earliest edrioasteroids lived unattached on the seafloor during the Early and Middle Cambrian, but by the Late Cambrian edrioasteroids lived attached to available hard substrates (e.g., Sprinkle and Guensburg, 1995) (Fig. 3). Similarly, several Early and Middle Cambrian eocrinoids were stemless and lived unattached on the seafloor (Ubaghs, 1967; Sprinkle, 1992) (Fig. 3). By the Late Cambrian, however, eocrinoids had evolved stems and also lived attached to available hard substrates (Fig. 3). Thus, by attaching to hard substrates or by developing stems, each of these Cambrian echinoderm groups avoided the detrimental effects of increased substrate instability caused by increasing bioturbation (Fig. 3), and they survived into the post-Cambrian Paleozoic. The remaining undisputed Cambrian echinoderms were all mobile deposit- or suspension-feeders (e.g., Sprinkle, 1992). Their mobility likely exacerbated the substrate changes occurring during this time, and, because they could adjust their position relative to the sediment-water interface, they would have been relatively

immune to the effects of this change in substrate character.

EARLY GRAZING MOLLUSKS

Similarly, how did mobile organisms that grazed the sediment surface (a life habit likely typical of early mollusks) respond to this change in substrate character? If organisms crawled on top of the sediment surface in late Neoproterozoic marine environments and scratched or scraped microbial mats for food, disappearance of mats from these settings might have restricted them to marine hard substrate environments where mats still flourished, such as those typical of the nearshore (e.g., rocks or reefs), where scratching or scraping microbial layers and biofilms off hard substrates was still a viable strategy. In addition, if organisms depended upon the relatively sharp water-sediment interface that the combination of mats and minimal vertical bioturbation produced in marine soft sediments, then, in response to this widespread change in substrate character, they also could have become restricted to soft substrate environments where these conditions still prevailed. The most likely environments in which to find such conditions are in the deep sea, where: (1) mats built by chemoautotrophic and heterotrophic microbes occur (e.g., Hagadorn and Bottjer, 1999; Simonson and Carney, 1999; and references within); and (2) biogenic reworking, although highly variable, may be several orders of magnitude less than on the shelf (e.g., Thayer, 1983; Gage and Tyler, 1991).

The evolutionary relationships of the mollusks are still controversial (e.g., Runnegar, 1996). Aplacophorans, polyplacophorans, and monoplacophorans are the most primitive mollusks living today (e.g., Salvini-Plawen and Steiner, 1996). Aplacophorans are generally thought to be the most primitive, because of their worm-like body form and spiculate skeleton, but they have no fossil record (Pojeta et al., 1987). Polyplacophorans, or chitons, have a broad muscular foot covered by eight dorsal shell plates (Fig. 4), and living representatives graze surficial microbial mats and biofilms (Pojeta et al., 1987). The oldest known polyplacophorans lived in the Late Cambrian and grazed on shallow-water stromatolites (Runnegar et al., 1979) (Fig. 4). Living monoplacophorans have a broad foot and are also surface grazers, but unlike chitons they have a single continuous dorsal shell (Fig. 4). Fossil monoplacophorans have a broader variety of shell morphologies than living genera, (e.g., Pojeta et al., 1987), and this complexity is reflected in the variety of interpretations that exist concerning monoplacophoran evolutionary relationships (e.g., Pojeta et al., 1987; Salvini-Plawen and Steiner, 1996; Runnegar, 1996). The oldest known monoplacophorans are Early Cambrian, and include substrate grazers (e.g., Pojeta et al., 1987) (Fig. 4). The post-Cambrian fossil record of both polyplacophorans and monoplacophorans is poor, and little is known about how and where they lived (e.g., Pojeta et al., 1987; Squires and Goedart, 1995; Cherns, 1998).

However, the modern occurrence of chitons and monoplacophorans exhibits the type of environmental distribution that one would predict as a long-range consequence of the Cambrian substrate revolution. Modern polyplacophorans typically occur in rocky coastline environments but some live in the deep sea (Pojeta et al., 1987; Squires and Goedart,1995) (Fig. 4). Living monoplacophorans occur in the deep sea on soft substrates, although one genus lives on hard substrates at the shelf edge (Pojeta et al., 1987) (Fig. 4). Thus, although little currently is known about the ecology of soft-bodied late Neoproterozoic and Cambrian ancestors of polyplacophorans and monoplacophorans, they may have lived on soft as well as hard substrates in shallow marine environments and grazed microbial mats that covered the seafloor, a lifestyle that today is typically restricted to hard substrates and the deep sea.

Behavioral evidence, in the form of trace fossils, provides additional insight into the life habits of early metazoans that lived on these soft substrates. For example, Upper Cambrian bedding surfaces from Oman contain large scratch marks that are morphologically identical to traces made by the grazing of modern gastropods upon hard substrates. Because these grazing traces are associated with ovate traces most likely produced by a soft-footed organism, they suggest that early mollusks were grazing on soft seafloor sediments (Seilacher, 1977, 1995). Gehling (1996) has also documented grazing traces, together with flattened ovoid body impressions, in Vendian strata of Australia, suggesting association with a soft-footed mollusk. Similar traces occur in Lower Cambrian strata in Yunnan Province, China (Dornbos and Bottjer, 2000b) and Vendian strata of the White Sea area, Russia (Martin et al., 2000). All of these scratch-style traces are associated with diagnostic sedimentary structures indicative of the presence of microbial mats, and all except the White Sea traces are from medium- to coarse-grained arenites. Considered together, these occurrences suggest that early in their evolutionary history, mollusks in nearshore to shelf-edge environments grazed upon sands, which

Cambrian Substrate *continued on p. 6*

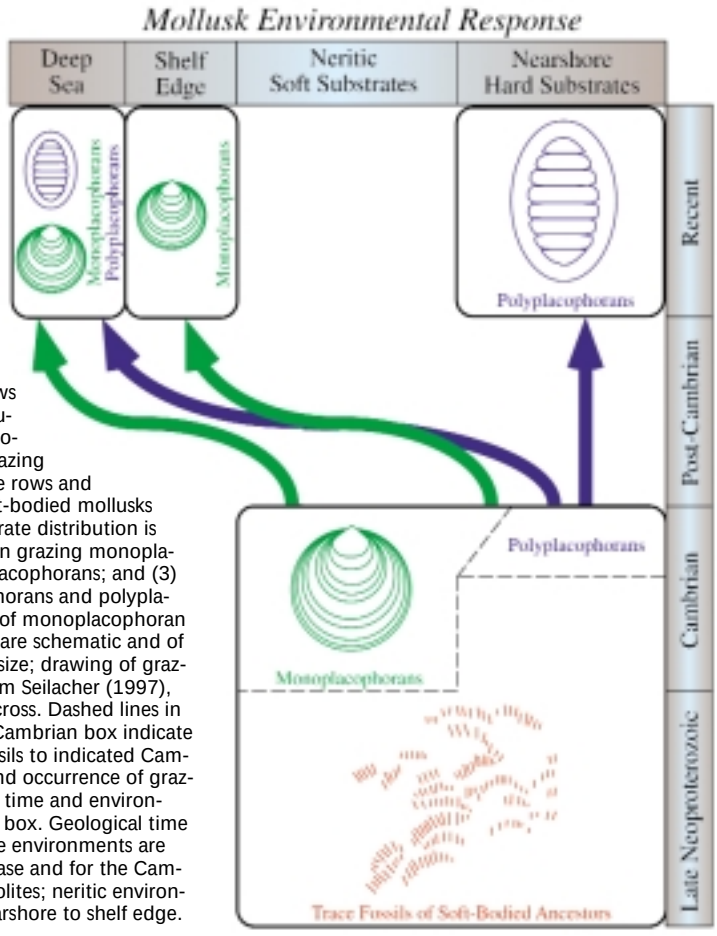

Figure 4. Environmental response of mollusks as part of Cambrian substrate revolution. Onshore-offshore diagram shows environmental distribution of: (1) late Neoproterozoic–Cambrian grazing traces made in arcuate rows and attributed to early soft-bodied mollusks (nearshore hard substrate distribution is inferred); (2) Cambrian grazing monoplacophorans and polyplacophorans; and (3) modern monoplacophorans and polyplacophorans. Drawings of monoplacophoran and polyplacophoran are schematic and of specimens 1–3 cm in size; drawing of grazing trace modified from Seilacher (1997), each row is 2–5 cm across. Dashed lines in late Neoproterozoic–Cambrian box indicate restriction of body fossils to indicated Cambrian environments and occurrence of grazing traces throughout time and environments represented by box. Geological time not to scale, nearshore environments are above normal wave base and for the Cambrian include stromatolites; neritic environments range from nearshore to shelf edge.

GSA Welcomes the Geological Society of South Africa as an Associated Society

At its May 2000 meeting, the GSA Council voted to accord Associated Society status to the Geological Society of South Africa (GSSA).

The GSSA was founded in 1895 after the discovery of gold on the Witwatersrand in 1886 concentrated the South African geological, mining, and financial fraternity in the infant Johannesburg. South African geologic features such as the world-renowned Witwatersrand, the Barberton Mountain Land, the Bushveld Complex, and the fossil-rich Karoo led B.B. Brock to coin the moniker "Land of Geological Superlatives" for this outstanding landscape.

A constitution based upon that of the Geological Society of London was adopted with the following objectives: to promote the study of the earth sciences; to do everything conducive to the advancement of the earth sciences and the earth science professions; to promote the interests of the earth sciences and the earth science professions; and to uphold high professional and ethical standards amongst its members.

GSSA has approximately 1,500 members in 13 geographic branches and five disciplinary divisions. GSSA has sponsored many Geocongress meetings over the years and has published a number of Congress abstract volumes representing documentation of otherwise largely unpublished data.

Affiliation as an Associated Society with GSA will solidify the societies' ties and ensure an increased awareness of the contributions the respective societies and science are making and can make in the future.

Additional information is available from the GSSA Web site at www.gssa.org.za.

Cambrian Substrate *continued from p. 5*

behaved in a semilithified manner due to the presence of microbial mats (Fig. 4).

ADDITIONAL IMPLICATIONS

Because adaptations to these mat-covered and more coherent Neoproterozoic-style soft substrates required different morphologies and behaviors than soupier Phanerozoic-style soft substrates, the Cambrian explosion is also characterized by a unique variety of bedding-parallel trace fossils. For example, large meandering trace fossils such as *Plagiogmus* and *Taphrhelminthopsis* (Fig. 1) were common in Early Cambrian shallow-marine environments, yet were likely made by soft-bodied metazoans for which we have no body fossil record (McIlroy and Heys, 1997; Hagadorn et al., 2000). Similarly, several other meandering trace fossils as well as those exhibiting a network pattern, including *Helminthoida* and *Paleodictyon*, also occur in Cambrian strata deposited in shallow-marine environments (Crimes and Fedonkin, 1994). A number of these Cambrian trace fossil genera, as well as ichnogenera with similar morphologies, are found only in deep-sea strata after the Cambrian, and thus are united by a similar paleoenvironmental history of onshore-offshore retreat (Bottjer et al., 1988; Crimes and Fedonkin, 1994; Hagadorn et al., 2000). This pattern of post-Cambrian restriction to the deep sea by bedding-parallel trace fossils is mirrored by the record of microbial structures produced in siliciclastic sediments (Hagadorn and Bottjer, 1999). Thus, as for grazing mollusks, the environmental restriction shown by trace fossils is likely also an effect of the Cambrian substrate revolution, caused by the broad increase in vertically directed bioturbation and consequent decrease in development of microbial mats, in shallow-marine environments.

Further analysis of the Cambrian substrate revolution may contribute to a better understanding of broader evolutionary phenomena. The Cambrian is characterized by a wide variety of metazoans, reflected in both body and trace fossils, many of which have morphologies that appear strange to the modern eye (e.g., Gould, 1989). Perhaps the co-occurrence during the Cambrian of benthic metazoans adapted more to Neoproterozoic-style soft substrates, with those more adapted to Phanerozoic-style substrates, contributed significantly to the high morphological disparity exhibited by animals of the Cambrian explosion.

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REFERENCES CITED

Awramik, S.M., 1991, Archaean and Proterozoic stromatolites, *in* Riding, R., ed., Calcareous algae and stromatolites: Berlin, Springer-Verlag, p. 289–304.

Bengtson, S., ed., 1994, Early life on Earth: New York, Columbia University Press, 630 p.

Bottjer, D.J., 1998, Phanerozoic non-actualistic paleoecology: Geobios, v. 30, p. 885–893.

Bottjer, D.J., Droser, M.L., and Jablonski, D., 1988, Palaeoenvironmental trends in the history of trace fossils: Nature, v. 333, p. 252–255.

Bottjer, D.J., and Hagadorn, J.W., 1999, The Cambrian substrate revolution and evolutionary paleoecology of the Mollusca: Geological Society of America Abstracts with Programs, v. 31, p. 335.

Cherns, L., 1998, *Chelodes* and closely related Polyplacophora (Mollusca) from the Silurian of Gotland, Sweden: Palaeontology, v. 41, p. 545–573.

Crimes, T.P., and Fedonkin, M.A., 1994, Evolution and dispersal of deepsea traces: Palaios, v. 9, p. 74–83.

Dornbos, S.Q., and Bottjer, D.J., 2000a, Evolutionary paleoecology of the earliest echinoderms: Helicoplacoids and the Cambrian substrate revolution: Geology, v. 28, p. 839–842.

Dornbos, S.Q., and Bottjer, D.J., 2000b, Radular grazing traces in the Lower Cambrian of China: Implications for the Cambrian substrate revolution: PaleoBios, v. 20, supplement to no. 1, p. 1.

Droser, M.L, 1987, Trends in extent and depth of bioturbation in Great Basin Precambrian-Ordovician strata, California, Nevada, and Utah [Ph.D. thesis]: Los Angeles, University of Southern California, 365 p.

Droser, M.L., and Bottjer, D.J., 1989, Ordovician increase in extent and depth of bioturbation: Implications for understanding early Paleozoic ecospace utilization: Geology, v. 17, p. 850–852.

Droser, M.L., Gehling, J.G., and Jensen, S., 1999, When the worm turned: Concordance of Early Cambrian ichnofabric and trace-fossil record in siliciclastic rocks of South Australia: Geology, v. 27, p. 625–628.

Ekdale, A.A., Muller, L.N., and Novak, M.T., 1984, Quantitative ichnology of modern pelagic deposits in the abyssal Atlantic: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 45, p. 189–223.

Fortey, R.A., Briggs, D.E.G., and Wills, M.A., 1996, The Cambrian evolutionary "explosion": Decoupling cladogenesis from morphological disparity: Biological Journal of the Linnean Society, v. 57, p. 13–33.

Fortey, R.A., Briggs, D.E.G., and Wills, M.A., 1997, The Cambrian evolutionary "explosion" recalibrated: BioEssays, v. 19, p. 429–434.

Gage, J.D., and Tyler, P.A., 1991, Deep-sea biology: A natural history of organisms at the deep-sea floor: Cambridge, Cambridge University Press, 504 p.

Gehling, J.G., 1986, Algal binding of siliciclastic sediments: A mechanism in the preservation of Ediacaran fossils: 12th International Sedimentological Congress, Canberra, Australia, Abstracts, p. 117.

Gehling, J.G., 1996, Taphonomy of the terminal Proterozoic Ediacaran biota, South Australia [Ph.D. thesis]: Los Angeles, University of California, 222 p.

Gehling, J.G., 1999, Microbial mats in terminal Proterozoic siliciclastics: Ediacaran death masks: Palaios, v. 14, p. 40–57.

Gould, S.J., 1989, Wonderful life: New York, W.W. Norton and Company, 347 p.

Hagadorn, J.W., and Bottjer, D.J., 1997, Wrinkle structures: Microbially mediated sedimentary structures common in subtidal siliciclastic settings at the Proterozoic-Phanerozoic transition: Geology, v. 25, p. 1047–1050.

Hagadorn, J.W., and Bottjer, D.J., 1999, Restriction of a late Neoproterozoic biotope: Suspect-microbial structures and trace fossils at the Vendian-Cambrian transition: Palaios, v. 14, p. 73–85.

Hagadorn, J.W., Schellenberg, S.A., and Bottjer, D.J., 2000, Paleoecology of a large Early Cambrian bioturbator: Lethaia, v. 33 (in press).

Martin, M.W., Grazhdankin, D.V., Bowring, S.A., Evans, D.A.D., Fedonkin, M.A., and Kirschvink, J.L., 2000, Age of Neoproterozoic bilatarian body and trace fossils, White Sea, Russia: Implications for metazoan evolution: Science, v. 288, p. 841–845.

McIlroy, D., and Heys, G.R., 1997, Palaeobiological significance of *Plagiogmus* arcuatus from the Lower Cambrian of central Australia: Alcheringa, v. 21, p. 161–178.

McIlroy, D., and Logan, G.A., 1999, The impact of bioturbation on infaunal ecology and evolution during the Proterozoic-Cambrian transition: Palaios, v. 14, p. 58–72.

Paul, C.R.C., and Smith, A.B., 1984, The early radiation and phylogeny of echinoderms: Biological Reviews of the Cambridge Philosophical Society, v. 59, p. 443–481.

Pojeta, J., Jr., Runnegar, D., Peel, J.S., and Gordon, M., Jr., 1987, Phylum Mollusca, *in* Boardman, R.S., et al., eds., Fossil invertebrates: Palo Alto, California, Blackwell Scientific Publications, p. 270–435.

Runnegar, B., 1996, Early evolution of the Mollusca: The fossil record, *in* Taylor, J., ed., Origin and evolutionary radiation of the Mollusca: Oxford, Oxford University Press, p. 77–87.

Runnegar, B., Pojeta, J., Jr., Taylor, M.E., and Collins, D., 1979, New species of the Cambrian and Ordovician chitons *Matthevia* and *Chelodes* from Wisconsin and Queensland: Evidence for the early history of polyplacophoran mollusks: Journal of Paleontology, v. 53, p. 1374–1394.

Salvini-Plawen, L.v., and Steiner, G., 1996, Synapomorphies and plesiomorphies in higher classification of Mollusca, *in* Taylor, J., ed., Origin and evolutionary radiation of the Mollusca: Oxford, Oxford University Press, p. 77–87.

Schieber, J., 1986, The possible role of benthic microbial mats during the formation of carbonaceous shales in shallow Mid-Proterozoic basins: Sedimentology, v. 33, p. 521–536.

Seilacher, A., 1977, Evolution of trace fossil communities, *in* Hallam, A., ed., Patterns of evolution: Amsterdam, Elsevier, p. 359–376.

Seilacher, A., 1995, Fossile kunst: Albumbatter der erdgeockickte: Korb, Germany, Goldschneck-Verlag, 48 p.

Seilacher, A., 1997, Fossil art: Drumheller, Alberta, Royal Tyrell Museum of Palaeontology, 64 p.

Seilacher, A., 1999, Biomat-related lifestyles in the Precambrian: Palaios, v. 14, p. 86–93.

Seilacher, A., and Pflüger, F., 1994, From biomats to benthic agriculture: A biohistoric revolution, *in* Krumbein, W.E., et al., eds., Biostabilization of sediments: Oldenburg, Germany, Bibliotheks und Informationssystem der Carl von Ossietzky Universität Oldenburg (BIS), p. 97–105.

Simonson, B.M., and Carney, K.E., 1999, Roll-up structures: Evidence of in situ microbial mats in Late Archaean deep shelf environments: Palaios, v. 14, p. 13–24.

Sprinkle, J., 1992, Radiation of echinodermata, *in* Lipps, J.H., and Signor, P.W., eds., Origin and early evolution of the metazoa: New York, Plenum Press, p. 375–398.

Sprinkle, J., and Guensburg, T.E., 1995, Origin of echinoderms in the Paleozoic evolutionary fauna: The role of substrates: Palaios, v. 10, p. 437–453.

Squires, R.L., and Goedert, J.L., 1995, An extant species of *Leptochiton* (Mollusca: Polyplacophora) in Eocene and Oligocene cold-seep limestones, Olympic Peninsula, Washington: The Veliger, v. 38, p. 47–53.

Sumrall, C.D., Sprinkle, J., and Guensburg, T.E., 1997, Systematics and paleoecology of Late Cambrian echinoderms from the western United States: Journal of Paleontology, v. 71, p. 1091–1108.

Thayer, C.W., 1975, Morphological adaptations of benthic invertebrates on soft substrata: Journal of Marine Research, v. 33, p. 177–189.

Thayer, C.W., 1983, Sediment-mediated biological disturbance and the evolution of marine benthos, *in* Tevesz, M.J.S., and McCall, P.L., eds., Biotic interactions in recent and fossil benthic communities: New York, Plenum Press, p. 480–625.

Ubaghs, G., 1967, Eocrinoidea, *in* Moore, R.C., and Teichert, C., eds., Treatise on invertebrate paleontology, Part S, Echinodermata 1: Boulder, Colorado, Geological Society of America, p. 445–495.

Vermeij, G.J., 1989, The origin of skeletons: Palaios, v. 4, p. 585–589.

Wray, G.A., Levinton, J.S., and Shapiro, L.H., 1996, Molecular evidence for deep pre-Cambrian divergences among metazoan phyla: Science, v. 274, p. 568–573.

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GSA Creates Earth Science Week Poster

In celebration of Earth Science Week (October 8–14), GSA is sending a poster that highlights Colorado geology and a list of member-recommended books that feature earth sciences to some of our neighbors here at headquarters—public libraries and public school libraries in Colorado. Librarians will be encouraged to use the materials in Earth Science Week displays.

Colorado librarians also will have a first-come-first-served opportunity to receive up to $50 in reimbursement from GSA for the purchase of general geology books or books that present the earth sciences as an integral part of story lines.

Copies of the poster are free for Colorado educators and may be purchased by GSA members for $8. To order, e-mail GSA at member@geosociety.org, or call 303-447-2020, ext. 774, or 1-888-443-4472. Members are also encouraged to submit titles for the book list to member@geosociety.org.

Rabbit Ears Pass, by Colorado photographer Todd Miller.

Engaging "My Neighbor" in the Issue of Sustainability Part IX: We Live in a World of Change

Christine Turner, *U.S. Geological Survey, Denver, CO, and* ***E-an Zen,*** *Reston, VA*

If it is true that our consumptive lifestyle, in combination with a burgeoning world population, is harming our ecosystems and the prospects of a sustainable future, what should we do? Some of us might want to restore the idealized halcyon days of yore, when human, technology-caused changes were slower and, we assume, less harmful. Whether or not humans have in some time past lived more sustainably, we certainly are not doing so now, given the way that we are altering Earth's surface, water bodies, and atmosphere in support of our own material wants. However, we do not know whether we should—and how to—reverse, halt, or even slow the undesirable changes to our collective habitat.

Our uncertainty about how to take responsible action to mitigate planetary damage arises partly from our lack of agreement about the human contribution to environmental and climate conditions and about the ability of both Earth and its inhabitants to adapt to those changes. Geologists' traditional interpretation of Earth's history told us that geologic changes affecting climate and ecosystems were relatively slow, allowing organisms to adapt, and that when these changes came about too quickly, life forms would transform or become extinct. In the geological past, there were times when fertile land was reduced to desert, when sea level rose and inundated lowlands, and when air temperature increased to the point where animal and plant life were stressed. Nobody was there to protect the threatened species. Contemporary humans, in contrast, seem disposed to engineer Earth to suit our perception of comfort and progress. We tend to view extinctions in the geologic record as the consequence of natural geologic processes, yet we resist the idea that either natural or human-enhanced or human-induced changes might similarly affect our own species.

Contrary to the traditional interpretation of the geologic record, recent studies of ice cores have identified rapid fluctuations in climate over very short periods of time, from years to decades (Severinghaus and Brook, 1999). These data suggest that perhaps our perceptions of rates of change in the geologic past need to be revised. For much of the geologic past, our time markers are few and far apart. Actual rates of some changes may have been much faster than our present ability to define them. Even so, some changes related to Earth may be truly slow by human standards. How do we deal with these conflicting perceptions and realities of the rates of change?

The history of many human societies has been one of attempting to control or harness nature, with man using his ingenuity to build levees to contain rivers, build jetties to retard wave erosion, and maintain farmland in the face of water shortages. What are the long-term consequences of these large-scale, engineered interventions? Do they create more harm than the condition we were originally trying to forestall or ameliorate? Do they subject us to using materials and energy for perpetual maintenance of all that we build? Should we put our faith in technology as a panacea, or is that taking too large a risk for future generations, who must live with the results of our choices?

As aspiring members of a civilized society, we must examine our role as overseers and instruments of change on the planet. We can choose to continue our present rates of unbridled use of Earth resources and our alteration of Earth's environments, or we can assume the role of responsible stewards. If our knowledge of Earth has expanded, so must our humility in the face of new theories of complexity, and the chaotic nature of natural phenomena. We have more evidence about the interdependence of all things natural, but less ability to develop precise predictions about the consequences of change. Presumably, if we share the broadest goal of maintaining a modest comfort zone for human habitation, we must also seek to learn where our intervention is necessary. We may need to reverse certain deleterious changes now happening to the Earth system, based on reasonable scientific judgments and our collective value system.

The realization that we cannot predict the future with certainty suggests that it behooves us to preserve our options—for ourselves, our fellow inhabitants of the planet, and future descendants of all living species. We need to consider possible effects of large-scale, human-induced changes that might interact with natural processes and magnify the effects. For example, carbon dioxide from human activities could lead to global warming sufficient to cause major shifts in ocean circulation patterns. These shifts, in turn, would drastically affect the productivity of the agricultural land in the circum-Atlantic region (Broecker, 1996, 1997). The geologic record of the last 10,000 years shows that major changes in ocean circulation patterns could be rapid even by human standards (years to decades; see Broecker, 1997, and Bond et al., 1997). Do we understand that we may be contributing to such changes? Do we have a right to cause such major changes that could affect the habitability of large tracts of our planet? Should we try to remove at least the human-induced changes from the trends?

These are difficult questions, and involve our most basic values and responsibilities. As we acquire new, reliable data and new insight about Earth processes and history, we are in a position to make better, informed choices about what changes we might cause or enhance in our habitat. For instance, should we continue down certain potentially harmful paths that accompany our current lifestyle choices? The geologic record shows that change is inevitable. Nevertheless, we can make use of our hard-won understandings of Earth, and the humility that should accompany such understanding. It will take both humility and the thoughtful use of the knowledge that we have acquired, and continue to acquire, to preserve our options for the future. We can thus challenge ourselves to become better stewards of a planet that we inhabit for only a brief geologic moment, for the benefit of future generations of man and of other inhabitants of the planet who cannot protect themselves.

References Cited

Bond, G., Showers, W.J., Cheseby, M., Lotti, R., Almasi, P., deMenocal, P., Priore, P., Cullen, H., Hajdas, I., and Bonani, G., 1997, A pervasive millennial-scale cycle in North Atlantic Holocene and glacial climate: Science, v. 278, p.1257–1266.

Broecker, W.S., 1996, Will our ride into the greenhouse future be a smooth one?: GSA Today, v. 7, no. 5, p. 1–7.

Broecker, W.S., 1997, Thermohaline circulation, the Achilles Heel of our climate system: Will man-made CO_2 upset the current balance?: Science, v. 278, p. 1582–1588.

Severinghaus, J.P., and Brook, E.J., 1999, Abrupt climate change at the end of the last glacial period inferred from trapped air in polar ice: Science, v. 286, p. 930–934. ■

Note: The other articles of this series, with some enhancements for teachers, and the text of the Guidelines for Sustainability Literacy are now available through a link on GSA's Web site, www.geosociety.org. From either Public Interest or the "Related Links" area of Geoscience Initiatives, click "Sustainability" then "Toward a Stewardship of the Global Commons."

Research Opportunities in Low-Temperature and Environmental Geochemistry

A condensed report of the NSF-sponsored workshop "Directions and Priorities in Low-Temperature Geochemistry for the Year 2000 and the Next Decade," June 5–6, 1999, Boston, Massachusetts

Low-Temperature Geochemistry

Low-temperature geochemistry is defined as the study of inorganic and organic geochemical phenomena at Earth's surface and within Earth's crust to temperatures of 300 °C. Low-temperature geochemists apply an array of techniques to quantify and predict the transfer of energy and matter among and within various global reservoirs (lithosphere, hydrosphere, atmosphere, and biosphere) through integrated studies of physical, biological, and chemical processes. Low-temperature geochemists focus on: (1) identifying and quantifying processes controlling the distribution of elements, both in the present and in the geologic past; (2) developing and applying measurements of the abundances of geochemical constituents; and (3) modeling and predicting geochemical behavior within complex spatial settings and over temporal scales ranging from femtoseconds to billions of years.

In addition to the study of geologic systems, a crucial need for more research in this subdiscipline comes from the increasing pollution of air, water, and land resources; the depletion of water, energy and mineral resources; and the potentially deleterious consequences of anthropogenic global phenomena such as greenhouse warming. Further motivation comes from recent advances in instrumental and experimental techniques, in conceptual and mathematical modeling, and in the availability of high-resolution temporal and spatial data. At the molecular level, spectroscopic and computational modeling techniques allow us to examine structure and bonding in a variety of phases. Biomolecular probes hold the promise of identifying microorganisms, their ecology, and their relationship to inorganic geochemical processes. At the global scale, new remote-sensing techniques, such as AVIRIS (NASA Airborne Visible/Infrared Imaging Spectrometer) and satellite-based sensors, will permit mapping of the distribution of geochemical constituents and contaminants. These powerful technological advances are timely for defining a new geochemical research initiative with the potential for meeting critical societal needs. Particular emphasis is placed on emerging research opportunities in the area of environmental geochemistry, defined as the application of low-temperature geochemistry to the sustainability of living organisms.

New Initiative

In terms of a major new initiative, a highly promising opportunity is integrative research linking geologic processes with biological sustainability. The priority in funding should be for studies that show greatest promise for establishing these links; however—and this is important—individual projects need not be interdisciplinary in and of themselves. The following themes are a nonexclusive list of key areas for establishing fundamental connections between geochemical and biological processes.

Biogeochemistry and Geomicrobiology: Feedbacks, Processes, and Rates

Interactions among microorganisms and minerals play key roles in biomineralization, in the migration and degradation of contaminants, and in controlling the composition of natural waters. Study of these interactions requires sophisticated analytical and cross-disciplinary approaches. Advances in microbiological characterization in situ are enabling biogeochemists to define microbial populations in natural environments and to explore the roles of exoenzymes and other extracellular organic molecules in geochemical processes. Understanding interactions between organisms and mineral surfaces will provide new insights relevant to old questions, such as the origin of life, the nature of biological signatures and fossilization processes, and biomineralization. Within environmental geochemistry, research on enzymatically catalyzed redox reactions (i.e., those involving arsenic, carbon, chromium, iron, manganese, mercury, nitrogen, oxygen, selenium, sulfur, and uranium) will improve understanding of the connections among biogeochemical processes, global change, and human health.

Cycling of Life-Supporting Elements

A pragmatic, well-known problem of global impact is the cycling of carbon through the atmosphere, hydrosphere, and lithosphere. Research on this topic is closely linked to global warming because CO_2 released by fossil fuel combustion may lead to significant climate change. In addition to carbon, the cycles of nitrogen, sulfur, phosphorus, silicon, and iron must be investigated further to understand the links between living organisms and terrestrial, oceanic, and atmospheric environments. Knowledge of integrated elemental cycling will greatly enhance our ability to reconstruct paleoenvironments accurately, to model the paleobiogeochemical transfer of elements, and to predict responses to future changes in climate. Furthermore, improved understanding of integrated elemental cycling is required for interpreting anthropogenic influences on natural element cycles.

Modern and Ancient Soils: Their Relationship to Climate

Our knowledge of continental paleoenvironments, including past CO_2 levels, has greatly improved in the past decade through carbon, hydrogen, and oxygen isotope analyses of minerals in soils and paleosols. Concerted effort is needed in mapping the chemical and biological signatures of modern soils and in integrating the agricultural soil database into a geologic framework to characterize modern weathering processes in different climates. Systematic study of chronosequences and climosequences is required to develop an understanding of soil genesis within a climatic framework. Likewise, improved knowledge of soil-forming processes on lithologic substrates is critical to a broad understanding of weathering as a ubiquitous earth surface process. Key priorities include developing, refining, and calibrating the indicators of paleoclimates preserved in soils and obtaining a better understanding of how these indicators are preserved in the rock record.

Further study also is needed in understanding the uptake and release of anthropogenic pollutants, through modern soils, oceans, rivers, and lakes. Large gaps exist in our knowledge of aqueous speciation, exchange, and partitioning of pollutants among solid (mineral, mineraloid, and organic) components in soils and sediments. Assessment of the natural resilience of soils with respect to human perturbations (e.g., deforestation) is critically needed.

Processes at the Mineral-Water Interface

Many of the key questions posed above can be answered only with a mechanistic understanding of reactions at the mineral-water interface. Although advances in surface chemistry, microscopy, and spectroscopic analyses have increased understanding of molecular reaction

mechanisms and rates, applications to geochemical problems and actual field sites are only just beginning. Molecular modeling (computational simulation of molecular interactions) is on the verge of being able to reproduce and predict such reactions. However, comparison of model calculations with analytical and experimental data must become routine in order to increase confidence in the calculated results. Detailed information about structures, compositions, and the properties of mineral surfaces is still needed to understand complex, low-temperature mineralogic systems. How does microscopic variability in composition and crystallographic structure affect surface chemical reactions? What are solid stabilities and reaction kinetics in systems that include organic components and microorganisms? New advances in surface-sensitive spectroscopies, in methods for quantifying solute concentrations and speciation, and in molecular modeling will provide the tools needed. Such advances must be aimed at micro- to nanoscale particles. Examples of new research problems include the roles of microorganisms and extracellular organic species in controlling redox reactions at mineral surfaces, kinetics of isotope exchange reactions pertinent to paleoclimatic studies, and the analysis of samples returned from Mars.

Geochemistry of the Rock Record

Efforts at investigating trends in past climates, marine and terrestrial ecology, ocean chemistry, redox state, and atmospheric composition have relied on our ability to distinguish primary geochemical signals from diagenetic and metamorphic overprints. In recent years, our ability to separate geochemical signatures according to process has improved through the development of high-precision analytical techniques (e.g., laser ablation ICP-MS [inductively coupled plasma–mass spectrometry], ion probes, selective chemical extractions for inorganic and organic compounds) and the applications of new stable isotope techniques. These techniques enhance the sensitivity of spatial resolution of elemental variations within individual phases. Potential benefits will be to understand the movement of geochemical constituents among the lithosphere, hydrosphere, and atmosphere at critical times in Earth's history as related to mass extinctions, the origin and evolution of life, ancient glaciation, past climates, and widespread ocean anoxia. Likewise, new instrumental methods (e.g., multicollector ICP-MS) permit exploratory efforts in the use of new isotope techniques for tracing biogeochemical processes.

Infrastructure, Analytical, and Computational Facilities

In order to strengthen existing research and to implement the new initiative in low-temperature geochemistry and environmental geochemistry, it is necessary to put in place new analytical and computational facilities.

(1) Natural laboratories. The development and long-term maintenance of natural laboratories would facilitate understanding of soil genesis and surface geochemical processes *in every way possible*. Long-term geochemical observatories of soils and weathered rock would be established on sites that cover a range of physical environments (i.e., climate, topography, bedrock, etc.) and biota. We envision these natural laboratories as open scientific resources dedicated to research by individual investigators or small teams of investigators. Site-based research proposals would be solicited from all qualified researchers. Natural laboratories would serve also as an educational resource to students (high school, undergraduate, and graduate). Development of natural laboratories is consistent with the National Science Foundation's (NSF) new Biocomplexity Initiative, which establishes long-term ecological laboratories as part of the National Ecological Observatory Network (NEON, NSF 00-22). The envisioned natural laboratories in soil genesis and geochemistry are a big step toward reaching the goals of this initiative.

(2) Regional instrumentation centers. Regional instrumentation centers (i.e., for instruments costing in the range of $100,000 and higher) should be established. These centers are intended for periodic use by a large number of investigators and could be housed in laboratories already containing other analytical facilities (e.g., X-ray photoelectron spectroscopy, field emission scanning electron microscopy, chromatographic analyses). Technical support must be available to assist users and maintain equipment. Also, improved accessibility to accelerator mass spectrometry (AMS) facilities is needed for measurement of cosmogenic isotopes (^{3}He, ^{10}Be, ^{14}C, ^{21}Ne, ^{26}Al, ^{36}Cl). TIMS (thermal ionization mass spectrometry) and improved multicollector ICP-MS are needed for measurements of stable and radiogenic isotopes.

(3) Computation. One of the forefront areas in geochemical computation is

Opportunities *continued on p. 12*

GSA's 2000 Research Grant Awards

***Leah Carter**, Research Grants and Awards Administrator*

The GSA Committee on Research Grants met in Boulder, Colorado, on April 14–15, 2000, and awarded $399,094 to 245 graduate student applicants. Committee members for 2000 are Allen F. Glazner (Chair), Brian G. Katz, Jim E. O'Connor, James G. Schmitt, Daniel K. Holm, John F. Bratton, Marith Cady Reheis, and Russell C. Kelz (National Science Foundation Conferee).

STUDENT AWARDS

This year, proposals were received from 600 students, of which 245 (41%) were awarded grants. Of these recipients, 118 are master's candidates, 126 are doctoral candidates, and one a postdoctoral fellow. Proposal requests totaled $1,380,749 for an average of $2,301. The average award was $1,622.

Sixteen alternate candidates were selected by the committee in the event that some of the grantees return all or part of their grant funds due to their having changed their research project or receiving funds from another source.

The Committee's budget included $131,050 from the Penrose Endowment and the Pardee Memorial; $130,000 from the National Science Foundation; $7,550 from the Harold T. Stearns Award Fund, the Geophysics Division, the Sedimentary Geology Division, and the Structural Geology and Tectonics Division; and $9,055 from funds returned too late in 1999 and early in 2000 to be re-awarded. The budget also included $121,360 from the GSA Foundation, which included $50,000 from the Research Fund, $48,000 from GEOSTAR and Unrestricted funds, $3,000 from the Lipman Research Fund, and $2,500 from the Hydrogeology Division.

The recipients of student research grants awarded by GSA divisions and sections will be announced in the October issue of *GSA Today.*

OUTSTANDING MENTION

The Committee on Research Grants specially recognized 32 of the proposals as being of exceptionally high merit in conception and presentation:

Alexander P. Bump, University of Arizona, for "Late Cretaceous to Eocene Tectonic Evolution of Five Colorado Plateau Uplifts, Utah and Colorado."

Matthew Hackworth, Louisiana State University, for "Effects of Gas Hydrates on Authigenic Carbonate Precipitation in Hydrocarbon Seep Sediments: Louisiana Continental Slope, Deepwater Gulf of Mexico."

Leigh Justet, University of Nevada—Las Vegas, for "Assessing the Role of Basalt Injection in the Geochemical Evolution of the Jemez Volcanic Field, New Mexico."

Michael Hren, Dartmouth College, for "Distribution of Metals in Stream Sediments in the Fisher Creek Drainage, New World Mining District, Montana."

Karen L. Willey, University of Kansas, for "Modeling the Timing of Erosion and Deposition Events in the Loess Canyons of the Arikaree Breaks, Cheyenne County, Kansas."

Emily H. Onasch, University of California—Santa Barbara, for "The Western Gneiss Region, Norway: A Missing Piece in the Puzzle of Ultrahigh-Pressure Rock Exhumation."

Derek J. Sjostrom, Dartmouth College, for "Characterization of Initial Precipitates in Acid Rock Drainage Environments: Implications for Holocene Paleoclimate Determination Using Stable Isotopes of Geothite."

Heather K. Wood, University of Kansas, for "Strontium Isotopes as Environmental Indicators of Mineral Weathering: A Study of the Interbedded Carbonates and Siliciclastics of the Konza Prairie Long-Term Ecological Research Site, Northeastern Kansas."

Tammy Rittenour, University of Nebraska—Lincoln, for "Late-Pleistocene to Early-Holocene Evolution of the Lower Mississippi River Valley: Fluvial Response to External Forcing."

Hunter J. Hickes, Washington State University, for "Lanai Basalts, a Petrogenetic and Geochemical Study of Anomalous Hawaiian Volcanics."

James W. Funderburk, University of South Florida, for "Modern Variation in Predation Intensity: Constraints on and Implications for Escalation."

Opportunities *continued from p. 11*

the coupling of mass and energy transport with chemical reactions. These fully coupled codes are computationally intensive, and they are recognized both inside and outside academia as important tools for interpreting and predicting geochemical processes. Emphasis should be placed on developing codes and on sharing computer facilities for running the codes. An additional computational approach, highly relevant to low-temperature geochemical problems, is molecular modeling. This tool permits fundamental molecular description of reactions in solutions and at the mineral-water interface. Molecular modeling would have more impact if access to it and use of it by researchers were made possible by: (1) the existence of more shared facilities, (2) increased support for new software and hardware, and (3) training of researchers and students in the use of new software and hardware. It is desirable to increase access of research results by investigators and students. Online project databases increase interest in ongoing research throughout the entire earth science community. Such databases also will enable the individual investigator to address important research problems that were previously out of reach. For example, testing hypotheses relevant to global-scale processes, such as carbon or nitrogen cycling, may take place more readily through acquisition of data from regional project databases available via the World Wide Web.

Summary Remarks

Fundamental research in low-temperature and environmental geochemistry addresses issues critical to the sustainability of life on Earth. This initiative is in line with the recently announced NSF initiatives in Biocomplexity in the Environment (BE) (http://nsf.gov/home/crssprgm/be/) and the new Nanoscale Science and Engineering (NSE) (www.nsf.gov/nano). Results from the new initiative in low-temperature and environmental geochemistry will have major impact on pressing problems such as pollution of water and soil, nutrient supply in relation to global elemental cycles, and fate and transport of inorganic and organic pollutants. This report is a starting point for continued discussion of research directions and priorities. Given the importance of the research priorities, the breadth of topics in low-temperature and environmental geochemistry, and the rapid evolution of geochemical research, subsequent workshops should be convened at three- to five-year intervals to discuss progress, trends, directions, and priorities in low-temperature and environmental geochemistry.

Opportunities *continued on p. 13*

Marwan A. Wartes, University of Wisconsin—Madison, for "Thermochronology of the Chugach and Saint Elias Mountains, Alaska: Examining the Impact of Tectonic Uplift on Climate Change."

Jennifer R. Smith, University of Pennsylvania, for "Climatic and Cultural Change in the Egyptian Sahara."

Aradhna Tripati, University of California—Santa Cruz, for "Tropical Sea Surface Temperature Reconstruction for the Early Paleogene Using Mg/Ca Ratios of Planktonic Foraminifera."

Jason P. Briner, University of Colorado, for "Late Pleistocene Fluctuations of the Northeastern Margin of the Laurentide Ice Sheet, Northeastern Baffin Island."

Ivan C. Higuera-Diaz, Northern Illinois University, for "3-Dimensional Geometry and Kinematics of the Nuncios Detachment Fold Complex in the Sierra Madre Oriental, Monterrey Salient, Mexico."

Elizabeth A. Scott, University of Albany, for "Investigating the Significance of Grain and Phase Boundary Migration in Igneous Crystal-Melt Systems."

Stephen John Piercey, University of British Columbia, for "Petrology, Timing and Tectonic Setting of Volcanogenic Massive Sulfide (VMS) Mineralization in the Finlayson Lake Region, Yukon-Tanana Terrane, Southeastern Yukon Territory, Canada."

Karina Gabrielle Hankins, University of Southern California, for "Paleoecological Changes in Marine Communities across the Triassic-Jurassic Boundary, New York Canyon, Western Nevada."

Mel Strong, Washington State University, for "Chemical and Physical Variations within Scoria Cones, Lassen Volcanic Field, California."

Heather L. Quevedo, University of Iowa, for "A High-Resolution Carbon Isotope Record of Atmospheric CO_2 Increases during the Last Deglaciation from Varved Lake Sediments from the Pequest River Valley, New Jersey."

Douglas Keith Tinkham, University of Alabama, for "Metamorphic History of the Central Nason Terrane, Cascade Core, Washington: The Temporal Relationships between Crustal Loading, High-Temperature Metamorphism, and Plutonism."

Stephanie Kienast, University of British Columbia, for "Unraveling North Pacific Deep Water Composition during the Last Climatic Cycle: Separating Deep Circulation Effects from Imprints of Local Primary Production."

Benjamin J.C. Laabs, Northern Arizona University, for "Evidence and Causes of Quaternary Lake-Level Change in the Bear Lake Valley, Northern Utah and Southern Idaho."

Gary Randolph O'Brien, Northern Arizona University, for "Reevaluation of Lava-Dammed Lake Deposits in the Grand Canyon, Arizona."

Michelle Kearney, University of New Mexico, for "Rates and Pathways of Nitrate Attenuation in the Hyporheic Zone of a First-Order Mountain Stream."

Alexandre D. Castrounis, University of New Mexico, for "Paleomagnetism of Lower Permian Redbeds in Central and North-Central New Mexico and the Kinematics of Deformation along the Eastern Margin of the Colorado Plateau."

Timothy A. Meckel, University of Texas—Austin, for "Stratigraphy and Chronology of Miocene Rift Sediments in Eritrea, East Africa and Their Application to Rift Development and Hominoid Vertebrate Evolution."

Melissa E. Lenczewski, University of Tennessee, for "Biodegradation of Trichloroethylene (TCE) in Fractured Shale Saprolite in East Tennessee."

Robin L. Whatley, University of California—Santa Barbara, for "Comparative Anatomy and Biostratigraphic Placement of a Triassic-Aged Reptile from Southwestern Madagascar."

Greg Stock, University of California—Santa Cruz, for "Geomorphic and Paleoclimatic Implications of Cave Deposits from the Sierra Nevada, California."

Michael Poland, Arizona State University, for "The Mechanism of En Echelon Dike Emplacement."

STUDENT RECIPIENTS OF SPECIAL AWARDS IN 2000

Gretchen L. Blechschmidt Research Award. This award supports research for women interested in achieving a Ph.D. in the geological sciences and a career in academic research. This year's recipient is Aradhna Tripati, University of California—Santa Cruz, for her project "Tropical Sea Surface Temperature Reconstruction for the Early Paleogene Using Mg/Ca Ratios of Planktonic Foraminifera."

Research Grants *continued on p. 14*

Opportunities *continued from p. 12*

Acknowledgments

Financial support for this workshop came from the Geology and Paleontology and the Petrology and Geochemistry programs in the Division of Earth Science, National Science Foundation (EAR-9908454).

Authors and Workshop Participants

Jillian F. Banfield, University of Wisconsin, Madison, WI

Jay L. Banner, University of Texas, Austin, TX

Craig M. Bethke, University of Illinois, Urbana, IL

Joel D. Blum, University of Michigan, Ann Arbor, MI

William H. Casey, University of California, Davis, CA

Oliver A. Chadwick, University of California, Santa Barbara, CA

Carrick M. Eggleston, University of Wyoming, Laramie, WY

W. Crawford Elliott, Convener and report compiler, Georgia State University, Atlanta, GA

Katherine H. Freeman, Pennsylvania State University, State College, PA

Martin B. Goldhaber, U.S. Geological Survey, Boulder, CO

H. Richard Lane, National Science Foundation, Arlington, VA

Timothy W. Lyons, University of Missouri, Columbia, MO

Claudia I. Mora, University of Tennessee, Knoxville, TN

Kathryn L. Nagy, University of Colorado, Boulder, CO

D. Kirk Nordstrom, U.S. Geological Survey, Boulder, CO

Fred M. Phillips, New Mexico Institute of Mining and Technology, Socorro, NM

Christopher S. Romanek, Savannah River Ecology Laboratory, Aiken, SC

Samuel M. Savin, Case Western Reserve University, Cleveland, OH

Garrison Sposito, University of California, Berkeley, CA

Alan T. Stone, Johns Hopkins University, Baltimore, MD

Michael A. Velbel, Michigan State University, East Lansing, MI

Crayton J. Yapp, Southern Methodist University, Dallas, TX

Herman B. Zimmerman, National Science Foundation, Arlington, VA ■

Research Grants *continued from p. 13*

John T. Dillon Alaska Research Award. John T. Dillon was noted for his radiometric dating work in the Brooks Range, the results of which have had a major impact on the geologic understanding of this mountain range. The recipient of this award is Marwan A. Wartes, University of Wisconsin—Madison, for "Thermochronology of the Chugach and Saint Elias Mountains, Alaska: Examining the Impact of Tectonic Uplift on Climate Change."

Robert K. Fahnestock Award. This award honors the memory of Ken Fahnestock, who was a member of the Committee on Research Grants. It is awarded to the applicant with the best proposal in sediment transport or related aspects of fluvial geomorphology. The 2000 recipient is Karen L. Willey, University of Kansas, for "Modeling the Timing of Erosion and Deposition Events in the Loess Canyons of the Arikaree Breaks, Cheyenne County, Kansas."

Lipman Research Award. The Lipman Research Fund is supported by gifts from the Howard and Jean Lipman Foundation to promote and support student research grants in volcanology and petrology. Peter W. Lipman, president of the Lipman Foundation, was the recipient of a GSA research grant in 1965. The 2000 Lipman Award recipient is Leigh Justet, University of Nevada—Las Vegas, for "Assessing the Role of Basalt Injection in the Geochemical Evolution of the Jemez Volcanic Field, New Mexico."

Bruce L. "Biff" Reed Scholarship Award. This award was established in Reed's memory to provide grants to graduate students pursuing studies in the tectonic and magmatic evolution of Alaska primarily, and it also can fund other geologic work in Alaska. This year's recipient is Alison M. Anders, University of Washington, for "Rate and Extent of Chemical Weathering at Bering Glacier, Southeast Alaska, from River Chemistry."

Alexander Sisson Research Award. Family members of Alexander Sisson established a fund in his memory to promote and support research for students pursuing studies in Alaska and the Caribbean. The recipient of the award this year is James W. Funderburk, University of South Florida, for "Modern Variation in Predation Intensity: Constraints on and Implications for Escalation."

Harold T. Stearns Fellowship Award. Harold Stearns established the Harold T. Stearns Fellowship Award in 1973 for student research on aspects of the geology of the Pacific Islands and the Circum-Pacific region. The 2000 recipients are: Hunter J. Hickes, Washington State University, for "Lanai Basalts, A Petrogenetic and Geochemical Study of Anomalous Hawaiian Volcanics;" Douglas Keith Tinkham, University of Alabama, for "Metamorphic History of the Central Nason Terrane, Cascade Core, Washington: The Temporal Relationships between Crustal Loading, High-Temperature Metamorphism, and Plutonism;" Alexander Lee Claypool, University of Vermont, for "Kinematic Evolution of Lower Crustal Shear Zones during the Transition from Collisional Orogenesis to Postorogenic Collapse, Fiordland, New Zealand;" and Valerie M. Monastra, Cornell University, for "Atmospherically Derived Lead Signatures across a Hawaiian Soil Chronosequence."

Bryce Hand Award. The Bryce Hand Research Award is a one-time gift to support research in the field of stratigraphy and/or sedimentology. The 2000 recipient is Timothy A. Meckel, University of Texas—Austin, for "Stratigraphy and Chronology of Miocene Rift Sediments in Eritrea, East Africa and Their Application to Rift Development and Hominoid Vertebrate Evolution."

John Montagne Fund. This fund was established in 1997 to support one recipient's research in the field of quaternary and/or geomorphology. The fund's first award recipient, for 2000, is Jennifer R. Smith, University of Pennsylvania, for "Climatic and Cultural Change in the Egyptian Sahara."

Horace R. Blank, Sr., Bequest. This bequest supports the research grants program in the fields of mineralogy, sedimentology, igneous and metamorphic petrology, and geology. The 2000 recipients are: Alexander P. Bump, University of Arizona, for "Late Cretaceous to Eocene Tectonic Evolution of Five Colorado Plateau Uplifts, Utah and Colorado"; Matthew Hackworth, Louisiana State University, for "Effects of Gas Hydrates on Authigenic Carbonate Precipitation in Hydrocarbon Seep Sediments: Louisiana Continental Slope, Deepwater Gulf of Mexico"; Michael Hren, Dartmouth College, for "Distribution of Metals in Stream Sediments in the Fisher Creek Drainage, New World Mining District, Montana"; Emily H. Onasch, University of California—Santa Barbara, for "The Western Gneiss Region, Norway: A Missing Piece in the Puzzle of Ultrahigh-Pressure Rock Exhumation"; Derek J. Sjostrom, Dartmouth College, for "Characterization of Initial Precipitates in Acid Rock Drainage Environments: Implications for Holocene Paleoclimate Determination Using Stable Isotopes of Geothite"; Heather K. Wood, University of Kansas, for "Strontium Isotopes as Environmental Indicators of Mineral Weathering: A Study of the Interbedded Carbonates and Siliciclastics of the Konza Prairie Long-Term Ecological Research Site, northeastern Kansas"; Elizabeth A. Scott, University of Albany, for "Investigating the Significance of Grain and Phase Boundary Migration in Igneous Crystal-Melt Systems"; Mel Strong, Washington State University, for "Chemical and Physical Variations within Scoria Cones, Lassen Volcanic Field, California"; Michael Poland, Arizona State University, for "The Mechanism of En Echelon Dike Emplacement"; Zachary J. Davis, State University of New York at Stony Brook, for "Lithic Resource Exploitation Strategies during the Upper Pleistocene in the Western Cape Province, South Africa"; Emmanuelle Arnaud, McMaster University, for "Sedimentological Evidence for a Snowball Earth"; David Dolejs, McGill University, for "Phase Relationships in Fluorine-Bearing Granitic Magmas: Experimental Study Using High-Pressure Differential Thermal Analysis"; Alan Edward Koenig, Colorado State University, for "Major and Trace Element Zoning and Sm-Nd Dating of Polymetamorphic Garnets: The Boehls Butte–Goat Mountain Metamorphic Complex, Northern Idaho"; Tara M. Curtin, University of Arizona, for "Seasonal Climate Signals Preserved in Laminated Lacustrine Rocks in Triassic Lake Ischichuca in the Ischigualasto Basin, Northwest Argentina"; Richard John Fink, Louisiana State University, for "Late Cretaceous–Paleogene Tectonic Evolution of the Central Andes Based on the Stratigraphic Record of the Altiplano and Eastern Cordillera, Bolivia"; Margaret E. McMillan, University of Wyoming, for "Late Cenozoic Exhumation of the Central Rocky Mountains"; Natalie C. Caciagli, University of California—Los Angeles, for "Effects of Fluid-Flux at High Pressures: Implications for the Geochemistry of High-Grade Metamorphic

COLE AWARDS FOR POSTDOCTORAL RESEARCH

Joel L. Pederson, Utah State University, was awarded the Gladys W. Cole Memorial Research Award for $11,500 for 2000 to support his project "Quaternary Incision and Geomorphic Evolution of Eastern Grand Canyon." This award is restricted to support research for the investigation of the geomorphology of semiarid and arid terrains in the United States and Mexico.

The W. Storrs Cole Memorial Research Award, which is restricted to support research in invertebrate micropaleontology, was not awarded in 2000 due to the lack of qualified applications.

Eligibility for both Cole awards is restricted to GSA Members and Fellows between 30 and 65 years of age.

Rocks"; Elizabeth Ruth Goeke, Indiana University, for "Metamorphic Overprinting: Influence of Alleghanian Metamorphism on Acadian Rocks of the Bronson Hill Terrane"; Ryan Zane Taylor, University of North Carolina—Chapel Hill, for "May Lake Interpluton Screen and its Bearing on Pluton Emplacement"; Elizabeth Pendleton, Boston University, for "Decadal Changes in Backbarrier Region of a Newly Formed Inlet in Response to an Increase in Hydraulic Regime, New Inlet, Cape Cod, Massachusetts"; Jorge Vazquez, University of California—Los Angeles, for "Constraining the Accumulation and Differentiation History of the Youngest Toba Tuff Magma Reservoir by Combining Mineral and Melt Inclusion Composition with Ion Microprobe Dating"; and Jonathan Guy Wynn, University of Oregon, for "Neogene Paleosols of the Hominoid-Bearing Samburu Hills, Northern Kenya."

OTHER SUCCESSFUL APPLICANTS

Other applicants recommended for funding are the following:

Stephen Ahlgren
Nadir Akpulat
Simone Alin
Stephen Allard
Nicholas Allmendinger
Lorin Amidon
Lee Amoroso
Gunilla Andreasson
Richard Ashmore
Gregory Bank
Rich Barclay
Soyini Baten
Claire Beaney
Paul Bedrosian
Christopher Berg
Matthias Bernet
Karen Bezusko
Paul Bigelow
Warren Bigelow
Eric Bilderback
Martin Bizzarro
Sarah Boon
Benjamin Bostick
Andrew Bowman
Rich Briggs
Rosalice Buehrer
Emily Burns
Sande Burr
Peter Buscemi
Andery Calkins
Deirdra Cantrell
Donna Carlson
Robert Carpenter
Tracey Carpenter
Eric Carson
Amy Carter
Brad Carter
Britt Cartwright-Kass
Peter Castiglia
Alice Chang
Mary Cheversia
Dave Clement
Angela Coleman
Joseph Colgan
Melissa Connely
Sean Cornell
Celeste Cosby
Samuel Coyner
Matthew Dalessio
Julia Daly
Ann Dansart
Carlos David
Gregory Dietl
Amanda Diulio
Amy Dougherty
Martin Doyle
David Dufeau
Eric Eddlemon
Martha Eppes
Adrian Ezeagu
Leigh Fall
Dan Ferdinand Fernandez
Manual Filgueira-Rivera
Mara Finkelstein
Seth Finnegan
Duane Froese
Sarah Gaddis
William Garcia
Geoffrey Garrison
Tim Gere
Scott Grasse
Phyllis Gregoire
Melissa Hicks
Barbara Hill
Joseph Hill
Heidi Hoffower
Christopher Holm
Robyn Howley
Chad Hults
Brenda Hunda
Sonja Ingram
Sara James
Marcia Jensen
Benjamin Johnson
Cari Johnson
Heather Jones
Shelley Judge
Alice Kelley
Susan Kelly
Michael Kerr
Lowell Kessel
Markus Kienast
Matthew Kirby
James Klaus
Richard Krause
Lori Krikorian
Nathan Kuhle
Sanghoon Kwon
Toti Larson
Peter Lask
Joel Le Calvez
Ellen Leavitt
Nancy Leawood
Varner Leggitt
Katherine Leonard
Elisabeth Levac
Laura Levy
Ian Lunt
Eugene MacDonald
Christopher Madden
Aaron Mango
Bryan Mark
Jefffrey Markle
Cynthia Martinez
James McCaughey
Daniel McCrumb
Daniel Michaud
Karen Michelsen
Leslie Mikesell
Daniel Morris
Christopher Moses
Stephen Moss
Christopher Moy
Jordan Muller
Jeffrey Munroe
Stephen Nathan
Mike Nicholis
Christopher Oze
Sean Pack
Darrin Pagnac
Yucheng Pan
William Parcell
William Parker
Kari Parson
Panagiota Passinos
Justin Pearce
Karin Peyer
Shaili Pfeiffer
William Phelps
Andrew Pitner
David Porinchu
Rebecca Price
Sarah Principato
Steven Quane
Margaret Quinn
Alexander Raab
J. Elmo Rawling III
Joanna Redwine
Jason Reed
Sarah Rieboldt
Holly Riffe
Michelle Roberts
Delores Robinson
Wilfredo Rosado
Harold Rowe
Martin Roy
Michael Rutter
Martin Saar
Steve Sahetapy-Engel
Karen Samonds
Jill Savage
Ilsa Schiefelbein
Adam Schoonmaker
Tim Schroeder
Jeffrey Schwartz
Nathan Sheldon
Mona-Liza Sirbescu
Kevin Smith
Michael Smith
Sara Smith
Darin Snyder
Jennifer Starr
Caroline Stromberg
James Sutherland
Mark Sweeney
Alexander Tate
Diana Thiel
Anna Thompson
Anne Tillery
J. Michael Timmons
Eric Tohver
Wooyong Um
Gerald Unterreiner
Jennifer Unterschutz
Natalie Uschner
Christopher Van De Ven
Stefan Vogel
Kristoffer Walker
Colin Walling
Honshan Wang
Andrew Webber
Paul Wetmore
Scott Wilkins
Trudy Wohlleben
Yongjun Yue
Brent Zaprowski
Haibo Zou ■

Earth Science Week 2000

Bound in this issue is the American Geological Institute's (AGI) Earth Science Week 2000 poster. Earth Science Week provides a focal point for public education about Earth and earth processes.

For ideas on how to participate, visit GSA's Web site at www.geosociety.org. The Society of Exploration Geophysicists also maintains an Earth Science Week site at http://students.seg.org/EarthScienceWeek/ and provides slide sets for presentation to K–12 classes. AGI's site at www.earthsciweek.org provides ideas, activities, and information about a kit of Earth Science Week materials. Single copies of the kit are free. Visit the Web site or contact Julie Jackson at AGI, 4220 King St., Alexandria, VA 22302, jjackson@agiweb.org, (703) 379-2480.

Preliminary Announcement and Call for Papers

NORTHEASTERN SECTION, GSA 36th Annual Meeting

Burlington, Vermont, March 12–14, 2001

REGISTRATION

Preregistration Deadline:
Friday, February 2, 2001
Cancellation Deadline:
Friday, February 9, 2001

GSA Headquarters will handle preregistration. Registration details will be in the December 2000 issue of *GSA Today* and at www.geosociety.org. You will be able to preregister online at www.geosociety.org in December.

The Northeastern Section is committed to making every event at the 2001 meeting accessible to all persons interested in attending. Please indicate any special requirements on the meeting registration form, or contact conference general chair, Tracy Rushmer. (See Detailed Information.)

CALL FOR PAPERS

Papers are invited from students and professionals for presentation in oral and poster general sessions and for presentations that may fit into the symposia and theme sessions listed below. Additional general discipline sessions will be scheduled on the basis of submitted abstracts. Oral technical sessions and symposia provide 15 minutes for presentation and five minutes for questions and discussion. All slides must fit a standard 35-mm carousel tray. Two projectors will be provided in each of the technical sessions. Speakers are encouraged to bring their own loaded tray to the meeting. Poster sessions will allow at least three hours of display time.

ABSTRACTS

Abstracts Deadline:
December 5, 2000

Abstracts for all sessions must be submitted online at the GSA Web site. Please see article announcing GSA's new electronic abstracts submittal system on page 17 of this issue. If you have questions, contact Andrea Lini, (802) 656-0245, alini@zoo.uvm.edu.

Only one volunteered paper may be presented by an individual; however a person may be a coauthor on other papers. Also, those invited for symposia may present additional papers.

SYMPOSIA

Symposia will include invited papers and selected volunteered papers. Prospective authors are encouraged to contact individual conveners directly. Address requests for general information regarding symposia to Tracy Rushmer, or Andrea Lini. (See Detailed Information.)

1. Caledonian Magmatism: Cross-Atlantic Connections. John Hogan, (573) 341-4618, jhogan@umr.edu; Calvin G. Barnes, (806) 742-3106, Cal.Barnes@ttu.edu; Øystein Nordgulen, oystein.nordgulen@ngu.no; A.K. Sinha, pitlab@vt.edu.
2. Fault Zone Evolution and Convergent Tectonics: A Symposium in Honor of Rolfe Stanley. Keith Klepeis, (802) 656-0246, kklepeis@zoo.uvm.edu.
3. Glacial Processes in New England: A Symposium in Honor of Fred Larsen. Stephen Wright, (802) 656-4479, swright@zoo.uvm.edu.
4. Multidisciplinary Research Topics: Lake Champlain Basin. Pat Manley, (802) 443-5430, manley@middlebury.edu; Tom Manley, (802) 443-3114, tmanley@middlebury.edu.
5. Thermochronology from Apatite to Monazite: Deciphering Polymetamorphic Terranes. Mary Roden-Tice, (518) 564-4032, mary.rodentice@plattsburgh.edu; Bob Wintsch, (812) 855-4018, wintsch@indiana.edu.
6. Environmental Records from Large Estuaries Along the Northeastern U.S. Seaboard. Johan C. Varekamp and Ellen Taylor, (860) 685-2248, jvarekamp@wesleyan.edu.
7. Early and Middle Paleozoic Sequence Stratigraphy—Tectonic and Eustatic Signatures in Eastern Laurentia. Ed Landing, (518) 474-5816, elanding@mail.nysed.gov; Carlton E. Brett, (513) 556-4556, brettce@email.uc.edu.

THEME SESSIONS

1. Terrestrial Records of Late Pleistocene and Holocene Climate Change. Paul Bierman, (802) 656-4411, pbierman@zoo.uvm.edu.
2. Paleolimnological Records of Holocene Climate Change. Andrea Lini, (802) 656-0245, alini@zoo.uvm.edu; Mark Abbot, (413) 545-0229, mabbott@geo.umass.edu.
3. Slope Stability in New England Environments. Kyle Nichols, (802) 656-3398, knichols@zoo.uvm.edu; Paul Bierman, (802) 656-4411, pbierman@zoo.uvm.edu.
4. Deformation, Metamorphism, and Melting: Interactions in the Crust. Tracy Rushmer, (802) 656-8136, trushmer@zoo.uvm.edu; Gayle Gleason, (207) 872-3248, gleasong@cortland.edu; Mike Brown, mbrown@geol.umd.edu.
5. Geologic Evolution of the Northern Appalachians. Barry Doolan, (802) 656-0248, bdoolan@zoo.uvm.edu.
6. Carbonate Geology with a Focus on the Trenton-Black River and Beekmantown. Gerald Friedman, (518) 273-3247.
7. Geologic Aspects of Environmental Problems in the Northeast. Jamie

Shanley, (802) 828-4466, jshanley@usgs.gov; Scott W. Bailey, (603) 726-8902, swbailey@fs.fed.us.
8. Paleoecology and Paleobiology of Oxygen Controlled Faunas. (*Sponsored by the Paleontological Society.*) Christopher McRoberts, mcroberts@cortland.edu; David Lehmann, lehmann@juniata.com.
9. K–12 Education: Earth and Environmental Science. Christine Massey, (802) 656-1344, cmassey@zoo.uvm.edu.

DEDICATED POSTER SESSION

Results from the Bedrock Vermont State Map Project

SHORT COURSES

Both short courses will be held in Perkins Hall, Computer Laboratory, University of Vermont.

Sunday, March 11
System Dynamic Modeling of Natural Environments: An Introduction to Stella. Al Cassell, School of Natural Resources, Jim Hoffman, Dept. of Botany, and Jack Drake, Dept. of Geology, University of Vermont. Please contact leaders for course specifics and requirements.

Monday evening (6:00–9:00 p.m.), March 12
Thermodynamic Modeling of Mineral Reactions: An Introduction to GIBBs. Frank Spear, Rensselaer Polytechnic Insitute, Troy, NY.

FIELD TRIPS

Trips planned at this time are listed below. The trips will run depending on weather.

Saturday, March 10. The Stanley Outcrops. Leaders: Barry Doolan and Keith Klepeis.

Sunday, March 11. Teaching Hydrology in the Winter, a Hands-On Field Trip. Leaders: Paul Bierman and Kyle Nichols.

Sunday, March 11, and Tuesday, March 13. The Champlain Thrust at Lone Rock Point. Leaders: University of Vermont staff, (2–3 hour trip, morning or afternoon).

Monday, March 12, and Wednesday, March 14. The Salmon Hole–Redstone Quarry. Leaders: University of Vermont Staff, (2–3 hour trip, morning or afternoon).

STUDENT TRAVEL GRANTS

The Northeastern Section is giving travel grants to students who are presenting papers at the Burlington meeting. The section is providing $3,000 which will be matched with $2,000 by the GSA Foundation making an aggregate fund of $5,000. The awards are open to both graduate and undergraduate students. To apply, please contact Kenneth N. Weaver, Secretary-Treasurer, GSA Northeastern Section, 2300 St. Paul Street, Baltimore, MD 21218, (410) 554-5532, fax 410-554-5502, kweaver438@aol.com.

The Northeastern Section also announces availability of undergraduate research grants: Students in the Northeastern Section who are juniors in the 2000–2001 academic year are eligible to apply for a research grant from Ken Weaver. Applications are available at the above address, and the deadline for completed applications is February 12, 2001.

EXHIBITS

Exhibits will be located in the Champlain Room of the Sheraton Convention Center. Snacks and refreshments will be continuously available for exhibit visitors. The cost of standard booths will be $250 for commercial exhibitors and $125 for educational or nonprofit groups or institutions. For further information and space reservations, contact Exhibits Coordinator Andrea Lini, Dept. of Geology, Perkins Geology Hall, University of Vermont, Burlington, VT 05405, (802) 656-0245.

DETAILED INFORMATION

For further information, see www.geosociety.org or contact General Chair Tracy Rushmer, Department of Geology, University of Vermont, Burlington, VT 05405, (802) 656-8136, trushmer@zoo.uvm.edu, or Andrea Lini, Technical Program Chair, Department of Geology, University of Vermont, Burlington, VT 05405, (802) 656-0245, alini@zoo.uvm.edu. ■

New Abstracts System: Appearing Live!

GSA is introducing a new abstracts management system based on the same software used by the American Association of Petroleum Geologists and the American Chemical Society. This software offers many improvements over our previous system and promises to make the entire process of submitting abstracts easier for authors.

"The new abstracts system is now 'live' and can be accessed from our home page at www.geosociety.org," says Nancy Carlson, GSA's abstracts program coordinator. "Those submitting abstracts for the upcoming section meetings can use the system, and in fact, calls for papers for all section meetings, which are published on our Web site, serve as convenient portals into the new abstract system."

Here are a few advantages to the new system:

- Lost connection? No problem. With this new system, authors can resume making a submission if they lose their Internet connection before they are finished.
- Inspect, revise, and tweak away. Authors can immediately inspect their submissions online, and they can revise their password-protected abstracts as necessary up until the published abstract submission deadline date.
- Collaboration encouraged. Each author and coauthor is provided (by e-mail) with a permanent record of the abstract identification number and password, and abstracts can be accessed from any Internet connection, making collaborative authoring more convenient.
- Special characters welcome. The new system supports the submission of complex abstracts that contain subscripts, superscripts, italic and boldface type, tables, Greek letters, and equations.

"We believe that most authors compose their abstracts in Microsoft Word or WordPerfect, and we encourage them to use these word processing programs for layout and to check spelling," says Carlson. "These programs—and most other new versions of other word-processing programs—also allow a file to be saved in HTML format. Authors will be instructed to take advantage of that 'File–Save As' feature to submit any complex content. This system of supporting both text and HTML submission has been extensively tested by authors around the world during the past three years, and we are confident that our members will be pleased with the new abstracts system."

Step-by-step instructions along the way will help with any questions you may have about using the system. After submitting your abstract, please feel free to contact Nancy Carlson at ncarlson@geosociety.org and share your thoughts and your experiences using the new system.

SOUTHEASTERN SECTION, GSA 50th Annual Meeting

Raleigh, North Carolina, April 5–6, 2001

The Department of Marine, Earth, and Atmospheric Sciences at North Carolina State University, in conjunction with the North Carolina Geological Survey, will host the 50th Annual Meeting of the Southeastern Section of the Geological Society of America. The meeting is scheduled for Thursday and Friday, April 5–6, 2001.

HEADQUARTERS, ACCOMMODATIONS, AND REGISTRATION

Preregistration Deadline:
February 23, 2001
Cancellation Deadline:
March 2, 2001

The meeting headquarters will be the Sheraton Capital Center Hotel in downtown Raleigh and the adjoining meeting facilities on the third floor of the Hannover Tower. A block of rooms is reserved for GSA at the Sheraton, and alternate accommodations are also available. Details will be found in the December issue of *GSA Today*, and also at www.geosociety.org.

Please preregister to qualify for lower fees and to assist the local committee in their planning and preparation. Online preregistration is strongly encouraged and may be accomplished through the GSA Web site at www.geosociety.org; a hard copy registration form will be included with the Final Announcement in the December issue of *GSA Today*, or may be downloaded as a pdf file from the GSA Web site.

ABSTRACTS

Abstract deadline: January 2, 2001

Abstracts for all sessions must be submitted online at the GSA Web site. Please see the article announcing GSA's new electronic abstracts submittal system on page 17 of this issue. If you have questions, contact Edward F. (Skip) Stoddard, (919) 515-7939, skip_stoddard@ncsu.edu.

Only one volunteered paper may be presented by an individual; however a person may be a coauthor on other papers. Also, those invited for symposia may present additional papers.

SYMPOSIA

If you would like to propose an additional symposium, please contact Ron Fodor, North Carolina State University, rfodor@ncsu.edu, (919) 515-7177.

1. 50th Anniversary Symposium: History of Geology in the Southeastern Section. *(Sponsored by the SEGSA Education Committee and the History of Geology Division.)* Gail Russell, University of Southern Mississippi, Gail.Russell@usm.edu, (601) 266-4077; Heather Macdonald, College of William and Mary; Bob Hatcher, University of Tennessee, Knoxville, and Oak Ridge National Lab; and Bill Thomas, University of Kentucky.
2. Groundwater Conditions in Coastal Aquifer Systems: Past, Present, and Future. Richard Spruill, East Carolina University, spruillr@mail.ecu.edu, (252) 328-4399.
3. Cenozoic Evolution of the Appalachian Orogen. Jim Knapp, University of South Carolina, knapp@geol.sc.edu, (803) 777-6886; Ray Christopher, Clemson University; and Dave Prowell, U.S. Geological Survey.
4. Advances in Geochronology and Thermochronology in the Appalachian Orogen. Brent Miller, University of North Carolina, Chapel Hill, bvmiller@email.unc.edu, (919) 962-6583; and Scott Samson, Syracuse University.
5. Great Ideas in Teaching Geoscience, K–16. *(Cosponsored by SE Section NAGT* and the *SEGSA Education Committee.)* Michael Gibson, University of Tennessee—Martin, mgibson@utm.edu, (901) 587-7435; and David Kopaska-Merkel, Geological Survey of Alabama.
6. Earth Science in the High School Curriculum. *(Cosponsored by SEGSA Education Committee* and the *SE Section NAGT.)* Charles Gardner and Mary Watson, North Carolina Geological Survey, Charles.Gardner@ncmail.net, (919) 733-3833.
7. Atlantic Coastal Plain Geology: A Symposium in Honor of Gerald H. Johnson. Heather Macdonald, College of William and Mary, rhmacd@mail.wm.edu, (757) 221-2443; and Scott Harris, Coastal Carolina University.
8. Beach Nourishment: The Wave of the Future for Erosion Control. Bill Cleary, University of North Carolina, Wilmington, clearyw@uncwil.edu, (910) 256-3721, ext. 251; and Orrin Pilkey, Duke University.
9. Terrane Boundaries and Paleosubduction Zones in the Inner Piedmont and Blue Ridge: Where Are They, What Is Their History? Calvin Miller, Vanderbilt University, millercf@ctrvax.vanderbilt.edu, (615) 322-2232; and Bob Hatcher, University of Tennessee, Knoxville, and Oak Ridge National Lab.

THEME SESSIONS

If you would like to propose an additional theme session, please contact Ron Fodor, North Carolina State University, rfodor@ncsu.edu, (919) 515-7177.

1. Geologic Maps and Digital Geologic Maps. Ralph F. Crawford and Michael W. Higgins, Applied Mapping Systems, Inc., mhiggins@mindspring.com, (770) 641-1268. POSTERS ONLY
2. The Stratigraphy of the Southeastern Atlantic Coastal Plain: A Poster Session with Core Samples. Kathleen Farrell, North Carolina Geological Survey, Kathleen.Farrell@ncmail.net, (919) 733-2423; and Bill Harris, University of North Carolina, Wilmington. POSTERS ONLY
3. Triassic Basins of the Southeastern United States. *(Sponsored by the SE Section SEPM.)* Paul Thayer, University of North Carolina, Wilmington, Thayer@uncwil.edu, (910) 962-3780; and Dan Textoris, University of North Carolina, Chapel Hill.
4. Engineering and Environmental Geology. *(Sponsored by Engineering Geology Division.)* Charles Welby, North Carolina State University, cwwelby@unity.ncsu.edu, (919) 515-7158.
5. Great Ideas in Teaching Geoscience, K–16. *(Cosponsored by SE Section NAGT* and the *SEGSA Education Committee.)* Lynne Gronback, McDougle Middle School, Chapel Hill, Lgronback@mindspring.com, (919) 644-2681. POSTERS ONLY
6. Geologic Linkages between Land and Sea: Estuarine Sediment Dynamics and Deposits. Clark Alexander, Skidaway Institute of Oceanography, clark@skio.peachnet.edu, (912) 598-2329; and John Wells, University of North Carolina, Chapel Hill.
7. Hard Rock Hydrogeology: The Occurrence and Movement of Ground Water in the Southern Appalachian Blue Ridge and Piedmont. Matt Heller, North Carolina Ground Water Section, Matt.Heller@ncmail.net, (704) 663-1699; Barbara Christian, North Carolina Ground Water Section; and Charles Daniel, U.S. Geological Survey.
8. Brittle Faulting in the Carolinas. Jack Garihan, Furman University, Jack.Garihan@furman.edu, (864) 294-2052; and Bill Clendenin, South Carolina Geological Survey.
9. Granitoid Plutons, Rocks, and Minerals. Loren Raymond, Appalachian State University, raymondla@appstate.edu, (828) 262-2749; and Sam Swanson, University of Georgia.
10. Undergraduate Research. *(Sponsored by the Council for Undergraduate*

Research.) POSTERS ONLY

FIELD TRIPS

For information concerning scheduled field trips, please contact Bill Hoffman, North Carolina Geological Survey, Bill.Hoffman@ncmail.net, (919) 733-7353, ext. 25.

1. Framing the Piedmont Zone in North Carolina and Southern Virginia. Jim Hibbard, North Carolina State University, jhibbard@ncsu.edu, (919) 515-7242; Kevin Stewart, University of North Carolina, Chapel Hill; and Bill Henika, Virginia Department of Mines, Minerals and Energy, and Virginia Tech.
2. Coastal Processes, Modern Habitats, and Evolution of the Cape Lookout Cuspate Foreland. Steve Snyder, North Carolina State University, sws@ncsu.edu, (919) 515-7912; and John Wells, University of North Carolina, Chapel Hill.
3. A Temporal View of Terranes and Structures in the Eastern North Carolina Piedmont. Dave Blake, University of North Carolina, Wilmington, blaked@uncwil.edu, (910) 962-3387; Tyler Clark, North Carolina Geological Survey; and Matt Heller, North Carolina Ground Water Section.
4. The Tate-Marble Hill Window in the Marble Belt of Northern Georgia. Mike Higgins, Applied Mapping Systems, Inc., mhiggins@mindspring.com, (770) 641-1268; Ralph Crawford, Applied Mapping Systems, Inc.; Tim La Tour, Georgia State University; W. Grant, Applied Mapping Systems, Inc.; M. Linkous, J.M. Huber Corp.; Tonya Edwards, Georgia State University; and John Costello.
5. Depositional and Structural Framework of Early Mesozoic Basins in North-Central North Carolina. *(Sponsored by SE Section SEPM.)* Tyler Clark, North Carolina Geological Survey, Tyler.Clark@ncmail.net, (919) 733-2423; Pamela Gore, Georgia Perimeter College. Note: Trips 5 and 6 will run on consecutive days.
6. Structural Features Exposed in Triassic Sedimentary Rocks near the Proposed Low-Level Radioactive Waste Disposal Site, Southwestern Wake County, North Carolina. *(Sponsored by Engineering Geology Division.)* Rick Wooten, North Carolina Geological Survey, Rick.Wooten@ncmail.net, (919) 733-2423; and Jerry Bartholomew, University of South Carolina. Note: Trips 5 and 6 will run on consecutive days.
7. Stratigraphy and Tectonics of the Central and Western Blue Ridge, Western North Carolina and Eastern Tennessee. Mark Carter and Carl Merschat, North Carolina Geological Survey, Mark.Carter@ncmail.net, (828) 251-6208.
8. Building Stone Walking Tour of Downtown Raleigh. *(Sponsored by SE Section NAGT and SEGSA Education Committee.)* Leader: Al Carpenter, North Carolina Geological Survey (Retired); Contact: Tyler Clark, Tyler.Clark@ncmail.net, (919) 733-2423.
9. A North-South Transect of the Goochland Terrane and Associated A-type Granites, Virginia and North Carolina. Stewart Farrar, Eastern Kentucky University, glyfarra@acs.eku.edu, (606) 662-1279; and Brent Owens, College of William and Mary.
10. Cape Fear River Transect: The Cretaceous Cape Fear and Black Creek Formations of Southeastern North Carolina, and the Overlying Tertiary Section. *(Sponsored by SE Section SEPM and Paleontological Society.)* Kathleen Farrell, North Carolina Geological Survey, Kathleen.Farrell@ncmail.net, (919) 733-2423; Lauck Ward, Virginia Museum of Natural History; and Duncan Heron, Duke University.
11. Inquiry-Based Field Trip to Outstanding Geological Sites in the Triangle. For all educators, especially secondary. (*Sponsored by SE Section NAGT, NCSTA, and SEGSA Education Committee.)* Lynne Gronback; Rob Greenberg; Reuben Giral, McDougle Middle School, Chapel Hill, Lgronback@mindspring.com, (919) 644-2681; and Mary Watson, North Carolina Geological Survey.

STUDENT TRAVEL GRANTS

The Southeastern Section is giving travel grants to students who are presenting papers at the meeting. All eligible students will receive some support, the amount depending on the number of applicants. The application form can be found at www.geology.ecu.edu/geology/segsa/travel.html. Applications must be postmarked no later than March 1, 2001. Additional information may be obtained from Donald Neal, (252) 328-4392, neald@mail.ecu.edu.

WORKSHOP (for educators, grades 6–12)

Earth Science–Environmental Science Education Workshop—Meeting the New North Carolina Teaching Standards. Staff of The Science House, North Carolina State University, Science_House@ncsu.edu, (919) 515-6118.

EXHIBITS

Exhibitor space will be available in a ballroom adjacent to the poster sessions and in other meeting rooms on the main floor of the hotel. For information, contact skip_stoddard@ncsu.edu.

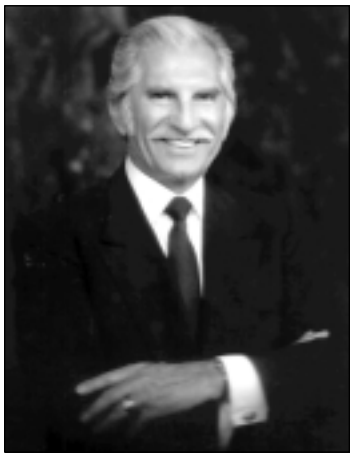
DETAILED INFORMATION

For more information, contact the general chair, Edward F. (Skip) Stoddard, Department of MEAS, North Carolina State University, Raleigh, NC 27695-8208, skip_stoddard@ncsu.edu, (919) 515-7939, see the GSA Web site at www.geosociety.org, or see the Southeastern Section's Web site at www.geology.ecu.edu/geology/segsa/segsa.html. You may request a printout of the announcement from GSA Meetings, P.O. Box 9140, Boulder, CO 80301-9140 or (303) 447-2020, ext. 113. ■

GSA FOUNDATION UPDATE

***Donna Russell**, Director of Annual Giving*

Halbouty Fund for Distinguished Lecturer Established



Michel T. Halbouty

The Foundation is pleased to announce the establishment of the Michel T. Halbouty Distinguished Lecturer Fund. The intent of the fund is to provide an honorarium for a Halbouty Distinguished Lecturer at GSA annual meetings. The first lecturer will be honored at the Reno meeting this fall.

Halbouty is an internationally renowned earth scientist and engineer whose career and accomplishments in the fields of geology and petroleum engineering have earned him recognition as one of the world's outstanding geoscientists.

Born in 1909 in Beaumont, Texas, he earned his B.S. in geology, an M.S. in geology and petroleum engineering, and his professional geological engineering degree from Texas A&M University. He also received a Doctor of Engineering (hc) degree from Montana College of Science and Technology, as well as a Doctor of Geoscience (hc) degree from the U.S.S.R. Academy of Sciences. The University of Nanjing, People's Republic of China, presented him with an honorary professorship in geology.

Halbouty began his career as a geologist and petroleum engineer with an independent oil company, and later as a consultant, before becoming chairman of the Michel T. Halbouty Energy Company in Houston. Throughout his career, he has been engaged in the exploration for and production of oil and gas. Widely recognized as one of the world's foremost geologists and petroleum engineers, he is acclaimed for his scientific expertise.

He is the author of more than 300 articles on geology and petroleum engineering, including several books on petroleum for encyclopedias. Many of his papers have been translated into Spanish, Russian, Chinese, and German.

Halbouty is a member of the National Academy of Engineering as well as many worldwide professional and technical societies, including the American Association of Petroleum Geologists, where he is a past president; the Geophysical Society; GSA, where he is a fellow; the American Institute of Mining, Metallurgical and Petroleum Engineers (AIME), and the Society of Petroleum Engineers of AIME, to name a few. Halbouty was also one of the founding trustees when the GSA Foundation was established in the early 1980s. He has served on GSA's Committee on Committees, Committee on Investments, and the Centennial Development Committee, was honorary chair of the Second Century Fund Committee, and in 1993 received GSA's Distinguished Service Award.

Halbouty was the first independent to explore and wildcat in Alaska. He discovered the West Fork Gas Field on the Kenai Peninsula in 1959, the first discovery by an independent in Alaska.

He chaired President Reagan's Energy Policy Advisor Task Force and was later appointed leader of the Transition Team on Energy by the president. During the past 40 years, he has been appointed to many governmental, energy-related committees and commissions, and has given much of his time and expertise to ensure energy sufficiency for America and the world. Recognized as the perennial wildcatter, he is exceptionally active and, despite his age, is in the Halbouty Energy Center office every day overseeing his wildcatting ventures.

"Michel Halbouty has had a remarkably long, effective, and illustrious career in the field of energy resources," Foundation Trustee Gordon Eaton said. "He has always held deep concern for all of this nation's natural resources, and it is this abiding concern for our country that led him to create this distinguished lectureship on the subject." ■

LETTER

GSA Today's "Toward a Stewardship of the Global Commons" series has been excellent, particularly A.R. Palmer's contributions on the issue of sustainability. His article, "Ecological Footprints and Carrying Capacity: Measuring Our Impact" (*GSA Today*, vol. 10, no. 6), was the best and most succinct treatment of the problem that I have seen in print. However, that article (like all of the others I have seen) neglected to address the ecological impacts of our groundwater extraction that supports our lavish life style.

Generally speaking, our extraction of groundwater is comparable to our mining of fossil fuels, with some of the similar repercussions (e.g., subsidence). Unfortunately, the ecological ramifications of groundwater mining just now are being recognized but the damage hasn't been quantified. There aren't even any estimates of the extent of the damage. For example, it is simple to measure the land-surface extent of an agricultural field, but determining the acreage of wetland ecosystems that may have been destroyed beyond the boundary of that field due to center-pivot irrigation with groundwater is much more difficult. This is the subsurface extent of our impact. In recent publications, I have provided a brief description of the nature of this problem in the southeastern Coastal Plain and discussed the technical constraints of detecting this damage (Bacchus, 2000; Bacchus et al., 2000). However, I have not discussed the problem in terms of our "ecological footprint." The problem is not confined to the southeastern Coastal Plain. I hope future articles on this topic will address both the surface and subsurface extent of our ecological footprint.

References Cited

Bacchus, S.T., 2000, Uncalculated impacts of unsustainable aquifer yield including evidence of subsurface interbasin flow: Journal of American Water Resources Association, v. 36, no. 3, p. 457–481.

Bacchus, S.T., Hamazaki, T., Britton, I.O., and Haines, B.L., 2000, Soluble sugar composition of pond cypress: A potential hydroecological indicator of groundwater perturbations: Journal of American Water Resources Association, v. 36, no. 1, p. 1–11.

Sydney T. Bacchus
Institute of Ecology
University of Georgia
Athens, GA 30602-2202

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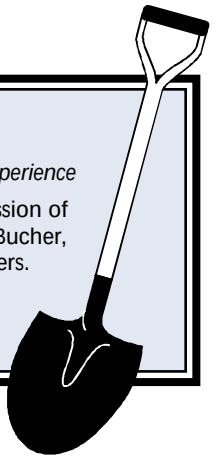
Digging Up the Past

Most memorable early geologic experience

"In 1954, listening in on a discussion of Death Valley geology by Walter Bucher, Marland Billings, and John Rodgers. Wow!"

—Richard H. Mahard



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Happy Birthday, NSF!

Cathleen May, *Chief Science Officer*

What does the National Science Foundation mean to you? Ask GSA's academic members that question and you're likely to get some variation of "Duh!" or perhaps "The Source." As one of the few sources of public funding for basic geoscience research, the NSF, which celebrates its 50th anniversary this year, supports and drives the professional activity of many GSA members.

Think about where our science would be if the NSF had not been established in 1950. Who funded geoscience research before the late 1950s? Before the NSF, who ensured that some young people with promise could achieve advanced degrees even if they did not come from a financially privileged background? If not the NSF, who would help us try to increase the participation of women and minorities in the geosciences?

Of course, the NSF cannot be equated with Santa Claus, and I grant you (no pun intended) that a significant proportion of our members' research and professional activity is not supported by NSF. But if you tend to think of NSF only in terms of grants and only in terms of your own career, I invite you to visit its Web site at www.nsf.gov. Take a look at its vision to be "a catalyst for progress through investment in science, mathematics, and engineering," and its pledge to "provide the stewardship necessary to sustain and strengthen the nation's science, mathematics, and engineering capabilities and to promote the use of those capabilities in service to society." The NSF was established to promote these values through an equitable and objective distribution of taxpayer money in support of science and its contract with society. With these concepts mirrored in GSA's values of science, stewardship, and service, it is no wonder that we find a strong overlap of mission, vision, and values between NSF and GSA.

GSA and NSF have a successful history of organizational partnership in our student research grants program. Chances are, if you received a GSA research grant in the last 60+ years, you have NSF to thank for at least a third of the total. We look forward to developing new efforts of this sort as both NSF and GSA become more forward looking in our roles as science-enabling institutions, and more responsive to the priorities identified by the geoscience community.

Toward that end, NSF's Division of Earth Science is hosting a Town Hall Meeting at the GSA Annual Meeting in Reno. NSF needs to know what is important to you, and it needs to know how supporting you as a researcher or educator will help it meet its mandates. We scheduled this on Monday afternoon because giving our members an opportunity to hear from and speak to the division director and NSF program directors is a priority service. Please take time to participate in the plenary and breakout sessions. Consider it both an opportunity and a professional obligation.

What does NSF mean to you? Think about where our science would be if there were no mechanisms for pursuing social equity in science funding. Think about the discourse of geoscience as a whole—what if there were no mechanism to pursue the seemingly esoteric? As a citizen and a scientist, you have more reasons to appreciate the NSF than you may realize.

Please see the message from Herman Zimmerman, Director of the Division of Earth Science at the NSF (this page). If you do not currently feel pride as a constituent and citizen-supporter of NSF, you will after reading his message. And do plan to attend the Town Hall Meeting in Reno, if only to say "Happy birthday, NSF." ■

The NSF: Where Discovery Begins

Herman Zimmerman, *Director, Division of Earth Sciences, National Science Foundation*

The National Science FOUNDATION is aptly named. After 50 years of service and leadership, the place of the NSF within the nation's scientific structure is clear—the base of the pyramid, the foundation of the scientific enterprise.

The men and women of the NSF are dedicated public servants. In service to our country, the NSF enables the U.S. scientific community to maintain a position of world leadership. In service to society, the NSF promotes the discovery and dissemination of knowledge about Earth. In service to our community, the NSF promotes the achievement of excellence in science and education. In common cause with other professional scientific organizations, the NSF promotes the stewardship of our planet.

In the 50 years that NSF has supported the nation's basic research effort, we have established methods of operation that have proven to be spectacularly successful: evaluation by peer review, program administration by scientist managers, and close interaction between the agency and the community. Our individual research and infrastructure grants form the backbone of the research effort of the earth science community. However, we are now learning that major gains in our knowledge are also achieved through community projects that go far beyond the capabilities of individuals or small groups of investigators. We have learned that the path ahead often begins at the interface of disciplines. We must continue to learn from our sister disciplines and apply the tools developed by other sciences (e.g., information technology, genomics, nanoscience, system science).

The NSF's Division of Earth Sciences advances the scientific understanding of integrated Earth systems by supporting basic research of the highest quality, improving the education of citizens and future scientists, and increasing our community's capacity to undertake the research effort. We recognize and celebrate the accomplishments of the past 50 years, but the next 50 will also see surprises and discoveries in the earth sciences. The Division of Earth Sciences, together with the community of earth scientists, will work diligently and deliberately to facilitate those discoveries. ■

New Day and Time!

Face to Face with the NSF: Town Hall Meeting

The Division of Earth Sciences of the National Science Foundation will host an afternoon of overviews and updates, breakout sessions, and open discussions of timely issues at Summit 2000, GSA's Annual Meeting in Reno.

Please join us to discuss

- new developments and opportunities with the division;
- new directions within the NSF;
- current issues;
- future challenges; and
- the National Research Council report on research opportunities in the earth sciences.

Following an open forum, individual directors will provide program overviews and facilitate more focused discussions in three concurrent breakout sessions.

Don't miss this chance to hear what's new in the Earth Sciences Division, to make your voice heard in open forum, and to say "Thank you" for 50 years of research funding and support of our profession.

Where: Atlantis Casino Resort (across from the Reno/Sparks Convention Center)

When: 1:30–3:30 p.m., Monday, November 13

Last Chance to Vote

Attention voting members:

The deadline for casting your electronic ballot for 2000 officer and councilor candidates is September 16. If you are voting by mail, your ballot must be postmarked by September 16.

Postcards were mailed to voting members in August giving instructions on how to access our secure Web site and your electronic ballot. The site also posts biographical information on each candidate and the 1999 GSA Annual Report.

If you did not receive these instructions, or if you need paper copies of the ballot and biographical information on the candidates, please contact us at (303) 447-2020, ext. 774, 1-888-443-4472, or member@geosociety.org.

Deadline:
Ballots must be submitted electronically or postmarked by September 16.

Free Registration for Students!

You can work as a student assistant during the 2000 GSA Annual Meeting in Reno and defer some of the cost of attending the meeting.

- Work just 12 hours and get FREE registration. (You'll be reimbursed after meeting.)
- Work just four additional hours (total of 16) and get a FREE Abstracts book.
- PLUS, get paid $5.00 per hour.

To sign up or get more information, e-mail meetings@geosociety.org with your name, address, phone number, e-mail address, school you attend, and the dates and times you are available to assist during the Annual Meeting. Or, call 800-472-1988, ext. 186.

Warm Climates in Earth History. *Edited by Brian T. Huber, Kenneth G. MacLeod, and Scott L. Wing. Cambridge University Press, Cambridge, 1999, 462 p., $115.*

The underlying causes, maintenance, and dynamics of globally warm climates have long been enigmas in paleoclimatology. Over the past few decades, geologic data and climate model studies have addressed these issues, and differences between the two approaches have sparked a lively and constructive debate. This timely new book contains a thematic set of 14 papers addressing many aspects of past warm climates and integrates both observational and theoretical perspectives. Both oceanic and terrestrial climates are covered in detail, including discussions in several chapters on the vexing problem of how warm climates are maintained in high-latitude continental interiors, even in winter. This example highlights one of the strengths of the book: Not only does it present our current understanding of warm climates but it also highlights what we do not yet fully understand about them and where future work is needed.

The book is divided into five sections. The first provides a general overview of globally warm climates and the nature of the problems they pose. The second through fourth sections provide case studies of several periods of warm climates. These include the Paleocene and Eocene, the Mesozoic, and examples from the Paleozoic. The fifth section contains a single chapter by Crowley discussing the role of carbon dioxide in maintaining warm (and cool) climates. The organization of this volume works well. The overview-oriented first and last sections frame the case studies well and collectively provide a synthesis and roadmap for future work. Although some time periods (e.g., Miocene, Pliocene) are not dealt with specifically (save for limited discussion in a few chapters) the chapters on Paleozoic warm climates are a nice addition to the traditional time periods of focus (Mesozoic and early Cenozoic). In all of the chapters, the illustrations are detailed and clear, and there is a centerpiece of color figures.

In the discussion of warm climates, there is invariably some temptation to make comparisons with potential future global warming. To the editors' and authors' credit, this body of work keeps its focus on the science of past warm climates. As the editors state in the preface, warm intervals dominate climates of the Phanerozoic and from that standpoint alone warrant detailed study. Although the price is on the high side, this volume will be an important addition to the library of anyone who has a general interest in paleoclimatology, and is a must-have volume for anyone conducting research in warm climates.

Peter J. Fawcett
University of New Mexico
Albuquerque, NM 87131-1116

Sustainability Criteria for Water Resource Systems *Edited by Daniel P. Loucks and John S. Gladwell. Cambridge University Press, Cambridge, 1999, 139 p., $85.*

Sustainability Criteria for Water Resource Systems is a monograph with little geology in it. That is actually very good, since most of us know the rudiments of hydrogeology but almost nothing about sustainable management of water resources. This book provides an important service to geoscientists—an accessible overview of a systems approach to a critical subject.

I would call this book a status report of the art and science of water management and planning by two committees, one of UNESCO (the United Nations Educational, Scientific, and Cultural Organization) and one of the American Society of Civil Engineers. Some 19 committee members made contributions and the two editors have done a commendable job of creating a well-organized, readable text.

In 12 chapters, the editors define sustainable water resource systems, provide important insight into useable guidelines for establishing managed water resources, and introduce us to broadly conceived cost vs. benefit analyses that include social, economic, technical, and aesthetic and cultural inputs. There are useful quantitative models as well as a well-documented score-card methodology that generates an overall sustainability index.

In several chapters, they provide brief (too brief, perhaps) case studies of water resource systems that have been (mis)managed. They carefully take no sides and use a wonderfully global range of examples. Some are familiar: the depletion of the Ogalalla aquifer, restoration of the Kissimmee River, the High Aswan Dam, the Aral Sea, and the Rhine River cleanup. Perhaps more interesting are the examples unfamiliar to many of us, e.g., drought management in Niger and hydropower in Malaysia.

The book should appeal to geologists who wish to learn more about the practice of sustainability management. While water is the focus, any resource or environmental geologist will find the book useful and the methodologies transferable to their specialty. It includes a bibliography and full index. The monograph's weaknesses lie in some poorly reproduced and hard-to-read illustrations and a few unfamiliar, site-based discussions with no supporting maps. The volume's greatest weakness, though, is that the text is only sparsely referenced. The student who is intrigued by some aspect of a presentation will lack guidance as to where to find the basic data and information required to pursue a subject further. For example, someone who wishes more detail about damming the Mekong River will find that this case study contains reference only to a "Work Bank study." In this age of unfettered and unreviewed Internet sites, professionals owe it to students in particular to provide guideposts to the best available literature.

P. Geoffrey Feiss
College of William and Mary
Williamsburg, VA 23187-8795

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Pardee Keynote Sessions

(invited speakers)

This year's Pardee Keynote Symposia feature eight topics of broad interest to the geoscience community.

Sessions for Wednesday, November 15, and Thursday, November 16:

K2 ▲ Sedimentary Extremes: Modern and Ancient

GSA Sedimentary Geology Division. Marjorie A. Chan, University of Utah, Salt Lake City; Allen W. Archer, Kansas State University, Manhattan. Wednesday, November 15, 8 a.m.– 12 noon.

Can mere humans comprehend the largest depositional phenomena of all geologic time? What are the greatest environmental and/or facies extremes? This innovative session will synthesize and stretch beyond our uniformitarian views to explore the hows and whys of sedimentary events that exceed the present norms by orders of magnitude. ORAL

K8 ▲ Lamont and Plate Tectonics: History of Geology Division Millennium Symposium: Lamont 1949–1999

GSA History of Geology Division; History of Earth Sciences Society (HESS). Gerald M. Friedman, Northeastern Science Foundation, Inc., Troy, New York. Wednesday, November 15, 1:30–5:30 p.m.

This may be the last opportunity to bring together the surviving founders of the global tectonics theory, which has been called one of the most profound additions to geology. The pioneers will describe how they made their discoveries. ORAL

Check the August ***GSA Today*** or www.geosociety.org for Pardee Sessions scheduled for Monday and Tuesday, November 13 and 14.

K3 ▲ Causes and Consequences of Floods: Geologic, Climatologic, Ecologic, and Human Dimensions

GSA Quaternary Geology and Geomorphology Division. Jim E. O'Connor, U.S. Geological Survey, Portland, Oregon; Kyle House, University of Nevada, Reno. Thursday, November 16, 8 a.m.–12 noon.

Practicing earth scientists and educators will gain expanded awareness about the varied research focused on flood processes, including the causes, hazards, and ecologic role of floods, and what part they play in forming the geologic record. Speakers will describe the questions that flood researchers are now asking, the methods being used to answer these questions, and current and emerging ideas regarding floods and their effects. ORAL

K5 ▲ Great Science in the Great Basin

U.S. Geological Survey, Nevada Bureau of Mines and Geology. Benita L. Murchey, U.S. Geological Survey, Menlo Park, California; Jonathan G. Price, University of Nevada, Reno. Thursday, November 16, 1:30–5:30 p.m.

In this symposium on the current and future trends in earth science in the Great Basin province, speakers will focus on the state of the science and fundamental unanswered questions in three major branches of research: geologic framework and ore genesis, geohydrology, and earth surface processes. Subtext issues will include the increase in interdisciplinary studies and the growing influence of land management issues and public policy on scientific directions. ORAL

SEPTEMBER *Bulletin* and *Geology* Highlights

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- Lake sediment record of Pleistocene climate
- Age of the late Paleozoic reversed superchron
- Late Cenozoic deformation in the Cook Inlet basin
- Cretaceous Western Interior Seaway connection to the Labrador Sea

In September *Geology*

- Atlas shrugged (geodynamically)
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Positions Open

GEODYNAMICS, DEPARTMENT OF EARTH SCIENCES, BOSTON UNIVERSITY

The Department of Earth Sciences at Boston University invites applications for a tenure track faculty position at the Assistant Professor level, to begin September 1, 2001. We seek scientists with the potential to build a vibrant research and teaching program that emphasizes quantitative approaches targeting, for example, active plate boundaries, continental or oceanic margins, orogenic systems, erosion-tectonic interactions, or basin evolution. The applicant should utilize methods such as numerical simulation of tectonic phenomena, continental or marine seismic imaging, field or physical laboratory measurements, geodesy, or other geophysical tools, and should complement existing departmental strengths in crustal tectonics, active margins and marine processes. The successful applicant will be expected to supervise graduate thesis work in M.A. and Ph.D. programs, maintain an externally funded research program, and teach at all levels in the Earth Sciences curriculum. Interaction is encouraged with the Departments of Geography and Physics, the Centers for Remote Sensing, and Energy and Environmental Studies, and the B.U. Marine Program. For more information about the department, see www.bu.edu/ES.

A Ph.D. at the time of appointment is required. Applicants should send a curriculum vitae, a statement of research and teaching interests, and the names and addresses of at least three referees to: Search Committee Chair, Department of Earth Sciences, Boston University, 685 Commonwealth Ave., Boston MA 02215 USA; e-mail: earth@bu.edu. Review of applications will begin on November 15, 2000. Boston University is an equal opportunity/affirmative action employer.

ASSISTANT PROFESSOR OF GEOLOGY, CALIFORNIA STATE UNIVERSITY, FULLERTON

The Department of Geological Sciences, California State University, Fullerton, invites applications for a tenure-track position that will be filled at the rank of Assistant Professor, starting August 2001. We are looking for applicants whose primary interests are in teaching general education courses, and secondarily in developing a research program that includes undergraduate and graduate students. The successful applicant will have the following credentials and capabilities:

Ph.D. in Geology with an interest in teaching geology to non-majors AND in coordinating the teaching activities of part-time faculty and graduate students.

Research in an area of geology that supports senior and graduate theses.

We are looking for a versatile person who will commit himself or herself to the success of our General Education program and who will add to our research programs. The new faculty member will oversee the department's general education course offerings and will supervise the graduate teaching assistants and part-time faculty. Teaching responsibilities may include physical geology, historical geology, and topics in geology such as geological hazards or environmental geology and upper division or graduate courses in the new faculty member's area of expertise. Research activities must result in publications in refereed journals.

CSU Fullerton is a large urban university dedicated to the preeminence of learning. Located 22 miles southeast of metropolitan Los Angeles, Fullerton is a full-service city renowned for its unique mix of residential, commercial and industrial, educational, and cultural environments that provide residents with an outstanding quality of life. The Department has nine full-time faculty with expertise in traditional and applied areas of geology. The nearby geological provinces provide abundant opportunities for field-based research, which the department emphasizes in its curriculum. We have about 50 undergraduate majors and have implemented a new masters degree program this year. Other information is available through our web page at http://geology.fullerton.edu/geology/.

To apply, please send the following: (1) a detailed curriculum vita; (2) a letter of application that explains how you meet the qualifications outlined above; (3) a statement about teaching that includes a discussion of relevant course work and/or experience in preparation for teaching, a list of courses you would feel comfortable teaching, and a statement of your teaching philosophy; (4) a statement of your future research plans and goals; and (5) the names, addresses, phone numbers, and email addresses of at least three references familiar with your teaching and research potential.

Send application to: Dr. John Foster, Chair, Department of Geological Sciences, California State University, PO Box 6850, Fullerton, California 92834-6850. Applications will be accepted until November 15, 2000. Applications received after this date will be reviewed only if the position is not filled from the original pool of applicants.

California State University, Fullerton is an Affirmative Action/Equal Opportunity Employer. All personnel policies conform to the requirements of Executive Order 11246, the Americans with Disabilities Act (ADA) of 1990, Title IX of the Higher Education Amendments of 1972 and other federal regulations regarding nondiscrimination.

ILLINOIS STATE GEOLOGICAL SURVEY GEOSCIENCE EDUCATION SECTION HEAD

Provide vision, leadership, and management for our Geoscience Education Section, coordinate outreach efforts, and conceive, design, and implement high-quality geoscience programs such as workshops for teachers, field trips for the public, and presentations to government officials, decision-makers, and other constituents. This position also involves the development of new teaching materials that include hands-on classroom activities, demonstrations, models, posters, videos, CDs, and websites. Requires a broad knowledge of geology, earth science, or related field with experience in teaching; training and experience in management and supervision; demonstrated leadership, team-building, and delegation skills; superior written and oral communication skills. Master's degree in geology, earth science, or related field with 12 years related work experience, or Ph.D. with 8 years related work experience, including supervisory training, is the minimum requirement. Starting salary range $55,000-$60,000. Closing date: 11/15/00. For more info visit www.isgs.uiuc.edu. For application form, contact walston@isgs.uiuc.edu or 217-244-2401, Human Resources, ISGS, 615 East Peabody, Champaign IL 61820. AA/EEO/ADA Employer

ILLINOIS STATE GEOLOGICAL SURVEY, HYDROGEOLOGIST

Conduct and/or support original, applied research in hydrogeology and geologic mapping; work with a team of geoscientists in mapping 1:24,000-scale quadrangles; develop hydrogeologic maps, cross-sections, reports, and other products; undertake surface and subsurface mapping of aquifers and the hydrogeologic properties of Quaternary sediments and bedrock. Requires knowledge of glacial geology and master's degree in geology or related field with 4 years related work experience in hydrogeology and geologic mapping. Salary range: $37,000-$43,000. Closing date: 10/13/00. For more info visit www.isgs.uiuc.edu. For application form, contact walston@isgs.uiuc.edu or 217-244-2401, Human Resources, ISGS, 615 East Peabody, Champaign IL 61820. AA/EEO/ADA Employer.

ASSISTANT MUSEUM DIRECTOR (OUTREACH SPECIALIST) UNIVERSITY OF WISCONSIN–MADISON

The Department of Geology and Geophysics is inviting applications to fill the newly established position of Assistant Museum Director (Outreach Specialist). This is a full-time fixed-renewable position with guaranteed funding for three years. Continuation of the position is dependent on the receipt of additional funding. We anticipate that the position will begin in January of 2001. M.S. in a natural science or science education is required; Ph.D. in a natural science is preferred.

Other required qualifications include two to three years in science-based education. Basic computer skills (word processing, spreadsheets) are essential. Experience with grant writing is desirable. Applicants must be enthusiastic about the earth sciences, and about communicating their knowledge to a broad spectrum of audiences, mainly K-12 students and their teachers.

Additional information about the Department, the Museum, and the position may be found at www.geology.wisc.edu.

Interested applicants should submit a cover letter, resume and the names/addresses of three references to Dr. Toni Simo, Department of Geology & Geophysics, 1215 W. Dayton Street, Madison WI 53706. Applications must be received by November 1, 2000.

The University of Wisconsin–Madison is an equal opportunity/affirmative action employer. Women and minority candidates are encouraged to apply. Unless confidentiality is requested in writing, information regarding the applicants must be released upon request. Finalists cannot be guaranteed confidentiality.

MALCOLM & SYLVIA BOYCE PROFESSORSHIP IN GEOLOGICAL SCIENCES, INDIANA UNIVERSITY

The Department of Geological Sciences at Indiana University invites applications and nominations for the newly created Malcolm & Sylvia Boyce Professorship of Geological Sciences in the field of HYDROGEOLOGY. As a named professorship in Geological Sciences, the position is expected to be filled at the full-professor level. However, under exceptional circumstances, the position may be filled at a tenured, associate-professor level. The Malcolm and Sylvia Boyce Professor should have research interests that complement existing programs in chemical and physical aspects of surface and shallow-subsurface hydrology. We are especially interested in an established scholar with a research focus on water and solute transport (including modeling) at the basin scale, although other areas of expertise will be considered. The successful candidate will provide a link between hydrogeology and sedimentary geology as part of an initiative aimed at developing an interdisciplinary program in the geology of sedimentary basins.

Excellent laboratories exist in the Department for chemical and stable-isotope analyses. The current hydrogeology faculty has strong interactions with a complementary program (Water Resources) at Indiana University in the School of Public and Environmental Affairs (SPEA), and with the Center for Geospatial Data Analysis at the Indiana Geological Survey. Many opportunities exist for collaboration with other on-campus researchers in the Department of Chemistry as well as the Indiana Geological Survey. A Ph.D. or equivalent degree is required. Applications should include a personal statement of vision for the future of research, a narrative of important research, teaching, and service accomplishments, a detailed curriculum vitae, and names and addresses (including e-mail) of five referees.

The application deadline has been extended to October 30, 2000, but the position will remain open until filled. Applications or nominations should be sent to: Boyce Professorship Search Committee, Department of Geological Sciences, Indiana University, 1001 E. 10th Street, Bloomington, IN 47405 USA.

This position is one of two newly endowed professorships in the Department of Geological Sciences at Indiana University. Further information about these positions and the Department can be found at: www.indiana.edu/~geosci/.

Indiana University as an Equal Opportunity/Affirmative Action Employer encourages the candidacies of women and minorities.

HASSELMANN ENDOWED CHAIR IN GEOLOGICAL ENGINEERING AT THE UNIVERSITY OF MISSOURI

The Department of Geological and Petroleum Engineering at the University of Missouri—Rolla seeks applications for the Fred Hasselmann Chair in Geological Engineering. This Chair has been established through a gift from an endowment fund for the purpose of ensuring faculty excellence in Geological Engineering. Candidates thus should have a well established reputation of academic and/or industrial experience and possess the communication and management skills necessary to provide leadership within the department. Rank will depend upon qualifications and previous experience in an area considered critical to the mission of the program. A Ph.D. in Geological Engineering or a related field is required and registration as a professional engineer or the qualifications to become registered is strongly desired. The successful candidate should possess a strong commitment to undergraduate and graduate level teaching and should have a demonstrated research record including the successful pursuit of external funding and publication. Preferred areas of expertise include ground water hydrology and contaminant transport, applied geomorphology, engineering geology and geotechnics, and geographic information systems.

The department is a part of the school of Mines and Metallurgy and currently has seven faculty members, approximately 100 undergraduates and 15 graduate students. The 10 year old McNutt Hall of Mineral Engineering houses the department along with four other mineral and materials engineering programs and a geology and geophysics program. All departments grant degrees through the Ph.D. and all undergraduate engineering programs

Classifieds *continued on p. 30*

Classifieds *continued from p. 29*

are ABET accredited. The University of Missouri—Rolla also grants degrees in seven traditional engineering programs in the School of Engineering as well as science and mathematics and liberal arts degrees through the College of Arts and Sciences.

Interested candidates should submit a resume, a statement of teaching and research accomplishments and goals, transcripts of all college work, and the names and addresses of three individuals from whom letters of reference may be solicited. The deadline for receipt of application materials is November 3, 2000, although the selection process will begin immediately upon receipt of applications. Please visit our website at www.umr.edu/~gee/. Applications materials should be directed to Human Resources Services, Reference Number: R51861, University of Missouri—Rolla, 1202 North Bishop, 1870 Miner Circle, Rolla, MO 65409-1050. The University of Missouri-Rolla as an equal opportunity and affirmative action institution, welcomes applications from qualified women, minorities, and persons with disabilities.

GEOMORPHOLOGY / NEOTECTONICS / ENGINEERING GEOLOGY / MINERALOGY
CALIFORNIA STATE POLYTECHNIC UNIVERSITY, POMONA

The Geological Sciences Department seeks to fill a tenure-track faculty position at the Assist. Prof. level, to begin Sep. 2001. An earned Ph.D. in Geology with expertise in one or more of the following disciplines: Geomorphology/Neotectonics/Eng. Geology/Mineralogy is required by the time of appointment. Responsibilities will vary depending on specialty but broadly include teaching and developing undergrad. core courses, e.g., Applied Geomorph/Engineering Geology/Applied Geophysics/Optical Min./GIS apps. in Geology, Env. Policy and Regs. and Gen. Ed. or Sci. Ed. or support courses; directing undergraduates in field-oriented research concentrating on geologic problems in southern. Calif.; co-coordinating and integrating GIS into an undergrad. curriculum; student advising; committee assignments. Preference will be given to applicants with documented effective undergraduate teaching, breadth of teaching abilities and an active research, publication, successful grant funding record. Send resume, statement of teaching and research interests, three current letters of reference, unofficial transcripts and completed app. form (supplied by Dept.) to: Dr. John A. Klasik, Chair, Geological Sci. Dept., Cal Poly Pomona, 3801 W. Temple Ave., Pomona, CA, 91768 (e-mail: jaklasik@csupomona.edu). Position open until filled. Initial review of apps, Jan. 2, 2001. Official transcripts required of all finalists. EO/AA employer.

FACULTY POSITION IN BIOGEOSCIENCE
DEPARTMENT OF GEOLOGY UNIVERSITY OF MARYLAND, COLLEGE PARK

The Department of Geology at UM is searching for a tenure-track faculty member who has made fundamental contributions in BioGeoScience. We seek an outstanding scientist with research interests in the interdisciplinary field of geomicrobiology/mineralogy, or a closely related field.

Research strengths in the Department of Geology are in the broad areas of mineralogy, petrology and geochemistry, in particular of crustal evolution and granites and associated mineralization; structural geology and tectonics; hydrological processes and integration of geomorphology, hydrology and ecology to understand surface environments; and, isotope geochemistry in support of these areas, and in mantle geochemistry, meteoritics, geochronology, carbonate diagenesis, sediment cycling, stratigraphy and paleoclimate studies. The Department of Geology encourages interdisciplinary approaches to the study of the Earth and participates in the Earth System Science Interdisciplinary Center, which is a new Center formed by the University of Maryland and NASA/Goddard Space Flight Center to advance fundamental knowledge about the earth system through preeminent research and teaching programs.

The Department expects to fill this position by Summer 2001. Salary will be commensurate with experience. The appointee is expected to develop and maintain an active, externally-funded research program, to direct graduate students, and to participate fully in teaching at the graduate and undergraduate levels, including courses in the introductory non-major program.

The University of Maryland is an affirmative action/equal employment opportunity employer. Applications should be submitted by September 29, 2000, for best consideration, and should be submitted to: Chair, Search Committee, Department of Geology, University of Maryland, College Park, MD 20742, USA (electronic submissions to: geology@geol.umd.edu). Persons interested in being considered for this position should provide a statement describing research and teaching interests, indicating how s/he envisions contributing to the Department's research and teaching activities, and a current curriculum vitae. Applicants should arrange to have a minimum of four letters of recommendation sent directly to the Chair of the Search Committee before September 29, 2000. The Search Committee encourages applicants to submit copies of up to two recent publications in support of their candidacy.

CENTRAL MICHIGAN UNIVERSITY
MINERALOGY/PETROLOGY
Assistant Professor Tenure-Track Position

The Department of Geology invites applications for an entry-level tenure-track position beginning in August, 2001. We seek a person with the following qualifications: (1) Ph.D. in geology with a specialty in mineralogy or petrology, (2) demonstrated excellence in teaching is preferred, (3) commitment to field-based studies, (4) demonstrated commitment to high-quality undergraduate research, (5) excellent communication skills. The successful applicant will be required to (1) teach mineralogy, introductory geology, and courses in his or her specialty, (2) develop a successful research program, and (3) develop and submit external grant proposals.

The Department of Geology currently has eight full-time faculty and 40 to 60 undergraduate majors. Teaching loads will range from 9 to 12 contact hours per 15-week semester. The department has a strong record of incorporating research into the undergraduate curriculum. For more information, visit our departmental web site at www.cst.cmich.edu/units/gel/.

Central Michigan University enrolls approximately 18,000 students (87% undergraduate), and is located in the heart of the Michigan Basin. The department has modern and well-equipped facilities which include: automated ARL-SEMQ electron microprobe, Phillips XRD, VG-PQ2 ICP-MS, fluid inclusion lab, rock and mineral sample preparation facilities, a networked IBM and Mac computer lab, geophysical instruments, in-house GIS, access to

other modern GIS and GPS systems, and two departmental vans. In addition, the department has access to other computing and analytical facilities on campus and at nearby universities.

Interested persons should send: (1) a resume, (2) statements of teaching philosophy, research interests, and vision for undergraduate education, (3) unofficial transcripts, and (4) three letters of reference to: Mineralogist/Petrologist Search Committee, Department of Geology, Central Michigan University, Mt. Pleasant, MI 48859.

All applications and materials must be received by October 6, 2000.

CMU, an AA/EO institution, is strongly and actively committed to increasing diversity and providing equal opportunity within its community. CMU does not discriminate in employment against person based on age, color, disability, gender, familial status, height, marital status, national origin, political persuasion, race, religion, sexual orientation, veteran status, or weight (see www.cmich.edu/aaeo.html).

ASSISTANT PROFESSOR
SOUTHERN METHODIST UNIVERSITY

The Department of Geological Sciences at Southern Methodist University invites applications for a tenure-track faculty position in the broad areas of surficial processes or geodynamics. We seek creative applicants with an excellent understanding of fundamental physical principles and processes, and a demonstrated ability to apply that understanding in a quantitative manner to important problems in the Earth sciences. The department seeks an individual who will complement existing strengths in one or more of the following areas: geochemistry, petrology/tectonics, geophysics, planetary dynamics, terrestrial paleoecology. We anticipate making the appointment at the assistant professor level with the appointment to begin no later than Fall, 2001. Applicants are required to have a PhD by the beginning of the Fall 2001 semester. The successful candidate will be expected to teach at the undergraduate and graduate levels, supervise graduate research, and establish an externally funded research program in his or her field of expertise. The committee will begin its review of the applications on or about November 1, 2000. To ensure full consideration, the application should be postmarked by November 1, 2000. Candidates should submit their curriculum vitae, names and addresses of three references, and a written statement of teaching and research interests to: Dr. Lee McAlester, Chair, Department of Geological Sciences, P.O. Box 0395, Southern Methodist University, Dallas, Texas 75275-0395. E-mail: geol@mail.smu.edu and website: www.geology.smu.edu. SMU is an Affirmative Action/Equal Opportunity/Title IX Employer.

UNIVERSITY OF CALIFORNIA
RIVERSIDE
Assistant Professor of Soil-Landscape Relations

DATE AVAILABLE: July 1, 2001. RESPONSIBILITIES: Applications are invited for a tenure track faculty position directed at studying soil resources at landscape to regional scales. The successful candidate is expected to develop an independent research program in which the spatial distributions of soil properties are quantitatively analyzed to address issues related to the use and conservation of land, water, air, and biological resources. The appointee will emphasize a broad scale approach within a strong, dynamic, and growing soil and water science program. S/he will also have the opportunity to bring a soils perspective into collaborations with other scientists addressing landscape and regional issues such as plant and wildlife habitats, agricultural sustainability, urban and rural interfaces, mediation of non-point source pollution, and water and watershed management.

The appointee will be expected to teach a 1-quarter undergraduate course in soil resources beginning the first year and additional undergraduate and graduate course(s) related to his/her area of specialization in subsequent years. The appointee will direct graduate students in the Soil & Water Sciences and Environmental Sciences graduate programs.

QUALIFICATIONS: Candidates must have a Ph.D. with strong training in soil science, particularly soil-landscape relations, soil morphology, and soil conservation/land use. S/he should have interest in, and experience with, methodologies applicable to landscape and regional scale studies, such as the use of soil survey databases, GIS, remote sensing, and geostatistical analysis. Candidates must possess a strong commitment to teaching excellence at both the undergraduate and graduate levels. Prior teaching experience is highly desirable.

APPLICATION PROCEDURES: Candidates for this position are requested to submit a curriculum vitae, a statement of teaching/research interests, transcripts, the names and addresses of at least three references, and any other supporting documentation to Dr. Marylynn Yates, Chair, Department of Environmental Sciences, University of California, Riverside, CA 92521. The closing date for applications is December 11, 2000.

More information regarding the Department of Environmental Sciences can be found at: http://envisci.ucr.edu. The University of California is an equal opportunity/affirmative action employer.

ASSISTANT PROFESSOR, UNIVERSITY OF CALIFORNIA, SANTA BARBARA

University of California, Santa Barbara, Department of Geography, invites applications for a tenure-track position at the Assistant Professor level in Terrestrial Biophysical Processes. A Ph.D. is required by the date of appointment. The successful applicant will have research and teaching interests in the interaction between biological and physical processes at local to regional spatial scales, and in quantitative spatial modeling. Relevant areas include atmosphere-biosphere interactions, regional vegetation dynamics, and biogeochemical cycles. The Department has strengths in three systematic areas: (1) modeling, measurement, and computation; (2) human-environment relations; and (3) earth system science. This position is most strongly associated with earth system science, but interests in one or both of the other systematic areas are also expected. The Department has a strong commitment to multidisciplinary research and teaching and provides opportunities for interactions with many other departments and research units on the campus. The application deadline is November 15, 2000, and the starting date is July 1, 2001. Qualified applicants should mail a complete curriculum vitae, a statement of research and teaching interests, and the names of at least three referees to: Frank Davis, Search Committee Chair, Department of Geography, University of California, Santa Barbara, CA 93106-4060; phone (805) 893-3438; FAX (805) 893-3146; email fd@geog.ucsb.edu. To learn more about the department, visit our website at www.geog.ucsb.edu. University of California is an Equal Opportunity/Affirmative Action Employer.

UNIVERSITY OF WISCONSIN–PARKSIDE
Assistant Professor Tenure-Track Position

The Geology Department at the University of Wisconsin—Parkside has a tenure track opening for an Assistant Professor of Sedimentology for Fall, 2001. Candidates must have a Ph.D. in geology, with an interest in environmental applications of geosciences. We are seeking an individual with a high level of enthusiasm for teaching undergraduates and for involving undergraduate students in his/her research. For a complete position announcement, visit the University of Wisconsin—Parkside at http://www.uwp.edu/admin/academic.affairs/geologyap.html or contact Dr. Christine V. Evans, Chair, Geology Department, University of Wisconsin—Parkside, Box 2000, 900 Wood Road, Kenosha, WI 53141-2000, evansc@uwp.edu. Faculty of UW–Parkside Geology will also conduct on-site interviews at GSA meetings in Reno, NV.

PALEOCLIMATOLOGY/PALEOECOLOGY/
BIOGEOCHEMISTRY
COLLEGE OF WILLIAM AND MARY

The Department of Geology at the College of William and Mary invites applications for a tenure-track assistant or associate professor beginning August 2001. The successful candidate will teach undergraduate courses in introductory geology, paleontology, and one or more courses in the area of specialization, supervise undergraduate research, and maintain an active research program. Expertise in GIS and/or applied geophysics is desirable. Ph.D. required. Applicants should submit a statement of their teaching and research experience and goals, a vitae, undergraduate and graduate transcripts, and contact information for three references to Heather Macdonald, Department of Geology, College of William and Mary, Williamsburg, VA 23187. E-mail rhmacd@wm.edu. Review begins November 1, 2000 and will continue until an appointment is made. The College is an EEO/AA university.

Services & Supplies

Opportunities for Students

Ph.D. Student Fellowships in Contaminant Hydrogeology/Colorado School of Mines. Colorado School of Mines (CSM) has been awarded a grant from the Department of Education's GAANN program that provides graduate fellowships. We seek applicants who wish to pursue PhD degrees in the general area of computational subsurface contaminant transport processes starting Spring 2001 or Fall 2001. Specific research topics are highly flexible. Fellows are encouraged to combine mathematical modeling with laboratory or field research. Fellowships are available through the following programs: Geological Engineering, Geology, Civil Engineering, Environmental Science and Engineering, and Geochemistry. Fellows will be affiliated with the International Ground Water Modeling Center (http://www.mines.edu/igwmc/). Fellowships include payment of tuition and fees and a stipend of $15,000 per year. CSM is located in Golden, Colorado in the foothills of the Rocky Mountains. For more information, contact Dr. John McCray [303-384-2181, jmccray@mines.edu, www.mines.edu/~jmccray/]. Applicants who have completed a Master's degree, and members of groups that are underrepresented in computational earth sciences and engineering, are especially encouraged to apply. Applicants must be U. S. citizens.

Ph.D. Opportunity/Sea-Level Research/University of Illinois at Chicago. The NSF-funded project "Rates of Holocene relative sea-level rise and differential crustal movements in the Mississippi Delta" provides a 3-year research assistantship for a Ph.D. candidate, to begin in January 2001. This project is part of the multidisciplinary Environmental Dynamics research program at UIC. The study is field-based, and aims at obtaining a large data set of high-resolution sea-level data from different parts of the Mississippi Delta, and to assess Holocene sea-level history in the context of differential subsidence rates and isostatic responses, climate change, and coastal wetland dynamics. An M.S. or equivalent degree in the geosciences is required, preferably with one or more relevant specialties (e.g., Quaternary geology, sedimentology, paleoecology). Send an application letter outlining research interests, along with a curriculum vitae, transcripts (copies are acceptable), and the names and addresses of three referees by October 15, 2000, to Dr. Torbjörn E. Törnqvist, Department of Earth and Environmental Sciences, University of Illinois at Chicago, 845 West Taylor Street, Chicago, IL 60607-7059, USA. More information can be obtained from our website (www.uic.edu/depts/geos.html) or directly by e-mail (tor@uic.edu).

New Graduate Student Opportunities in Coastal and Marine Studies at LSU. A new coastal research project is starting near New Orleans, Louisiana, funded jointly by EPA, NSF and the USDA as part of the national Water and Watersheds competition. Mississippi River water is being diverted into coastal marshes at Caernarvon, LA, in large-scale (pulsed) flood events to promote coastal restoration. Graduate stipends are available within the PULSES project for studies in four areas: (1) Hydrology and Coastal Sedimentation (Jaye Cable, jcable@lsu.edu), (2) Hydrological and Water Quality Modeling (Dubravko Justic, djusti1@lsu.edu), (3) Landscape Modeling (Enrique Reyes, ereyes@lsu.edu), and (4) Stable Isotope Biogeochemistry (Brian Fry, bfry@lsu.edu). PULSES is a 3-year, multi-investigator, multi-disciplinary project that includes socioeconomic as well as physical and biological components, and as such, provides an excellent broad framework for detailed graduate research studies. More information about the PULSES project and the above faculty is available at: http://its2.ocs.lsu.edu/guests/ceiweb, & http://lsu.edu/guests/wwwcei/pulses. Interested students should complete a pre-application on the LSU Department of Oceanography website (http://www.oceanography.lsu.edu/) using MS Internet Explorer). Students can qualify for graduate assistantships up to $16,000/yr, with competitive GRE scores (>1200). Minimum acceptance requirements for the LSU Department of Oceanography include an 1100 GRE score. Inquiries and applications should be directed to the above-listed individual faculty or to Ms. Jeanne Johnson at 225-388-6308. LSU is an equal-opportunity employer. ■

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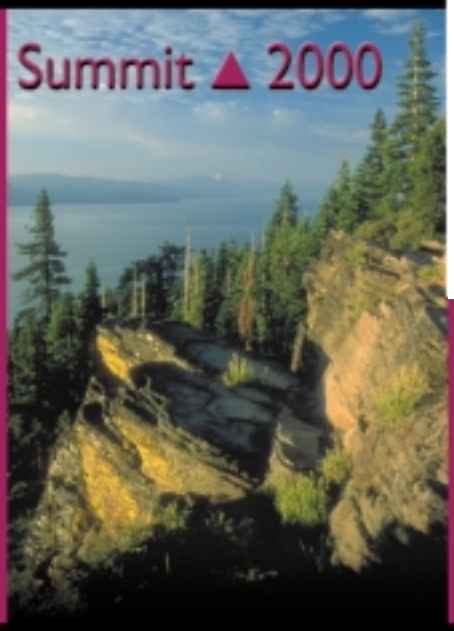

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