GSA TODAY

VOL. 18, No. 3 A PUBLICATION OF THE GEOLOGICAL SOCIETY OF AMERICA MARCH 2008

The mystery of the pre–Grand Canyon Colorado River—Results from the Muddy Creek Formation

Inside this issue:

Penrose Conference Report, p. 13
Call for Committee Service, p. 16


It's Not Just Software. . .
It's RockWare.
For Over 24 Years.
RockWorks™
3D Subsurface Data Management, Analysis, and Visualization
• Powerful well database for queries
• Pick stratigraphic tops from well/raster logs
• Generate strip logs, cross-sections, fence diagrams, stratigraphic models, block models
• Contour maps and surfaces in 2D & 3D
• Import/export data, models & graphics
• Includes the RockWorks Utilities tools
Free trial available at www.rockware.com.
$1,999 Commercial/$749 Academic
DeltaGraph™
The Most Comprehensive Charting Application Available
• Analyze, visualize and customize your numbers efficiently with high quality output
• Formula Builder with 50 mathematical/statistical functions
• Curve fitting with advanced regression tools
• Over 80 different chart types and 200 different styles
• High quality screen and printer output
Free trial available at www.rockware.com.
$295 Commercial/$195 Academic
RockWare GIS Link 2™
Connecting RockWorks2006 and ArcMap
• Load RockWorks well locations as an ArcMap layer
• Pick profile, section, and fence diagram locations in ArcMap, generate the diagrams automatically in RockWorks
• Create contour maps of formation tops and isopachs, surface elevations
• Generate strip logs
Free trial available at www.rockware.com.
$349
RockWorks Utilities™
An Indispensible Collection of Modeling, Analysis, and Display Tools
• Point maps, contour maps, 3D surfaces
• Gridding tools
• Solid models
• Volumetrics
• Piper/Stiff plots
• Rose & Stereonet diagrams
Free trial available at www.rockware.com.
$495
RockWare®
Since 1983
303.278.3534 • 800.775.6745
RockWare.com
ESRI
AUTHORIZED
BUSINESS
PARTNER

GSA TODAY

GSA TODAY publishes news and information for more than 20,000 GSA members and subscribing libraries. *GSA Today* lead science articles should present the results of exciting new research or summarize and synthesize important problems or issues, and they must be understandable to all in the earth science community. Submit manuscripts online at www.geosociety.org/pubs/submit_ms.htm.

GSA TODAY (ISSN 1052-5173 USPS 0456-530) is published 11 times per year, monthly, with a combined April/May issue, by The Geological Society of America®, Inc., with offices at 3300 Penrose Place, Boulder, Colorado. Mailing address: P.O. Box 9140, Boulder, CO 80301-9140, USA. Periodicals postage paid at Boulder, Colorado, and at additional mailing offices. Postmaster: Send address changes to *GSA Today*, GSA Sales and Service, P.O. Box 9140, Boulder, CO 80301-9140.

SUBSCRIPTIONS for 2008 calendar year: Society Members: *GSA Today* is provided as part of membership dues. Contact GSA Sales and Service at +1-888-443-4472, +1-303-357-1000, option 3, or gsaservice@geosociety.org for membership information. Nonmembers & Institutions: Free with paid subscription to both *GSA Bulletin* and *Geology*, otherwise US$60. Contact Subscription Services at +1-800-627-0629 or gsa@allenpress.com. Also available on an annual CD-ROM (together with *GSA Bulletin*, *Geology*, *Geosphere*, GSA Data Repository, and an Electronic Retrospective Index to journal articles from 1972); US$99 to GSA Members, others call GSA Subscription Services for prices and details. Claims: For nonreceipt or for damaged copies, members contact GSA Sales and Service; all others contact Subscription Services. Claims are honored for one year; please allow sufficient delivery time for overseas copies, up to six months.

GSA TODAY STAFF:
Executive Director: John W. Hess
Science Editors: Stephen T. Johnston, University of Victoria, School of Earth & Ocean Sciences, Victoria, British Columbia V8W 3P6, Canada, stj@uvic.ca, and David E. Fastovsky, University of Rhode Island, Department of Geosciences, Woodward Hall, Rm. 317, Kingston, Rhode Island 02881, USA, defastov@uri.edu.
Director of Publications: Jon Olsen
Managing Editor: Kristen E. Asmus, kasmus@geosociety.org
Editorial Staff: Kathryn Roche, April Leo
Production Coordinator: Margo Y. Sajban
Graphics Production: Margo Y. Sajban

ADVERTISING:
Classifieds & Display: Ann Crawford, +1-800-472-1988, ext. 1053, +1-303-357-1053, Fax +1-303-357-1070; acrawford@geosociety.org

GSA ONLINE: www.geosociety.org

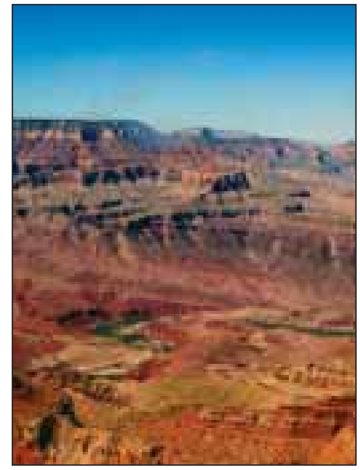
Printed in the USA using pure soy inks.

50% Total Recovered Fiber
10% Postconsumer

THE GEOLOGICAL SOCIETY OF AMERICA®

VOLUME 18, NUMBER 3 ▲ MARCH 2008

SCIENCE ARTICLE



Cover: View to the north across eastern Grand Canyon from Lipan Point. Here, the Colorado River flows around the Unkar tributary debris fan and through tilted Proterozoic Grand Canyon Supergroup sedimentary and volcanic rocks. These are overlain in angular unconformity by Paleozoic strata. On the left horizon is the north rim of Grand Canyon at the highest part of the Laramide Kaibab uplift. The Colorado River cut most of Grand Canyon in the past 6 m.y. since it became integrated off the Colorado Plateau. But the river's pathway and evolution before that time are a long-debated mystery. Photo by Jonathan Harvey. See "The mystery of the pre–Grand Canyon Colorado River—Results from the Muddy Creek Formation" by Joel L. Pederson, p. 4–10.

GSA celebrates our three-year association with the International Year of Planet Earth
planetearth® Earth Sciences for Society

The mystery of the pre–Grand Canyon Colorado River—Results from the Muddy Creek Formation

Joel L. Pederson, *Department of Geology, Utah State University, Logan, Utah 84322-4505, USA, joel.pederson@usu.edu*

ABSTRACT

The Colorado River's integration off the Colorado Plateau remains a classic mystery in geology, despite its pivotal role in the cutting of Grand Canyon and the region's landscape evolution. The upper paleodrainage apparently reached the southern plateau in the Miocene, and recent work supports the longstanding idea that the river was superimposed over the Kaibab uplift by this time. Once off the plateau, the lower river integrated to the Gulf of California by downstream basin spillover from ca. 6–5 Ma. An unknown link remains: the history of the river in the western Grand Canyon region in Miocene time. One of the viable hypotheses put forward by previous workers—that the late Miocene Muddy Creek Formation represents the terminal deposits of the paleo–Colorado River in the Basin and Range northwest of Grand Canyon—is tested in this paper. Results indicate instead that local drainages along with the paleo–Virgin River are the likely sources of this sediment. The remaining hypothesis—that the paleo-upper Colorado River dissipated and infiltrated in the central-western Grand Canyon area—has modern analogs, provides a potential source for extensive Miocene spring and evaporite deposits adjacent to the southwestern plateau, and implies a groundwater-driven mechanism for capture of the upper drainage.

INTRODUCTION—THE GRAND DEBATE

The path of the pre–Grand Canyon Colorado River and how it came to its present course off the Colorado Plateau and into the lowlands of the Basin and Range have been debated for decades. Solving the problem of how the river came to flow off the plateau is key to understanding the formation of Earth's most famous erosional landscape—the Grand Canyon region. The Colorado River did not tap into its potential energy for erosion until it was integrated over the Grand Wash Cliffs and off the Colorado Plateau, dropping its base level ~1500 m and driving much of the subsequent canyon incision upstream (Pederson et al., 2002a). Understanding how this happened has been hampered by a lack of data, mostly the result, ironically, of erosion having removed much of the geologic record of the river's history.

Based on his early river expeditions, John Wesley Powell believed the Colorado River to be antecedent—relatively old, with younger uplifts raised across its path (Powell, 1875). However, it was soon thereafter established that the monoclinal uplifts of the Colorado Plateau formed in the early Cenozoic Laramide orogeny and that the Colorado River and its major tributaries are younger. Walcott (1890) first suggested that the river was superimposed across the southern flank of the Kaibab uplift while still flowing in overlying, less resistant Mesozoic strata (Fig. 1). William Morris Davis likewise recognized that the Colorado River is superimposed across the exhumed older uplifts of the plateau (Davis, 1901). He envisioned ancestral drainages that flowed northeast and then reversed direction due to down-faulting to the west, with recent uplift of the plateau rejuvenating the Colorado River and forming Grand Canyon.

Broadly speaking, Davis' model was validated and supplemented by the work of subsequent workers. It was recognized early on that the upper basin fill in the Lake Mead region, southwest of the plateau margin, is relatively young and that it precludes the existence of the present Colorado River in that area (Blackwelder, 1934; Longwell, 1946). Closer analysis of the sedimentary record of the Grand Wash Trough, where the Colorado River enters the Basin and Range, revealed a switch from internal basin deposition to subsequent dissection upon the arrival of the exotic Colorado River at 6 Ma (Lucchitta, 1966). Thus, the Colorado River was integrated ca. 6 Ma and carried out most of the incision of Grand Canyon since then (Lucchitta, 1972; McKee and McKee, 1972).

How the river reorganized to flow west and what the drainage was like before that time are elusive problems. After the Laramide orogeny, drainages in the Grand Canyon region were directed northeast off the ancestral Mogollon highland (Young and McKee, 1978). In Oligocene time, these consequent drainages were disrupted by magmatism in the central plateau, by the onset of arid climate, and potentially by epeirogenic uplift (e.g., Cather et al., 2008). In Charlie Hunt's extensive work (1956, 1969), he concluded that much of the upper Colorado River drainage had established itself on the northern and central plateau by Miocene time. So where did the drainage go when it reached the southern plateau? Research along the Mogollon Rim indicates that there was no Miocene exit route for the river to the southwest (Young and Brennan, 1974). Therefore, the main working hypotheses have been that the ancestral upper Colorado River: (a) issued southeast along the Little Colorado River trough either off the plateau or into the Bidahochi Formation of the south-central plateau (McKee et al., 1967); (b) crossed the Kaibab uplift and terminated in the southwestern Colorado Plateau (Hunt, 1956); or (c) crossed the Kaibab uplift and continued northwest across the low plateaus and into the Basin and Range (Fig. 1; Lucchitta, 1990).

Regarding hypothesis (a), researchers proposed that the Miocene river exited the plateau to the southeast to account for earlier Miocene erosion in the area (McKee et al., 1967). But there is no evidence for such a river, and the presence of the Bidahochi Formation along this path is a problem (e.g., Hunt, 1969). The Bidahochi dates to the time in question, but it

GSA Today: v. 18, no. 3, doi: 10.1130/GSAT01803A.1

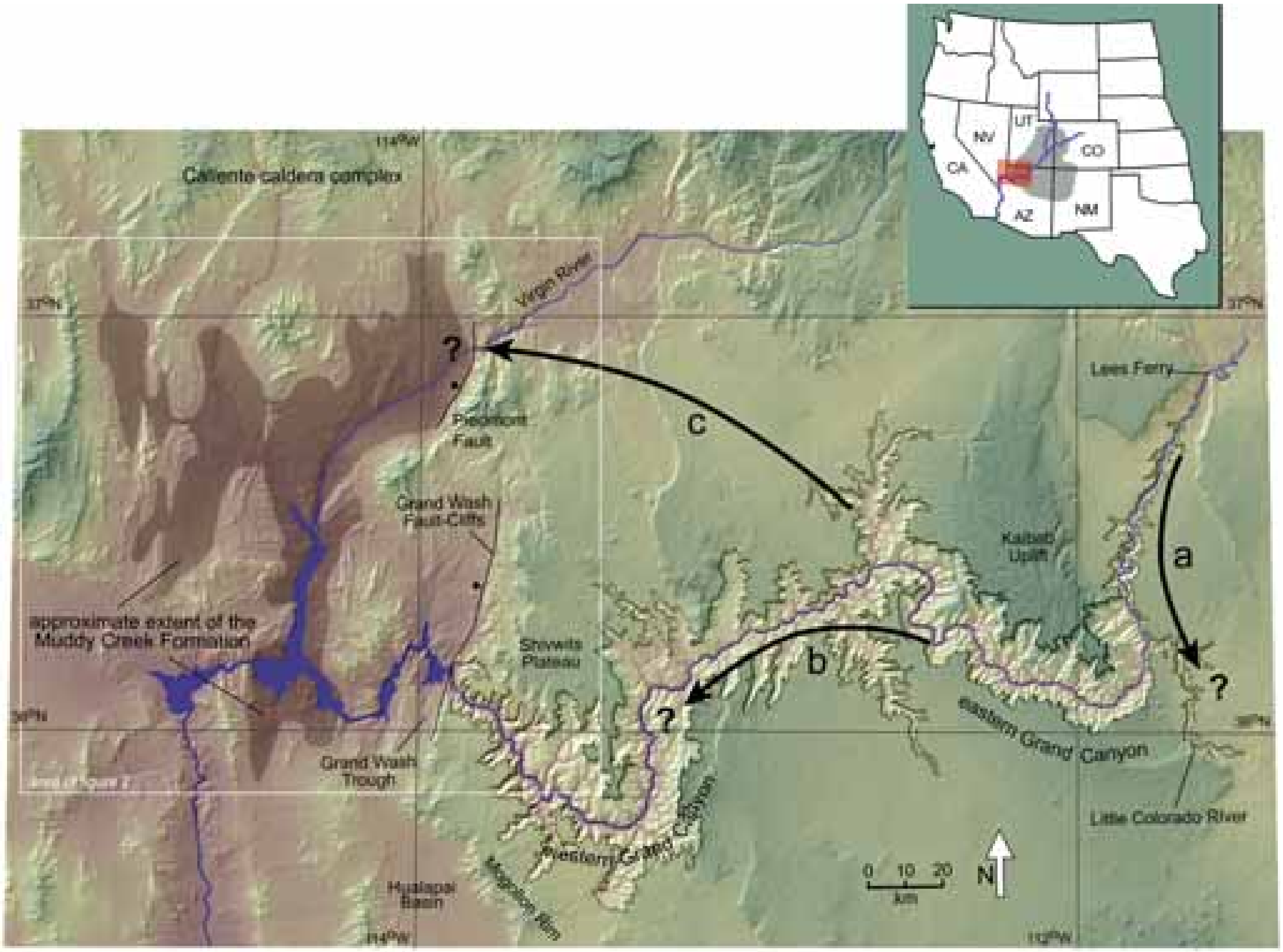
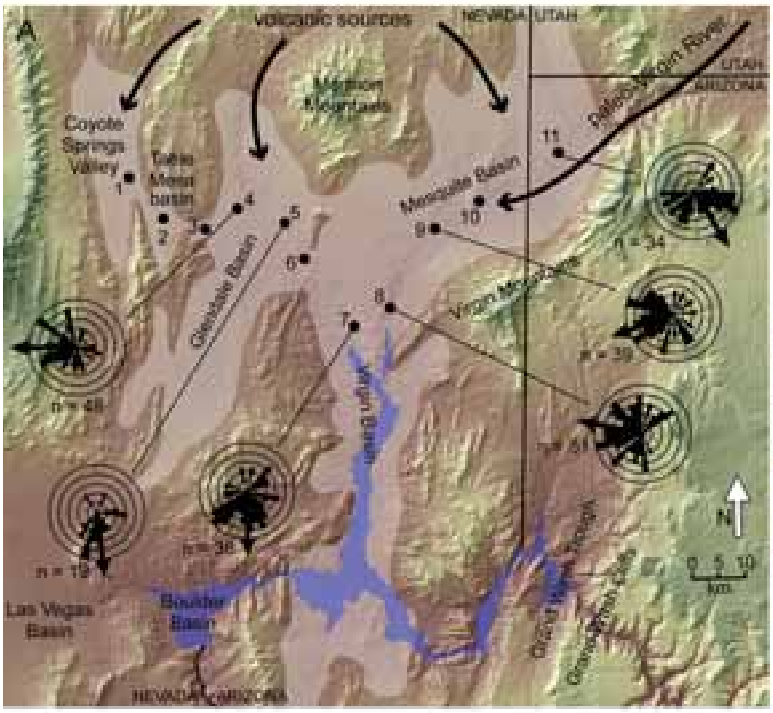


Figure 1. Regional geography and topography of Grand Canyon and Lake Mead region along the Colorado River at the edge of the Colorado Plateau (gray area of inset), southwestern United States. Large arrows indicate hypothetical paths of late Miocene upper Colorado River before major incision of Grand Canyon, with letters matching the hypotheses as reviewed in the text.

comprises local fluvial and volcaniclastic deposits rather than basin fill from an exotic river, and it is a small-volume unit with low sediment accumulation rates (Love, 1989; Dallegge et al., 2001).

Hunt's hypothesis (b), that the river arrived in the central-western Grand Canyon area and simply infiltrated and terminated, never gained traction—and was not well loved even by Hunt himself. The final hypothesis (c), that the river exited the Colorado Plateau to the northwest and debouched into the Basin and Range, has been described by Lucchitta (1990). These two ideas are both predicated upon the Colorado River gaining its path across the Kaibab uplift in middle Cenozoic time (Fig. 1). Davis (1901) and Strahler (1948) long ago recognized that the river's maneuver across this particular uplift does not require a different explanation than the one evident for the other Laramide orogens of the plateau—superposition. Indeed, thermochronological data indicate that significant canyon relief developed across the Kaibab uplift ca. 30–25 Ma, when a thick Mesozoic sedimentary section remained in the area east of the Kaibab uplift where there is now an erosional declivity (Lee, 2007; Flowers et al., 2008). It therefore seems likely that as it established its present path through the central plateau in late Oligocene–early Miocene time, the paleoriver flowed westward on the Mesozoic section, was superimposed along the curving south edge of the Kaibab uplift, and crossed into the central-western Grand Canyon region (Lucchitta, 1990).

The most viable candidate for a sedimentary record of this potential drainage in hypothesis (c) is the Muddy Creek Formation in the basins north of Lake Mead (Fig. 1). To understand the origin of this basin fill, a series of exposures and samples along a west-to-east transect from the Table Mesa basin through the Glendale Basin and into the Virgin Basin were studied to determine provenance and record how the exposed upper Muddy Creek facies change laterally (Fig. 2). Could this basin fill represent the terminus of the ancestral upper Colorado River? Longwell's (1928) original assessment of the Muddy Creek in the southern Virgin Basin was that its fine-grained sedimentary fill is incompatible with a Colorado River origin. But the Colorado River's famously large sediment load is ~90% clay, silt, and sand, and recent research on the Muddy Creek basin fill has resurrected the idea that the ancestral Colorado may have been a sediment source (Pederson et al., 2000). If this is true, then the Muddy Creek would be a slightly older analog for a series of units along the lower



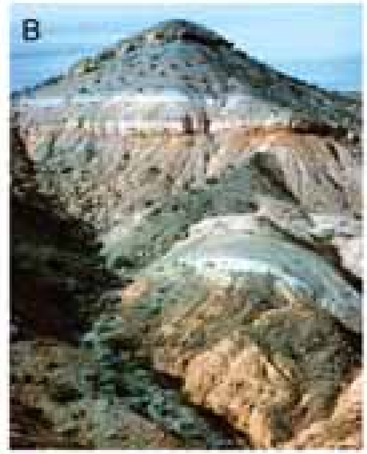


Figure 2. (A) Features of study area and transect of numbered study sites across the northern basins of the Lake Mead region. Paleocurrent data are represented in rose diagrams. Bold arrows are interpreted sediment pathways feeding the Muddy Creek Formation. Photographs illustrate trends in the Muddy Creek: (B) from Table Mesa basin between localities 1 and 2, and (C) of locality 8 on the east flank of Mormon Mesa. The unit generally coarsens upward, and finer-grained sediment of alluvial slope and lacustrine environments (B) transitions eastward to coarser fluvial sediment. Studied exposures of the middle member of the Muddy Creek lie below the younger capping or inset gravels in these photos.

Colorado River corridor and the Salton Trough, which record the progressive southward arrival and deltaic sedimentation of the early Pliocene Colorado River (cf. Lucchitta, 1972; Buising, 1990; House et al., 2005; Dorsey et al., 2007).

MUDDY CREEK FORMATION NORTH OF LAKE MEAD

The Muddy Creek Formation has been defined as the late-stage (mostly post-faulting) basin fill of a series of somewhat connected extensional basins in the Lake Mead area (Stock, 1921; Bohannon, 1984). The Muddy Creek Formation has been dated by fossils, absolute dating, and tephra correlation as from 11 Ma to ca. 5 Ma. Neither the basin fill of the Grand Wash Trough, which is termed Muddy Creek Formation by some workers, nor the Muddy Creek in the Las Vegas and Boulder basins to the southwest are included here because they were sedimentologically and topographically disconnected from the study basins (Fig. 2).

Basin-forming extension, accommodated by dip-slip on normal faults, detachment faulting, and large-scale transfer zones with oblique-slip, tapered off in the study area after middle Miocene time (e.g., Anderson, 1973; Bohannon, 1984; Duebendorfer and Simpson, 1994). An exception to this is the eastern margin of the Mesquite Basin (Fig. 1), where Pliocene and Pleistocene faulting has deformed the Muddy Creek Formation (Williams, 1996; Billingsley and Bohannon, 1995). Generally, the unit was accommodated in basins that were underfilled as local tectonic activity waned. Although these structural basins had internal surface drainage during their formation, depositional systems overtopped low divides between basins, and the region became hydrologically and sedimentologically interconnected in the late Miocene, though not externally drained. This area was subsequently integrated into the greater present-day Colorado River drainage, which ended Muddy Creek deposition and led to downcutting and incision of the fill in latest Miocene to early Pliocene time, varying according to the timing of local drainage integration (Bohannon, 1984).

The Muddy Creek Formation contains laterally gradational facies that are interpreted to range from evaporate- and travertine-rich lake deposits lower in the stratigraphy and to the south and west to pebbly fluvial gravel as the unit coarsens upward and to the east (Longwell, 1946; Bohannon, 1984; Kowallis and Everett, 1986; Dicke, 1990; Schmidt, 1994; Billingsley, 1995; Schmidt et al., 1996; Williams, 1996; Pederson et al., 2000). In the westernmost basins, the upward transition from saline-lacustrine deposits to the overlying subaerial, siliciclastic-rich deposits of the middle Muddy Creek is abrupt, suggesting basin interconnection and the introduction of extrabasinal sediment at this time (Pederson et al., 2000). The siliciclastic middle member thickens greatly to the east from ~80 m in Table Mesa basin to ~2000 m, mostly in the subsurface, in the Mesquite Basin (Bohannon et al., 1993). It is dominated by pink to light red, laminated, cross-stratified or bioturbated and massive, calcareous and gypsiferous, thin to medium interbeds of mud and sand. This fine-grained, monotonous Muddy Creek is characteristic of sediment deposited in late-stage continental basins having mostly subaerial, sedimentary environments, such as alluvial slopes (Langford et al., 1999; Smith, 2000). In most areas, coarse facies are absent in the lower and middle Muddy Creek or are restricted to piedmont gravels found at the very basin edges.

The contrasting, strongly upward-coarsening capping beds of the upper Muddy Creek Formation have been recognized across the study area and are generally early Pliocene in age (Schmidt, 1994; Williams, 1996; Pederson et al., 2001). In the western study basins, these capping beds reflect a climate-driven change to the strong progradation of piedmont gravel from local mountainsides into the basins (Pederson et al., 2001). At the east end of the study transect, part of this capping unit has been identified as Virgin River gravel entering the Mesquite Basin from the Colorado Plateau (Billingsley, 1995; Billingsley and Bohannon, 1995; Williams, 1996). The early Pliocene change from Muddy Creek deposition to incision of the basin fill is marked by the first of a series of inset piedmont gravels and Virgin River gravels in the Mesquite Basin (Schmidt, 1994; Williams, 1996).

The new data here are from outcrops of the fine-grained, siliciclastic middle member of the Muddy Creek Formation, not from the capping or inset gravels. These outcrops are probably all sediment of latest Miocene age, and the study basins were apparently connected at this stratigraphic level. The gradation from finer and more lacustrine to coarser, thicker fluvial deposits from west to east, as well as upward within the unit at a given locality, is broadly consistent with the hypothesis that a river source entered the Mesquite Basin from the east. Regarding the sources of this sediment, one may infer that, like most of the Basin and Range, the basin fill was derived from surrounding mountainsides. The Virgin Mountains on the south flank of the Mesquite Basin include Proterozoic metamorphic rock, but the mountains surrounding Coyote Springs Valley, Table Mesa basin, Glendale Basin, and Virgin Basin are dominated by a 3000-m-thick Paleozoic sedimentary succession, almost entirely of marine carbonates. Carbonate rock is strong and difficult to weather in an arid climate, and petrologic studies in the western study basins confirm that the local mountains were not a major source of the siliciclastic middle member (Pederson et al., 2001). What, then, are the extrabasinal sources of this sediment?

SEDIMENT SOURCES FOR THE MUDDY CREEK FORMATION

A series of outcrops along a west-to-east transect from the east edge of the Coyote Springs Valley and Table Mesa basin through the Glendale Basin and into the Virgin and Mesquite basins were described and sampled (sites 1–11, Fig. 2; see GSA Data Repository Table DR1[1]). All sampled localities lie ~30 m below the top of the siliciclastic middle member. Where possible, paleocurrent indications were recorded from cross-bedding and pebble imbrication. To explore the provenance of sediment, samples were collected from the study sites and their fine-sand fractions were mounted and thin-sectioned, stained for K-feldspar, and grain mineral types were counted under a microscope to a total of 400 (see data repository Table DR2 [footnote 1]). In addition, heavy-mineral suites from samples were separated using a heavy liquid. These were mounted, and minerals were counted until >400 non-opaque grains were recorded (data repository Table DR3 [footnote 1]). At localities 5, 8, and 10, vertical transects of three subsamples were taken (a, b, and c) and spaced through the entire exposure of the middle member, in order to explore trends as the unit coarsens upward.

Petrographic analyses were also made on samples of unconsolidated sand representative of five distinct sediment sources: a lower-member sample from Table Mesa basin derived from local Paleozoic bedrock (sample LoC); a sample from Pleistocene alluvium of Beaver Dam Wash in the Mesquite Basin derived from volcanic terrain of the Caliente caldera complex (sample LoV); Pleistocene piedmont alluvium on the north flank of the Virgin Mountains derived from metamorphic bedrock (sample LoM); Pleistocene Virgin River sand sampled from a terrace where the river enters the eastern Mesquite Basin upstream of Littlefield, Arizona (sample VR); and Pleistocene Colorado River sand from a terrace at Lees Ferry (sample CR). This last sample is intended to approximate the composition of sand from an ancestral Colorado River. The Miocene upper drainage would have been eroding mostly the Mesozoic and early Cenozoic sections of the plateau, just as the present river above Lees Ferry does, and the paleodrainage would have lacked Paleozoic detritus before the deep incision of Grand Canyon downstream of Lees Ferry (Fig. 1; Pederson et al., 2002b).

The sedimentology of the upper-middle member of the Muddy Creek at the study sites is consistent with the overall trend of coarsening upward and coarsening to the east, becoming more fluvial in depositional environment (Table DR1 [see footnote 1]). For example, localities 1–3 on the western end of the transect are characterized by sandy calcareous and gypsiferous mud likely deposited in shallow lacustrine or alluvial slope environments (Fig. 2B). Starting at locality 4 in the western Glendale Basin, these facies become interbedded with lenticular channel sand and gravel bodies; a few eolian sand beds confirm subaerial deposition. Eastward to the Virgin Basin, the predominant facies is lenticular crossbedded pebbly sand interbedded with overbank fines (Table DR1; Fig. 2C). This general picture is, however, locally complicated. Paleocurrent indicators at localities 5, 7, and 11 are south- or southeast-directed instead of westward, and the sediments at these same localities do not follow the trend of coarsening to the east (Fig. 2; Table DR1). Localities 1 and 5 are anomalously coarser-grained relative to neighboring localities, and the easternmost of all localities (11), near the hypothetical mouth of the paleoriver source, has fine-grained deposits and southeast-directed paleocurrents.

Transect and source-area samples are plotted in ternary diagrams (Tables DR2 and DR3 [see footnote 1]) with endpoint grain types chosen to best distinguish sediment sources (Fig. 3), because traditional quartz-feldspar-lithics (QFL) plots do not

[1]GSA Data Repository item 2008077, sedimentary descriptions and petrographic point-count data, is available at www.geosociety.org/pubs/ft2008.htm. You can also obtain a copy by writing to editing@geosociety.org.

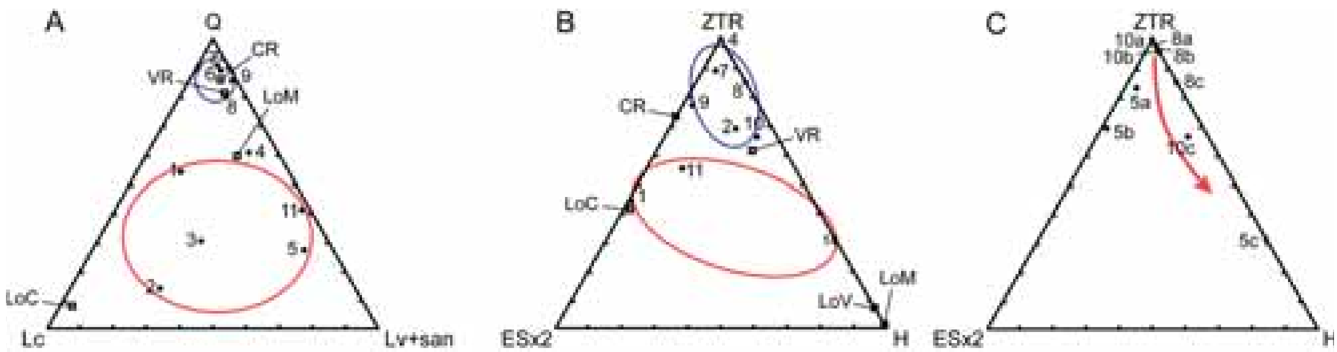


Figure 3. Ternary plots of Muddy Creek Formation samples representing possible sediment sources (data are summarized in GSA Data Repository Tables DR2 and DR3 [see text footnote 1]). Plotted numbers correspond to samples from locations on Figure 2 and Table DR1. Plotted letters are samples representing sediment sources: CR—Colorado River; VR—Virgin River; LoM—local metamorphic terrain; LoC—local carbonate terrain; LoV—volcanic bedrock source. (A) Plot of grain-mount results with corner points designed to distinguish potential sediment sources; Q—quartz; Lc—carbonate lithics; Lv+san—volcanic lithics and sanidine. Ovals outline two populations: one with a compositionally mature exotic river source and another that is a combination of local and volcanic sediment sources. No data for location 10. (B) Plot of heavy mineral results: ZTR—zircon, tourmaline, and rutile maturity index distinguishing exotic fluvial sources; ES×2—epidote and sphene counts multiplied by two in order to draw from the right axis those samples with a component of local Paleozoic sources; H—hornblende for sediment with volcanic and metamorphic bedrock sources. Ovals outline the same two populations of samples. (C) Heavy mineral plot showing vertical transect samples at localities 5, 8, and 10, going from base (a) to top (c) of exposed middle member. Note trend of increasing volcanic input upward in the section (red arrow).

succeed in this. The "Lc" apex represents lithic carbonate grains derived from Paleozoic carbonate bedrock of the surrounding mountains. "Lv+san" comprises volcanic lithic clasts and sanidine, which must be derived from the volcanic terrain to the north of the basins. Likewise, the "ES×2" apex of the heavy mineral plots is intended to draw out local carbonate bedrock sources, which produce very low heavy-mineral yields. The low abundances of epidote and sphene, perhaps recycled from yet older basement sources, are amplified and used in the absence of more indicative minerals. Hornblende is abundant in the heavy-mineral suites of both metamorphic and volcanic bedrock sources. Finally, quartz and the zircon-tourmaline-rutile (ZTR) heavy-mineral maturity index are intended to distinguish the mature compositions of the Colorado and Virgin rivers.

The ternary plots reveal two populations of samples (Figs. 3A and 3B). One set is interpreted as a mixture of local carbonate and metamorphic sources, as well as slightly farther-traveled volcanic detritus (red oval). The other population is similar to sediment of the Colorado and Virgin rivers (blue oval). Only the three westernmost samples (localities 1–3) have significant local Paleozoic carbonate bedrock contributions. Volcanic sources are strongly represented at localities 5 and 11, and samples from localities 6–10 in the central part of the transect are compositionally mature (relatively rich in quartz and ZTR), like Colorado and Virgin rivers samples (Figs. 3A and 3B). Heavy-mineral results are less distinct than light mineral grains, but the vertical transects at locations 5, 8, and 10 indicate an increased contribution from volcanic sources upward through the sections, from subsamples a–c (Fig. 3C). The result that local sources dominate areas to the west and north, whereas compositionally mature sediment is more abundant in the southern Mesquite Basin, confirms that an exotic sediment source from the east (the Colorado Plateau) provided sand lacking in carbonate-, volcanic-, and basement-derived grains.

If a major paleo–Colorado River entered the east end of the Mesquite Basin, sample compositions from locations 1–11 should become increasingly similar to Colorado River sediment from west to east. However, they do not (Figs. 3A and 3B). Petrographic results instead indicate a significant contribution to the Muddy Creek Formation by volcanic sources, including at the easternmost sample locality, consistent with the sedimentologic and paleocurrent observations (Table DR1 [see footnote 1]; Fig. 2). The middle member also becomes more volcanically derived as it coarsens upward (Fig. 3C). This matches the present-day pattern of large drainages that have source areas in the volcanic terrain of the Caliente and Kane Springs caldera complexes to the north (Figs. 1 and 2). Colorado River and Virgin River sands are compositionally similar and cannot be distinguished by these petrographic data alone. In fact, sample compositions may be explained entirely with an ancestral Virgin River source, consistent with field evidence for a Virgin River source in the Muddy Creek Formation of the Mesquite Basin (Billingsley, 1995; Billingsley and Bohannon, 1995; Williams, 1996).

DISCUSSION

Geographically, the Muddy Creek Formation is a logical candidate for terminal deposits of a pre–Grand Canyon Colorado River. There is evidence for a moderate amount of extra-basinal fluvial sediment entering the Mesquite Basin in late-Miocene time, but the most likely candidate for this is the ancestral Virgin River. Sedimentological, petrographic, and field data indicate that Miocene sediment pathways imitated present-day drainage patterns into these basins (Fig. 2) and that much of the Muddy Creek is derived from volcanic terrain to the north of the Mormon Mountains. Therefore, a northwest passage out of the Grand Canyon region with a Muddy Creek Formation terminus for the ancestral Colorado River can be ruled out.

A single hypothesis for the fate of the Miocene Colorado River remains: Hunt's largely forgotten idea that a relatively meager paleo–Colorado River made its way to the central-western Grand Canyon region and infiltrated into the cavernous

Paleozoic limestones that dominate the bedrock there. The concept of a major drainage area terminating in a desert basin is not far-fetched. Modern analogs of the same scale as the upper Colorado or larger include (1) the greater Tarim River system and tributaries draining the high Kunlun and Tien Shan and ending in the deserts of northeast China's Tarim Basin; (2) the Cubango-Okavango River rising in Angola and terminating in its famous delta at the edge of the Kalahari; and (3) the large drainages leading to Lake Eyre and other central basins of Australia. Closer by are the significant, mountain-fed drainages of the northern Great Basin that terminate in the saline lakes and pans of the Bonneville and Lahontan Basins.

The infiltration and dissipation hypothesis may help resolve more than one conundrum, including the mechanics of the capture of the upper Colorado River. Blackwelder (1934) and Longwell (1946) recognized early on that the upper Colorado River could have been captured by either top-to-bottom spilling over divides or by headward erosion. Headward erosion as a process has an inherent shortcoming, expressed by Charlie Hunt as the problem of the "precocious gully" (Hunt, 1969). How could the head of a single drainage along a desert escarpment have the necessary stream power or mass-movement activity to erode headward and shift its divide hundreds of kilometers, when none of its neighbors could lengthen measurably at all? On the other hand, although House et al. (2005) have shown that the lower Colorado River corridor was integrated by spilling over topographic divides, there are problems in applying this mechanism to the drainage in the Grand Canyon region. Specifically, why are there no distinctive lacustrine and deltaic sedimentary remnants in the southern plateau like the younger examples that record basin spillover along the lower Colorado corridor? Instead, there are late Miocene volcanic rocks and deposits attributed to local streams (Lucchitta and Jeanne, 2001; Love, 1989).

Perhaps the best solution for the integration of the Colorado River involves different styles of both headward erosion and basin spillover, with the key factor being groundwater. Surface drainage capture typically follows capture of the groundwater drainage by lower, adjacent topography (Pederson, 2001). Groundwater sapping and spring discharge then provide viable erosion mechanisms for a surface drainage to extend headward. There is also the possibility that a karst plumbing system formed by this groundwater could have collapsed, aiding in surface drainage development. The now-dissected karst system exposed in the walls of western Grand Canyon is impressive and may provide a history of Neogene groundwater lowering and canyon formation (Polyak et al., 2007). Finally, infiltrated water from the Miocene plateau likely would have resurfaced through springs in the low basins neighboring the plateau edge. Hunt (1969) suggested this was the source of the Hualapai Limestone of the Grand Wash Trough, and Colorado River infiltration could have provided the needed source for the voluminous Miocene spring deposits in the Hualapai Basin and elsewhere in the Lake Mead region (Fig. 1; Faulds et al., 1997, 2001).

In summary, the ancestral Colorado River itself may not have made it off the plateau until 6 Ma, although it seems likely that part of its water did. But where is the paleoriver's sediment? The Miocene upper drainage, having lower relief, a relatively steady, arid climate, and not having been fully integrated to its present size, must have had a relatively minor sediment load. The burden it did carry may have been transported away by wind or stored elsewhere along its path through the central plateau, a region that subsequently has been deeply exhumed. This remains yet another conundrum. For now, Hunt's dissipation and infiltration hypothesis is the last one left standing against the geologic evidence in the region.

ACKNOWLEDGMENTS

Part of the petrographic data of this study was produced by Jamie Farrell for his senior thesis at Utah State University. This research relied upon the groundwork laid by the late desert geologist Dwight Schmidt on the sedimentology, hydrology, and geomorphology of these basins. The manuscript was greatly improved by reviews from Rebecca Dorsey, Tim Lawton, Paul McCarthy, and Stephen Johnston.

REFERENCES CITED

Anderson, R.E., 1973, Large-magnitude Late Tertiary strike-slip faulting north of Lake Mead, Nevada: U.S. Geological Survey Professional Paper 794, 18 p.

Billingsley, G.H., 1995, Geologic map of the Littlefield quadrangle, northern Mohave County, Arizona: U.S. Geological Survey Open-File Report 95-559, 15 p., scale 1:24,000.

Billingsley, G.H., and Bohannon, R.C., 1995, Geologic map of the Elbow Canyon quadrangle, northern Mohave County, Arizona: U.S. Geological Survey Open-File Report 95-560, 16 p., scale 1:24,000.

Blackwelder, E., 1934, Origin of the Colorado River: Geological Society of America Bulletin, v. 45, p. 551–566.

Bohannon, R.G., 1984, Nonmarine sedimentary rocks of Tertiary age in the Lake Mead region, southeastern Nevada and northwestern Arizona: U.S. Geological Survey Professional Paper 1259, 72 p.

Bohannon, R.G., Grow, J.A., Miller, J.J., and Blank, R.H., Jr., 1993, Seismic stratigraphy and tectonic development of Virgin River depression and associated basins, southeastern Nevada and northwestern Arizona: Geological Society of America Bulletin, v. 105, p. 501–520, doi: 10.1130/0016-7606(1993)105<0501:SSATDO>2.3.CO;2.

Buising, A.V., 1990, The Bouse Formation and bracketing units, southeastern California and western Arizona: Implications for the evolution of the proto–Gulf of California and the lower Colorado River: Journal of Geophysical Research, v. 95, p. 20,111–20,132.

Cather, S.M., Connell, S.D., Chamberlin, R.M., Jones, G.E., Potochnik, A.R., Lucas, S.G., and Johnson, P.S., 2008, The Chuska erg: Paleogeomorphic and paleoclimatic implications of an Oligocene sand sea on the Colorado Plateau: Geological Society of America Bulletin, v. 120, p. 13–33, doi: 10.1130/B26081.1.

Dallegge, T.A., Ort, M.H., McIntosh, W.C., and Perkins, M.E., 2001, Age and depositional basin morphology of the Bidahochi Formation and implications for the ancestral upper Colorado River, *in* Young, R.A., and Spamer, E.E., eds., The Colorado River: Origin and evolution: Grand Canyon, Arizona, Grand Canyon Association Monograph 12, p. 47–52.

Davis, W.M., 1901, An excursion to the Grand Canyon of the Colorado: Bulletin of the Museum of Comparative Zoology, Harvard College, v. 38, Geological Series, no. 4, p. 107–201.

Dicke, S.M., 1990, Stratigraphy and sedimentology of the Muddy Creek Formation, Southeastern Nevada [M.S. Thesis]: Lawrence, University of Kansas, 36 p.

Dorsey, R.J., Fluette, A., McDougall, K., Housen, B.A., Janecke, S.U., Axen, G.J., and Shirvell, C.R., 2007, Chronology of Miocene-Pliocene deposits at Split Mountain Gorge, southern California: A record of regional tectonics and Colorado River evolution: Geology, v. 35, p. 57–60, doi: 10.1130/G23139A.1.

Duebendorfer, E.M., and Simpson, D.A., 1994, Kinematics and timing of Tertiary extension in the western Lake Mead region, Nevada: Geological Society of America Bulletin, v. 106, p. 1057–1073, doi: 10.1130/0016-7606(1994)106<1057:KATOTE>2.3.CO;2.

Faulds, J.E., Schreiber, B.C., Reynolds, S.J., Gonzalez, L.A., and Okaya, D., 1997, Origin and paleogeography of an immense, nonmarine Miocene salt deposit in the Basin and Range (western USA): The Journal of Geology, v. 105, p. 19–36.

Faulds, J.E., Price, L.M., and Wallace, M.A., 2001, Depositional environment and paleogeographic implications of the Late Miocene Hualapai Limestone, northwestern Arizona and southern Nevada, *in* Young, R.A., and Spamer, E.E., Colorado River Origin and Evolution: Grand Canyon, Arizona, Grand Canyon Association Monograph No. 12, p. 81–87.

Flowers, R.M., Wernicke, B.P., and Farley, K.A., 2008, Unroofing, incision and uplift history of the southwestern Colorado Plateau from (U-Th)/He apatite thermochronometry: Geological Society of America Bulletin, in press.

House, P.K., Pearthree, P.A., Howard, K.A., Bell, J.W., Perkins, M.E., and Brock, A.L., 2005, Birth of the lower Colorado River—Stratigraphic and geomorphic

evidence for its inception near the conjunction of Nevada, Arizona, and California, *in* Pederson, J., and Dehler, C.M., eds., Interior western United States: Geological Society of America Field Guide 6, p. 357–388.
Hunt, C.B., 1956, Cenozoic geology of the Colorado Plateau: U.S. Geological Survey Professional Paper 279, 99 p.
Hunt, C.B., 1969, Geologic history of the Colorado River, *in* The Colorado River Region and John Wesley Powell: U.S. Geological Survey Professional Paper 669-C, p. 59–130.
Kowallis, B.J., and Everett, B.H., 1986, Sedimentary environments of the Muddy Creek Formation near Mesquite, Nevada, *in* Thrusting and extensional structures and mineralization in the Beaver Dam Mountains, southwestern Utah: Salt Lake City, Utah Geological Association Publication 15, p. 69–75.
Langford, R.P., Jackson, M.L.W., and Whitelaw, M.J., 1999, The Miocene to Pleistocene filling of a mature extensional basin in Trans-Pecos Texas: Geomorphic and hydrologic controls on deposition: Sedimentary Geology, v. 128, p. 131–153, doi: 10.1016/S0037-0738(99)00065-2.
Lee, J.P., 2007, Cenozoic unroofing of the Grand Canyon region, Arizona [M.S. Thesis]: Lawrence, University of Kansas, 119 p.
Longwell, C.R., 1928, Geology of the Muddy Mountains, Nevada: U.S. Geological Survey Bulletin 798, p. 91–97.
Longwell, C.R., 1946, How old is the Colorado River?: American Journal of Science, v. 244, no. 12, p. 817–835.
Love, D.W., 1989, Bidahochi Formation: An interpretive summary, *in* Anderson, O.J., ed., Southwestern Colorado Plateau: Socorro, New Mexico Geological Society Fortieth Field Conference Guidebook, p. 273–280.
Lucchitta, I., 1966, Cenozoic geology of the upper Lake Mead area adjacent to the Grand Wash Cliffs, Arizona [Ph.D. dissertation]: State College, Pennsylvania State University, 218 p.
Lucchitta, I., 1972, Early history of the Colorado River in the Basin and Range Province: Geological Society of America Bulletin, v. 83, p. 1933–1948, doi: 10.1130/0016-7606(1972)83[1933:EHOTCR]2.0.CO;2.
Lucchitta, I., 1990, History of the Grand Canyon and of the Colorado River in Arizona, *in* Beus, S., and Morales, M., eds., Grand Canyon geology: New York, Oxford University Press, p. 311–332.
Lucchitta, I., and Jeanne, R.A., 2001, Geomorphic features and processes of the Shivwits Plateau, Arizona, and their constraints on the age of western Grand Canyon, *in* Young, R.A., and Spamer, E.E., eds., The Colorado River: Origin and evolution: Grand Canyon, Arizona, Grand Canyon Association Monograph 12, p. 65–70.
McKee, E.D., and McKee, E.H., 1972, Pliocene uplift of the Grand Canyon region—Time of drainage adjustment: Geological Society of America Bulletin, v. 83, p. 1923–1932, doi: 10.1130/0016-7606(1972)83[1923:PUOTGC]2.0.CO;2.
McKee, E.D., Wilson, R.F., Breed, W.J., and Breed, C.S., eds., 1967, Evolution of the Colorado River in Arizona: Flagstaff, Arizona, Museum of Northern Arizona Bulletin 44, 74 p.
Pederson, D.T., 2001, Stream piracy revisited: A groundwater sapping solution: GSA Today, v. 11, no. 9, p. 4–10, doi: 10.1130/1052-5173(2001)011<0004:SPRAGS>2.0.CO;2.
Pederson, J.L., Pazzaglia, F.J., Smith, G.A., and Mou, Y., 2000, Neogene through Quaternary hillslope records, basin sedimentation, and landscape evolution of southeast Nevada, *in* Lageson, D.E., Peters, S.G., and Lahren, M.M., eds., Great Basin and Sierra Nevada: Geological Society of America Field Guide 2, p. 117–134.
Pederson, J.L., Smith, G.A., and Pazzaglia, F.J., 2001, Comparing the Neogene, Quaternary, and modern records of climate-controlled hillslope sedimentation in southeast Nevada: Geological Society of America Bulletin, v. 113, p. 305–319, doi: 10.1130/0016-7606(2001)113<0305:CTMQAN>2.0.CO;2.
Pederson, J., Karlstrom, K., Sharp, W., and McIntosh, W., 2002a, Differential incision of Grand Canyon related to Quaternary faulting—Constraints from U-series and Ar/Ar dating: Geology, v. 30, p. 739–742, doi: 10.1130/0091-7613(2002)030<0739:DIOTGC>2.0.CO;2.
Pederson, J.L., Mackley, R.D., and Eddleman, J.L., 2002b, Colorado Plateau uplift and erosion—amounts and causes evaluated with GIS: GSA Today, v. 12, no. 8, p. 4–10, doi: 10.1130/1052-5173(2002)012<0004:CPUAEE>2.0.CO;2.
Polyak, V.J., Hill, C.A., and Asmerom, Y., 2007, Timing of formation of Grand Canyon from U-Pb dates on groundwater-table speleothems: Geological Society of America Abstracts with Programs, v. 39, no. 6, p. 513.
Powell, J.W., 1875, Exploration of the Colorado River of the West and its tributaries: Washington, D.C., U.S. Government Printing Office, 291 p.
Schmidt, D.L., 1994, Preliminary geologic map of the Farrier Quadrangle, Clark and Lincoln Counties, Nevada: U.S. Geological Survey Open File Report OF 94-625, 31 p., scale 1:24,000.
Schmidt, D.L., Page, W.R., and Workman, J.B., 1996, Geologic map of the Moapa West quadrangle, Clark County, Nevada: U.S. Geological Survey Open File Report OF 96-521, 17 p., scale 1:24,000.
Smith, G.A., 2000, Recognition and significance of streamflow-dominated piedmont facies in extensional basins: Basin Research, v. 12, p. 399–411, doi: 10.1046/j.1365-2117.2000.00125.x.
Stock, C., 1921, Later Cenozoic mammalian remains from Meadow Valley Region, southeastern Nevada: American Journal of Science, 5th series, v. 2, p. 250–264.
Strahler, A.N., 1948, Geomorphology and structure of the West Kaibab fault zone and Kaibab Plateau, Arizona: Geological Society of America Bulletin, v. 59, p. 513–540, doi: 10.1130/0016-7606(1948)59[513:GASOTW]2.0.CO;2.
Walcott, C.D., 1890, Study of a line of displacement in the Grand Canyon of the Colorado, in northern Arizona: Geological Society of America Bulletin, v. 1, p. 49–64.
Williams, V.S., 1996, Preliminary Geologic Map of the Mesquite Quadrangle, Clark and Lincoln Counties, Nevada and Mohave Counties, Arizona: U.S. Geological Survey Open-File Report OF 96-676: http://pubs.usgs.gov/of/1996/ofr-96-0676/, scale 1:24,000.
Young, R.A., and Brennan, W.J., 1974, Peach Springs Tuff: Its bearing on structural evolution of the Colorado Plateau and development of Cenozoic drainage in Mohave County, Arizona: Geological Society of America Bulletin, v. 85, p. 83–90, doi: 10.1130/0016-7606(1974)85<83:PSTIBO>2.0.CO;2.
Young, R.A., and McKee, E.H., 1978, Early and middle Cenozoic drainage and erosion in west-central Arizona: Geological Society of America Bulletin, v. 89, p. 1745–1750, doi: 10.1130/0016-7606(1978)89<1745:EAMCDA>2.0.CO;2.

Manuscript received 14 June 2007; accepted 4 January 2008.

THE GEOLOGICAL SOCIETY OF AMERICA®

2007 AMERICAN GEOLOGICAL INSTITUTE (AGI) Medal in Memory of Ian Campbell

AGI MEDAL IN MEMORY OF IAN CAMPBELL
Arthur A. Socolow
Pennsylvania Geological Survey

The 2007 AGI Medal in Memory of Ian Campbell was presented to Arthur A. Socolow of the Pennsylvania Geological Survey (retired) at the GSA Annual Meeting in Denver, Colorado, October 2007. The citationist was Walter A. Anderson, and the award was accepted by Dr. Socolow's son, Carl Socolow.

This AGI Medal is given in recognition of singular performance in and contribution to the profession of geology. Candidates are measured against the distinguished career of Ian Campbell, whose service to the profession touched virtually every facet of the geosciences. Campbell was a most uncommon man of remarkable accomplishment and widespread influence. In his career as a geologist, educator, administrator, and public servant, he was noted for his candor and integrity.

ATTENTION VOTING MEMBERS

GSA Elections Start 13 March 2008

The success of GSA depends on you, its Members, and on the work of the elected officers who serve on GSA's Executive Committee and Council. All GSA member types are eligible to vote.

You will receive a postcard this month with instructions for accessing our secure Web site and your electronic ballot. Biographical information on each candidate is available for review at **www.geosociety.org**. Paper versions of the ballot and candidate information are also available.

Please make your wishes known by voting for the nominees listed here.

THE GEOLOGICAL SOCIETY OF AMERICA®

JULY 2008 OFFICER AND COUNCILOR NOMINEES

PRESIDENT
(July 2008–June 2009)
Judith Totman Parrish
University of Idaho
Moscow, Idaho, USA

VICE PRESIDENT
(July 2008–June 2009)
Jean M. Bahr
University of Wisconsin–Madison
Madison, Wisconsin, USA

TREASURER
(July 2008–June 2009)
Robbie R. Gries
Priority Oil & Gas LLC
Denver, Colorado, USA

COUNCILOR Position 1
(July 2008–June 2012)
Brian R. Pratt
University of Saskatchewan
Saskatoon, Saskatchewan, Canada

Víctor A. Ramos
Universidad de Buenos Aires
Buenos Aires, Argentina

COUNCILOR Position 2
(July 2008–June 2012)
Antonio Arribas Jr.
Newmont Mining Company
Castle Rock, Colorado, USA

Murray W. Hitzman
Colorado School of Mines
Golden, Colorado, USA

COUNCILOR Position 3
(July 2008–June 2012)
Janet S. Herman
University of Virginia
Charlottesville, Virginia, USA

Claudia I. Mora
University of Tennessee–Knoxville
Knoxville, Tennessee, USA

Ballots must be submitted electronically or postmarked by 13 April 2008.

UPCOMING DEADLINES

MARCH

33rd International Geological Congress Travel Grant Program†—Applications due 1 March 2008 at www.geosociety.org/grants/travel.htm, with supplemental material sent to awards@geosociety.org.

John C. Frye Environmental Geology Award*—Nominations due 31 March 2008 to Grants, Awards, and Recognition, GSA, 3300 Penrose Place, P.O. Box 9140, Boulder, CO 80301-9140, USA.

APRIL

Don J. Easterbrook Distinguished Scientist Award* (Quaternary Geology and Geomorphology Division)—Nominations due 2 April 2008 to Lisa L. Ely, Dept. of Geological Sciences, 400 E. University Way, Central Washington University, Ellensburg, WA 98926, USA, +1-509-963-2821, ely@cwu.edu.

Farouk El-Baz Award for Desert Research* (Quaternary Geology and Geomorphology Division)—Nominations due 2 April 2008 to Marith C. Reheis, U.S. Geological Survey, MS 980, Federal Center, P.O. Box 25046, Denver, CO 80225-0046, USA, +1-303-277-1843, mreheis@usgs.gov.

National Awards*: William T. Pecora Award, National Medal of Science, Vannevar Bush Award, and Alan T. Waterman Award—Nominations due 30 April 2008 to Grants, Awards, and Recognition, GSA, 3300 Penrose Place, P.O. Box 9140, Boulder, CO 80301-9140, USA.

Stephen E. Dwornik Student Research Paper Award†—For papers presented at the 10–14 March 2008 39th Lunar and Planetary Science Conference; see www.lpi.usra.edu/meetings.

*For details, see the October 2007 *GSA Today*, visit www.geosociety.org/awards, or call +1-303-357-1028. Division named award funds are administered by GSA Foundation.

†For more information, see the January 2008 *GSA Today*.

2008 Section Meeting & Mentor Program Calendar

CORDILLERAN AND ROCKY MOUNTAIN JOINT MEETING — 19–21 March

University of Nevada, Las Vegas, Nevada
www.geosociety.org/sectdiv/cord/08mtg/
General meeting co-chairs: Rod Metcalf, +1-702-895-4442, rod.metcalf@unlv.edu; Larry Middleton, +1-928-523-2429, larry.middleton@nau.edu.
Shlemon Mentor Program Luncheons:
Thurs.–Fri., 20–21 March, 11:30 a.m.–1:00 p.m.
Mann Mentors in Applied Hydrogeology Program:
Thurs., 20 March, 5–6:30 p.m.

NORTHEASTERN — 27–29 March

Hyatt Regency Buffalo, Buffalo, New York
www.geosociety.org/sectdiv/northe/08mtg/
Meeting chair: Gary Solar, +1-716-472-7015, solargs@buffalostate.edu.
Shlemon Mentor Program Luncheons:
Thurs.–Fri., 27–28 March, 11:30 a.m.–1:00 p.m.
Mann Mentors in Applied Hydrogeology Program:
Thurs., 27 March, 5–6:30 p.m.

SOUTH-CENTRAL — 30 March–1 April

Hot Springs Convention Center, Hot Springs, Arkansas
www.geosociety.org/sectdiv/southc/08mtg/
Local Committee chairs: Jeff Connelly, +1-501-569-3543, jbconnelly@ualr.edu; Scott Ausbrooks, +1-501-683-0119, scott.ausbrooks@arkansas.gov.
Shlemon Mentor Program Luncheons:
Mon.–Tues., 31 March–1 April, 11:30 a.m.–1:00 p.m.
Mann Mentors in Applied Hydrogeology Program:
Mon., 31 March, 5–6:30 p.m.

SOUTHEASTERN — 10–11 April

Hilton Charlotte University Place, Charlotte, North Carolina
www.geosociety.org/sectdiv/southe/08mtg/
Local Committee chair: Andy R. Bobyarchick, +1-704-687-5998, arbobyar@uncc.edu.
Shlemon Mentor Program Luncheons:
Thurs.–Fri., 10–11 April, 11:30 a.m.–1:00 p.m.
Mann Mentors in Applied Hydrogeology Program:
Thurs., 10 April, 5–6:30 p.m.

NORTH-CENTRAL — 24–25 April

Casino Aztar, Evansville, Indiana
www.geosociety.org/sectdiv/northc/08mtg/
Local committee chairs: Paul K. Doss, +1-812-465-7132, pdoss@usi.edu; John P. Szabo, jpszabo@uakron.edu.
Shlemon Mentor Program Luncheons:
Thurs.–Fri., 24–25 April, 11:30 a.m.–1:00 p.m.
Mann Mentors in Applied Hydrogeology Program:
Thurs., 24 April, 5–6:30 p.m.

Mentor programs are sponsored by the GSA Foundation.

THE GEOLOGICAL SOCIETY OF AMERICA®

Extension of a Continent: Architecture, Rheological Coupling, and Heat Budget

Conveners

Uwe Ring, *Department of Geological Sciences, Canterbury University, Christchurch 8140, New Zealand, uwe.ring@canterbury.ac.nz*

Brian Wernicke, *Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California 91125, USA, brian@gps.caltech.edu*

Klaus Regenauer-Lieb, *School of Earth and Geographical Sciences, University of Western Australia, Crawley 6009 WA, Australia, klaus@cyllene.uwa.edu.au*

Charalampos Fassoulas, *Natural History Museum, University of Crete, Heraklion 71409, Crete, Greece, fassoulas@nhmc.uoc.gr*

Continental breakup and the formation of oceanic basins are fundamental processes in earth sciences. Most of our process understanding of the early and intermediate stages of continental extension comes from landborne studies of incipient or failed rifts. Over the past two decades, there has also been a growing appreciation of the role of extensional tectonics in convergent orogens. This trend was initiated early on by the discovery of highly attenuated crustal sections in the Basin and Range province and the recognition that the attenuation was caused by regional-scale horizontal extension, as manifested by low-angle normal faulting.

The Aegean Sea above the retreating Hellenic subduction zone is a well-known example of large-scale continental extension. Horizontal extension in the Aegean occurs directly above the subducting plate, and lithospheric extension is caused by slab rollback. Extension in the Aegean occurs from the forearc through the backarc. Furthermore, it is an onshore-offshore ("amphibian") setting that allows combining land- and seaborne studies. Within this context, we organized a Penrose Conference to examine all processes that contribute to horizontal extension of continental lithosphere and the origin of oceanic basins.

CONFERENCE DETAILS

The conference was held on 8–12 October 2007 at the Naxos Palace Hotel on the Island of Naxos in the Aegean Sea of Greece. It included three days of presentations and two days of field trips. There were 78 participants, 34 from the United States, 13 from Australia, seven from Greece, six from France, five from Switzerland, four from the UK, three from New Zealand, and one each from Canada, Israel, Norway, Finland, Germany, and Spain. The participants included 17 Ph.D. students, and the conference had a relatively large number of women participants: 11 professionals and six students.

FIELD TRIPS

Field trips were lead by Olivier Vanderhaeghe from Université de Nancy in France and his colleagues Christian Hibsch, Luc Siebenaller, and Seth Kruckenberg and focused on geologic evidence for Miocene extension and associated high-temperature metamorphism and migmatization. The Island of Naxos is presently in the backarc of the south-facing Hellenic subduction zone, but extension commenced while the island was gradually shifting from a forearc into an intra-arc position. The island has spectacular exposures of high-temperature metamorphic rocks that formed as a consequence of lithospheric extension at depths of ~30 km and were rapidly exhumed in the Miocene.

SESSION DETAILS

Session 1: Observations and Models of Narrow Continental Rifts

Brian Wernicke opened the conference with a summary of previous Penrose Conferences on orogenic process and what their major impact on the community was. Cindy Ebinger followed with her keynote on three-dimensional (3-D) aspects of continental breakup using the East Africa Rift. Paul Umhoefer presented new data from the very fast spreading Gulf of California. In contrast to the East African rift, oblique rifting in the Gulf of California initiated above an active continental margin.

Panel discussions focused on differences and common aspects of three narrow rifts, the Taupo Volcanic Zone in New Zealand, the Afar triangle in Ethiopia, and the Gulf of California. The major topic was the role magmas plays in weakening the lithosphere and what mechanism is subsequently driving extension. A key question was how much rifting has to take place before magmatism takes over and controls the breakup processes. Recurring themes throughout the conference were the roles of temperature, magmatism, and differential extension between various layers of the lithosphere in the upper and middle-lower crust and the lithospheric mantle and gravitational potential energy.

Session 2: Local Expression of Extensional Deformation and the Role and Significance of Low-Angle Normal Faulting in Accommodating Large-Scale Extension

This session focused on the old controversy of whether low-angle normal faults exist in nature or not. Gordon Lister's keynote presented examples from the Basin and Range province arguing for incontrovertible evidence for the existence of low-angle normal faults, a view that Nick Christie-Blick challenged in his subsequent talk. Later on, Daniel Stockli summarized the newest developments in low-temperature thermochronology. Brian Tucholke showed how normal faulting contributes to extension and mantle exhumation in weakly magmatic rifts and mid-oceanic ridges.

The panel debated the low-angle paradox in a lively fashion. It was stressed that there are numerous examples from extensional settings worldwide that appear to prove the existence of low-angle normal faults and that they are capable of achieving large-magnitude extension. Another major issue was the relationship between ductile extensional shear zones and brittle detachments.

Session 3: Tectonic Significance of Metamorphism Associated with Extensional Deformation

John Platt started the session off asking, "Can we use *P-T*-time data to fingerprint the mechanism and cause of late-orogenic extension?" Klaus Gessner followed with a talk on granites, suggesting that radioactive decay causes long-term crustal weakening and continental extension. Geoff Clarke showed the relationship of granulite-facies metamorphism and extension in the Cretaceous magmatic arc of New Zealand.

The panel discussed which critical observations are needed to resolve whether metamorphism, and especially high-temperature weakening of the crust, is facilitating extension or whether metamorphism is a result of extension. Most critical in this context is obtaining precise geochronologic information on the relationship between the structural evolution and the metamorphic history. New developments in geochronology highlight the limited applicability of the closure-temperature concept for dating tectonometamorphic processes. What is required instead of "cooling ages" are precise ages for both ductile deformation processes and for temperature-induced metamorphic reactions.

Session 4: Geodynamic Role of Magmatism

In his keynote presentation, Chris Hawkesworth concentrated on the magmatic record of continental extension and stressed that this record needs to be incorporated in numerical modeling of extension. Bill Collins reviewed granite generations in backarc settings, and Olivier Vanderhaeghe focused on the role of migmatization in the formation and evolution of core complexes.

How magmatism might influence extensional deformation remained the primary topic in the panel discussions. Critical questions are the buoyancy of magmas and their level of emplacement in the crust and how magmatism affects deformation and heat transfer during extension.

Session 5: Geodetic Constraints on Extensional Deformation

This evening session was kicked off by Rick Bennett, who reviewed how horizontal and vertical components of crustal deformation during extension can be resolved by global positioning system (GPS) geodesy. Tim Stern then presented constraints on the short- and long-term evolution of backarc extension in the Taupo Volcanic Zone of New Zealand, followed by Brian Wernicke who presented new results of the BARGAN GPS network in the Basin and Range province and argued for the existence of an active, high-temperature mega-detachment beneath the western United States.

The discussion stressed the importance of geodesy for constraining slip rates and crustal rheology. A very important question would be whether or not rifting events are inherently episodic and non–steady-state in nature or not.

Session 6: Influence of Deep-Seated Phenomena: Heat Input from the Mantle and the Role of the Moho and the Brittle-Ductile Transition on the Evolution of Extensional Provinces

Mike Sandiford started the day with an intriguing talk on extensional stress fields, highlighting again the importance of heat and gravitational potential energy on the evolution of the lithosphere. Tim Little discussed the role of eclogite-facies metamorphism and gneiss dome development for the Woodlark Rift. Ritske Huismans stressed the significance of the rheologic stratification of the lithosphere for strain weakening and the formation of passive margins.

Much emphasis in the discussion concerned thermal softening of overthickened crust and delamination of a thickened mantle root. Thermal softening would reduce the strength of the crust and mantle, and delamination would increase the average topography of an extending region.

Session 7: Dynamic Aspects of Extending Lithosphere

The talks by Jean Braun on 3-D mechanical instabilities in extensional tectonic environments and the role of surface processes on the mechanical behavior of the continental crust and by Christian Teyssier on dynamic feedbacks among lithospheric layers during orogenic collapse were followed by Roger Buck's keynote on the roles of buoyancy and strength in continental rifting. The final two talks ended the conference as it started by stressing the fundamental role that magmatism and heat input plays in the extension of the continents.

CONCLUDING REMARKS

The general consensus among the participants was that the conference succeeded in providing a broad overview of the extension problem. It became clear that normal faulting is typically initiated by some major change in the geodynamic system, such as a change in boundary conditions (e.g., plate motions), or a change in the constitutive behavior of the crust (e.g., thermal softening), or a change in the position of rocks relative to a heterogeneous stress field.

New research frontiers are seen in the application of geodesy for addressing steady and non–steady-state behavior of the lithosphere during extension. Ideally, the emerging new results from this approach should be combined with studies on deeply exhumed fossil extensional complexes. A key issue in the latter is to merge our understanding and gain more information on the exact timing of episodic deformation with magmatic, metamorphic, and tectonic microstructures. A general problem is that the new developments and achievements in numerical modeling far outstrip our observations, stressing the importance of more and detailed field-based research in much closer interaction with numerical models.

ACKNOWLEDGMENTS

We acknowledge partial support from the National Science Foundation (EAR-07-29518) and The Geological Society of America.

Participants: Thomas H. Anderson, Dov Avigad, Mark Behn, Richard Bennett, Robert Bialas, Richard Blewlett, Chloe Bonamici, Jean Braun, Stephanie Brichau, Michael Brown, Sarah Brown, Roger Buck, Cathy Busby, Marion Campani, Nicholas Christie-Blick, Geoffrey Clarke, Bill Collins, Frances Cooper, Darrel Cowan, Karol Czarnota, Yildirim Dilek, John Dixon, Cindy Ebinger, Babbis Fassoulas, Marnie Forster, Phil Gans, Klaus Gessner, Johannes Glodny, Eric Gottlieb, Brad Hacker, Derrick Hasterok, Chris Hawkesworth, Christian Hibsch, Thomas Hickson, Ritske Huismans, Micah Jessup, Fawna Korhonen, Annakaisa Korja, Haralambos Kranis, Seth Kruckenberg, Mary Leech, Gordon Lister, Tim Little, Christelle Loiselet, Neil Mancktelow, Antonios Marsellos, Rory McFadden, Elena Miranda, Gwenn Peron-Pinvidic, Adonis Photiades, John Platt, Klaus Regenauer-Lieb, Uwe Ring, Gideon Rosenbaum, Mike Sandiford, Eric Seedorff, Diane Seward, Luc Siebenaller, Nikos Skarpelis, Emmanuel Skourtsos, Steven Smith, Juan Soto, Konstantinos Soukis, Dave Stegman, Tim Stern, Danny Stockli, Mike Taylor, Christian Teyssier, Markos Tranos, Brian Tucholke, Paul Umhoefer, Jolante van Wijk, Olivier Vanderhaeghe, Roberto Weinberg, Brian Wernicke, Lloyd White, Donna Whitney, Eliane Wüthrich.

Your Science, Your Colleagues, Your Society:

Make an Impact—Serve on a GSA Committee!

2009–2010 COMMITTEE VACANCIES
DEADLINE: 15 JULY 2008

Now is your chance to influence your Society, your science, and your colleagues. GSA invites you to volunteer or nominate one of your fellow GSA Members to serve on a Society committee or as a GSA representative to other organizations. Student Members are especially encouraged to become involved in Society activities both as committee volunteers and as nominators.

If you volunteer or make recommendations, please give serious consideration to the specified qualifications for serving on a particular committee, as outlined in this article, and be sure that your candidates are GSA Members or Fellows.

To volunteer or nominate someone else, go to **www.geosociety.org/aboutus/committees** and follow the link to our online form, or download the form and complete it on paper. If you use the paper form, please return it to Pamela Fistell, GSA, P.O. Box 9140, Boulder, CO 80301-9140, USA; fax +1-303-357-1070. Questions? Please contact Pamela Fistell at +1-303-357-1000, ext. 0, +1-800-472-1988, ext. 0, or pfistell@geosociety.org. *Please use one form per candidate.*

Nominations received at GSA headquarters by **15 July 2008** on the official one-page or online form will be forwarded to the Committee on Nominations. The committee will present at least two nominations for each open position to the GSA Council at its fall meeting. Appointees will then be contacted and asked to serve, thus completing the process of bringing new expertise into Society affairs. **Terms begin 1 July 2009 (unless otherwise indicated).**

Academic and Applied Geoscience Relations Committee (AM, T/E)
Two member-at-large Vacancies (three-year terms)

Strengthens and expands relations between GSA Members in the academic and applied geosciences. Proactively coordinates the Society's effort to facilitate greater cooperation between academia, industry, and government geoscientists. **Qualifications:** must be a member of academia, industry, or government who is committed to developing better integration of applied and academic science in our meetings, publications, short courses, field trips, and education and outreach programs.

Annual Program Committee (AM, B/E)
Two Vacancies: one member-at-large, one Councilor/ former Councilor (four-year terms)

Develops a long-range plan for increasing the quality of the annual meeting and other Society-sponsored meetings in terms of science, education, and outreach. Evaluates the technical and scientific programs of the annual meeting. **Qualifications:** broad familiarity with different disciplines, previous program experience, or active involvement in applying geologic knowledge to benefit society and raising awareness of critical issues.

Arthur L. Day Medal Award (T/E)
Two member-at-large vacancies (three-year terms)

Selects candidates for the Arthur L. Day Medal Award. **Qualifications:** knowledge of those who have made "distinct contributions to geologic knowledge through the application of physics and chemistry to the solution of geologic problems."

Education Committee (AM, B/E, T/E)
Three vacancies: one member-at-large, one pre-college educator (K–12), and one student representative (four-year terms)

Works with other members representing a wide range of education sectors in the development of informal, pre-college (K–12), undergraduate, and graduate earth science education and outreach objectives and initiatives. **Qualifications:** ability to work with other interested scientific organizations and science teachers' groups to develop pre-college earth science education objectives and initiatives.

Geology and Public Policy (AM, B/E, T/E)
Two member-at-large vacancies (three-year terms)

Translates knowledge of earth sciences into forms most useful for public discussion and decision making. **Qualifications:** experience with public-policy issues involving the science of geology; ability to develop, disseminate, and translate information from the geologic sciences into useful forms for the general public and for GSA Members; and familiarity with appropriate techniques for the dissemination of information.

Honorary Fellows (T/E)
Two member-at-large vacancies (three-year terms)

Selects candidates for Honorary Fellows, usually non–North Americans. **Qualifications:** knowledge of geologists throughout the world who have distinguished themselves through their contributions to the science.

Joint Technical Program Committee (T/E)
Two vacancies: one paleoceanology/paleoclimatology representative; one Precambrian geology representative (three-year terms begin 1 Jan. 2009)

Assists in finalizing the technical program of the GSA Annual Meeting: reviews abstracts or provides names of reviewers to evaluate abstracts, participates in Web-based activities in the selection and scheduling of abstracts, and participates in topical session proposal review. **Qualifications:** must be familiar with computers and the Web, be a specialist in one of the specified fields, and be available in mid-late July for the organization of the electronic technical program.

Membership (B/E)
One member-at-large vacancy (three-year term)

Contributes to the growth of GSA membership and attends to Members' changing needs. Focuses on attracting and retaining students, professionals working in industry, and those studying or working outside the United States. Reviews and makes recom-

*Extensive time commitment required
• AM—Meets at the Annual Meeting • B/E—Meets in Boulder or elsewhere • T/E—Communicates by phone or electronically

mendations for Fellowship to Council. **Qualifications:** experience in benefit, recruitment, and retention programs is desired.

Minorities and Women in the Geosciences (AM)
Three member-at-large vacancies (three-year terms)

Stimulates recruitment and promotes positive career development of minorities and women in the geoscience professions. **Qualifications:** familiarity with the employment issues of minorities and women; expertise and leadership experience in such areas as human resources and education is desired.

Nominations (B/E, T/E)
Two member-at-large vacancies (three-year terms)

Recommends nominees to GSA Council for the positions of GSA Officers and Councilors, committee members, and Society representatives to other permanent groups. **Qualifications:** familiarity with a broad range of well-known and highly respected geological scientists.

Penrose Conferences and Field Forums (T/E)
Two member-at-large vacancies (three-year terms)

Reviews and approves Penrose Conference proposals and recommends and implements guidelines for the success of the conferences. **Qualifications:** past convener of a Penrose Conference or a Field Forum.

Penrose Medal Award (T/E)
Two member-at-large vacancies (three-year terms)

Selects candidates for the Penrose Medal Award. Emphasis is placed on "eminent research in pure geology, which marks a major advance in the science of geology." **Qualifications:** familiarity with outstanding achievers in the geosciences that are worthy of consideration for the honor.

Professional Development (T/E)
One member-at-large vacancy (three-year term)

Directs, advises, and monitors GSA's professional development program, reviews and approves proposals, recommends and implements guideline changes, and monitors the scientific quality of courses offered. **Qualifications:** familiarity with professional development programs or adult education teaching experience.

Publications (AM, B/E, T/E)
One member-at-large vacancy (four-year term)

Nominates candidates for editor positions, approves editorial boards, reviews the quality and health of Society publications, and explores the initiation of new ventures, including electronic publishing. **Qualifications:** extensive publications experience.

Research Grants* (B/E)
Five member-at-large vacancies (three-year terms)

Evaluates student research grant applications and selects grant recipients. **Qualifications:** should have experience in directing research projects and in evaluating research grant applications.

***Treatise on Invertebrate Paleontology* Advisory Committee (AM)**
One member-at-large (paleontologist) vacancy (three-year term)

Advises the Council, the Committee on Publications, and the *Treatise* editor on matters of policy concerning this publication. **Qualifications:** must be a paleontologist.

Young Scientist Award (Donath Medal) (T/E)
Two member-at-large vacancies (three-year terms)

Committee members investigate the achievements of young scientists who should be considered for this award and makes recommendations to Council. **Qualifications:** should have knowledge of young scientists with "outstanding achievement(s) in contributing to geologic knowledge through original research which marks a major advance in the earth sciences."

GSA REPRESENTATIVES TO OTHER ORGANIZATIONS

GSA Representatives to the American Association for the Advancement of Science

Three section representative vacancies: *Section E—Geology and Geography; Section W—Atmospheric and Hydrospheric Sciences; Section X—Societal Impacts of Science and Engineering (three-year terms begin 21 Feb. 2009)*

Must be a member of the American Association for the Advancement of Science (AAAS), or be willing to join, and must represent the appropriate section background.

GSA Representative to the AGI Environmental Geoscience Advisory Committee
One GSA Representative vacancy (three-year term begins 1 Jan. 2009)

Fosters communication within the community about issues related to serving the broader international community; helps identify and focus on the highest priority environmental informational needs and issues best addressed by the geoscience community. **Qualifications:** well-acquainted with GSA programs in environmental geoscience.

North American Commission on Stratigraphic Nomenclature (AM, possibly B/E)
One GSA Representative vacancy (three-year term runs November 2009–November 2012)

Develops statements of stratigraphic principles, recommends procedures applicable to classification and nomenclature of stratigraphic and related units, reviews problems in classifying and naming stratigraphic and related units, and formulates expressions of judgment on these matters.

Liaison to the U.S. National Committee on Soil Science
One GSA Liaison vacancy (three-year term)

Should be a soil scientist and Society member.

THE GEOLOGICAL SOCIETY OF AMERICA®

COMMITTEE, SECTION, AND DIVISION VOLUNTEERS:

COUNCIL THANKS YOU!

The GSA Council acknowledges the many Member-volunteers who, over the years, have contributed to the Society and to our science through involvement in the affairs of the GSA.

*Extensive time commitment required

• AM—Meets at the Annual Meeting • B/E—Meets in Boulder or elsewhere • T/E—Communicates by phone or electronically

Donna L. Russell, *Director of Operations*

The Bromery Fund's First Annual Award

Cecile and Bill Bromery

I am very pleased and honored to announce that the GSA Presidential Address and Awards Ceremony in Houston will be the setting for the first annual Bromery Award for the Minorities.

Randolph W. "Bill" Bromery and Cecile T. Bromery established the Bromery Fund for Minorities within the GSA Foundation in December 1999. The purpose of the fund and the award is: ***to support minorities who have made significant contributions to research in the geological sciences or those who have been instrumental in opening the geoscience field to other minorities.***

Bromery has a long history of service to GSA. He served on GSA Council, chaired the Audit and Nominating Committees, was a leading member of the Committee on Committees, and played a prominent role in the recognition and advancement of minorities in geology. He was GSA's 101st president, and he chaired the Second Century Fund for Earth Education and the Environment from 1992 to 1996.

Bromery was the first black scientist and educator to be involved in a large number of organizational and geographic venues. His career paralleled the giant advances in race relations and recognition in the years following World War II, and his achievements have served as a model for the members of many minority groups who now populate science, education, and business. The National Academy of Sciences named Bromery as an outstanding black scientist in 1997.

Bromery has served on the boards of several corporations in the industry, including Exxon, Chemical Bank, NYNEX, John Hancock, Singer, New England Telephone, and Northwestern Life. He has served as president for two Massachusetts companies (Weston Geophysical International and Geoscience Engineering).

Born in Cumberland, Maryland, Bromery served as one of the Tuskegee Airmen during World War II. In 1948, he began working for the U.S. Geological Survey as a geophysicist and during the next 19 years also earned B.S., M.S., and Ph.D. degrees from Howard, American, and Johns Hopkins Universities, respectively. The University of Massachusetts at Amherst was his entrance into the academic world, and he continued with that state university for most of the balance of his career as professor, department chair, vice chancellor for student affairs, and chancellor and senior vice president with the Office of the President.

Bill married Cecile in 1947, and they raised five children. They now split their time between two residences—one in Amherst, Massachusetts, and the other on Hilton Head Island, South Carolina.

Nominations for this outstanding award should be directed to GSA at awards@geosociety.org, by 1 April 2008. The selection of the recipient will be made by the GSA Committee on Minorities and Women in the Geosciences in consultation with the National Association of Black Geologists and Geophysicists. For further information please go to www.gsafweb.org

Strong advocates of W.E.B. Dubois' concept of the "talented tenth," a cadre of educated leaders who will devote their talents to racial uplift, Cecile and Bill Bromery hope that this fund will encourage such leadership within the minority communities.

To all the many donors who so generously gave their support to the Foundation during 2007, we extend our sincere thanks and appreciation. Please see our insert in this issue.

GSA Foundation
3300 Penrose Place, P.O. Box 9140, Boulder, CO 80301-9140
+1-303-357-1054 drussell@geosociety.org
www.gsafweb.org

Enclosed is my contribution in the amount of $__________________.

Please credit my contribution to the:

☐ Bromery Fund
☐ Greatest need ☐ Other: ____________________________________ Fund
☐ I have named GSA Foundation in my Will.

____
Name

____
Address

____
City/State/ZIP

____
Phone

IN MEMORIAM

Please contact the GSA Foundation at +1-303-357-1054, drussell@geosociety.org, www.gsafweb.org, to contribute to the Memorial Fund. To honor a friend or colleague with a GSA Memorial, please go to www.geosociety.org/pubs/mmlGuid.htm.

G. Christian Amstutz
Sigriswil, Switzerland
notified 28 December 2007

Charles A. Barlow
Charleston, West Virginia, USA
1 October 2007

Paul C. Bateman
Los Altos, California, USA
20 August 2007

Robert Brownfield
Davenport, Iowa, USA
notified 7 November 2007

D.W. Caldwell
Groton, Massachusetts, USA
11 December 2006

Agnes Creagh
Ridgefield, Connecticut, USA
23 October 2007

Stanley N. Davis
Tucson, Arizona, USA
18 November 2007

Edward Eschner
Boulder City, Nevada, USA
notified 20 December 2007

Sankar P. Das Gupta
Kolkata, India
notified 2 November 2007

George Hofman
Campbell, California, USA
notified 5 December 2007

Frank H. Howd
Dana Point, California, USA
16 March 2007

Henry E. Kane
Muncie, Indiana, USA
10 March 2007

Frederick L. Klinger
Bethesda, Maryland, USA
26 May 2007

Harold E. Malde
Boulder, Colorado, USA
4 November 2007

Charles E. Mear
Austin, Texas, USA
18 September 2007

George W. Moore
Corvallis, Oregon, USA
4 October 2007

Dallas L. Peck
Herndon, Virginia, USA
notified 28 December 2007

Ralph J. Roberts
Tacoma, Washington, USA
1 August 2007

Edward Carl Roy Jr.
San Antonio, Texas, USA
9 November 2007

Michel P. Semet
Sauveniere, Belgium
29 August 2007

James A. Zimmer
Mankato, Minnesota, USA
28 June 2007

EKU

Applied Geoscientist - Hydrologist/Hydrogeologist

EASTERN KENTUCKY UNIVERSITY

The Department of Geography and Geology (**http://www.geoscience.eku.edu**) invites applications for a 3 year visiting position as an Assistant Professor beginning August 15, 2008. We seek a colleague who is broadly educated in the geosciences. Candidates must exhibit a commitment to excellence in teaching, and ultimately will teach general education geology courses, courses for undergraduate and graduate majors, and courses for pre- and in-service teachers. We require expertise in an applied aspect of hydrogeology or hydrology where the added ability to teach remote sensing and GIS is desirable. The successful applicant is expected to build and maintain a research program, to involve students in their research, and to supervise Master's degree candidates. Ph.D. from a regionally accredited institution at the time of appointment is required.

Must apply online at **http://jobs.eku.edu**
(Search requisition # **0602419**).

Offers of employment are contingent upon satisfactory background check and educational credential verification. Eastern Kentucky University is an EEO/AA institution that values diversity in its faculty, staff, and student body. In keeping with this commitment, the University welcomes applications from diverse candidates and candidates who support diversity.

Kentucky UNBRIDLED SPIRIT

Classified Rates—2008

Ads (or cancellations) must reach the GSA Advertising office no later than the first of the month, one month prior to issue. Contact Advertising Department: advertising@geosociety.org; +1.800.472.1988 x1053; +1.303.357.1053. Complete contact information, including mailing and email address, must be included with all correspondence. Rates are in U.S. dollars.

Classification	Per Line for 1st month	Per line each addt'l month (same ad)
Positions Open	$8.00	$7.75
Opportunities for Students		
First 25 lines	$0.00	$4.20
additional lines	$4.20	$4.20
Fellowship Opportunities	$8.00	$7.75
Situations Wanted	$3.60	$3.60

To estimate cost, count 54 characters per line, including all punctuation and blank spaces. Actual cost may differ if you use capitals, centered copy, or special characters.

Positions Open

**HYDROGEOLOGIST
BRIGHAM YOUNG UNIVERSITY**

The Department of Geological Sciences at Brigham Young University invites applications for a tenure-track faculty appointment in the specific area of hydrogeology. Qualified candidates at any rank may be considered, although a Ph.D. at the time of appointment is required. We are looking for a candidate who can contribute to our environmental studies program, a core subdiscipline of the department. The successful candidate will be expected to teach undergraduate and graduate courses in physical hydrogeology and to maintain a vigorous externally-funded research program involving undergraduate and M.S. seeking students. Given the department's excellent analytical facilities, an interest in hydrogeochemistry is a plus. Brigham Young University has a faculty expectation of excellence in both teaching and research.

The department is well equipped to support hydrogeology studies. In addition to field equipment, other facilities include access to a state-of-the-art stable isotope lab (C, N, O, H, S), in-house facilities for ^{3}H, ^{14}C, gas GC as well as solute analysis. Other relevant equipment includes a wavelength dispersive XRF system, electron microprobe, X-ray diffractometers, environmental seismic equipment & ground-penetrating radar, as well as subsurface visualization facilities.

The Department of Geological Sciences consists of 13 professorial and 3 professional faculty and offers B.S. and M.S. degrees. Major research areas include hydrogeology, paleoclimatology, petroleum geology, continental magmatism, shallow and deep geophysics, tectonics, stratigraphy, paleontology, and mineral surface chemistry.

Applicants should send a curriculum vita, graduate transcripts, statement of teaching and research interests, and the names and contact information for three references to: Stephen T. Nelson, Chair, Search Committee, Dept. of Geological Sciences, S-389 ESC, Brigham Young University, Provo, UT 84602. Evaluation of applications will begin April 1, 2008.

Brigham Young University, an equal opportunity employer, does not discriminate on the basis of race, color, gender, age, national origin, veteran status, or against qualified individuals with disabilities. All faculty are required to abide by the university's honor code and dress and grooming standards. Preference is given to qualified candidates who are members in good standing of the affiliated church, The Church of Jesus Christ of Latter-Day Saints. Successful candidates are expected to support and contribute to the academic and religious missions of the university within the context of the principles and doctrine of the affiliated church.

**ASSISTANT OR ASSOCIATE PROFESSOR
GEOLOGICAL ENGINEERING
SOUTH DAKOTA SCHOOL OF MINES
& TECHNOLOGY**

The Dept. of Geology and Geological Engineering at South Dakota School of Mines and Technology invites applications for a nine-month tenure track position in geological engineering at the Assistant or Associate Professor level. The successful applicant should be able to teach courses at the undergraduate and graduate level, and is expected to advise graduate students and develop a funded research program that strengthens current department emphases in surface and groundwater, environmental studies, geotechnical applications, mining, or mine reclamation. It would be an advantage for the candidate to have experience in soft rock geology. The department offers degrees through the Ph.D. in Geology and Geological Engineering, and opportunities for research at a deep underground laboratory at the former Homestake mine. A Ph.D. in Geological Engineering or closely related engineering discipline is required.

To apply for this position, applicants must apply online at http://sdmines.sdsmt.edu/sdsmt/employment. If you need an accommodation to the online application process, please contact Human Resources +1-605-394-1203. It is anticipated the appointment will begin in August 2008. Applications are being reviewed and will continue until the position is filled. For more information regarding the university, visit www.sdsmt.edu.

SDSM&T is an EEO/AA/ADA employer & provider.

**ASSISTANT PROFESSOR, GEOLOGY
INDIANA UNIVERSITY–PURDUE UNIVERSITY
FORT WAYNE (IPFW)**

IPFW seeks to fill a full-time, tenure-track position at the Assistant Professor level in geology. The successful applicant for the position will have a Ph.D. and be expected to share with other faculty responsibilities for teaching introductory geology, introductory planetary geology and regional field geology. Over a multi-year cycle, the successful applicant will teach courses in structural geology, GIS, and geomorphology. Geosciences faculty are expected to maintain an active research program and to involve undergraduate students in research. IPFW's geology research program is well-supported in both equipment (e.g. thin section lab, SEM, XRD) and opportunities for new faculty.

There are four other full-time faculty in the department. IPFW is a comprehensive university. Send a letter of application, statement of teaching and research interests, curriculum vitae, copies of transcripts, and the names and contact information for three references to: Prof. J. Farlow, Search Committee Chair, Department of Geosciences, Indiana University-Purdue University Fort Wayne, 2101 East Coliseum Boulevard, Fort Wayne, IN 46805. Review of applications will begin May 1, 2008. IPFW is an equal opportunity, equal access, affirmative action employer.

**GEOLOGY AND GEOPHYSICS DEPARTMENT
WOODS HOLE OCEANOGRAPHIC INSTITUTION**

The Geology and Geophysics Department at WHOI invites applicants for a tenure-track position focusing on the role of fluids in geologic systems. We seek an individual performing innovative research in one or more of the following areas: fluid circulation, heat flow, hydrocarbons, hydrofracture, and the geomechanical behavior of permeable media in marine settings. Research interests should complement one or more on-going programs within the institution, including those in active margins, mid-ocean ridges, hydrothermal systems, geohazards, fault mechanics, earthquake rupture, and seismic tremor. We encourage candidates who successfully combine sea-going, laboratory-based, and modeling approaches. In addition, opportunities exist for collaboration with the scientists and engineers in other departments at the institution, particularly in the Marine Policy Center, Department of Marine Chemistry and Geochemistry, and the Department of Applied Ocean Physics and Engineering.

Successful candidates are expected to maintain an externally funded research program. We particularly encourage individuals with research interests relating to the Integrated Ocean Drilling Program and the Ocean Observatories Initiative. WHOI maintains an Office of Applied Oceanography with interests in energy, oil exploration, mineral resources, and carbon sequestration.

A Ph.D. is required at the time of appointment as well as a demonstrated record of excellence in research. The level of appointment will depend on the candidate's background and experience. Opportunities exist for teaching and advising graduate students through the MIT/WHOI Joint Program in Oceanography/Applied Ocean Sciences and Engineering. Women and minority applicants are particularly encouraged to apply. To begin the online application process, please visit http://jobs.whoi.edu. EOE: M/F/D/V.

**POSTDOCTORAL POSITION
TECTONOPHYSICS/STRUCTURAL GEOLOGY
UNIVERSITY OF MICHIGAN**

The Department of Geological Sciences invites applications for a university-funded, two-year Postdoctoral Fellowship in Tectonophysics or Structural Geology, starting September 2008.

We are interested in creative research with preference for projects that have a connection to our ongoing work in brittle faulting processes. Research can include field work, experimental work, geochemical analysis and computer modeling, based on the goals and experiences of the successful applicant. The position will also involve research mentoring of undergraduate and graduate students. Potential applicants are encouraged to contact Ben van der Pluijm, vdpluijm@umich.edu, for additional information and to discuss research interests.

Send a curriculum vitae, up to 3 articles that are published or in submission, a brief research proposal (up to 3 pages), and the names and addresses of three references.

Applications will be considered through April 2008 with a decision in May 2008.

Submit electronic applications to: tectonophysics@umich.edu, or mail to Tectonophysics Postdoctoral Position, Ben van der Pluijm, Dept. of Geological Sciences, Univ. of Michigan, 1100 North University Ave., Ann Arbor, MI 48109-1005.

The University of Michigan is an affirmative action/equal opportunity employer.

**GEOLOGY INSTRUCTOR, MOUNT ROYAL COLLEGE
COMPETITION #5934AB**

The Department of Earth Sciences at Mount Royal College invites applications for a tenure track position which will commence August 15, 2008, subject to final budgetary approval. The College is seeking candidates with a commitment to teaching and learning. It provides the opportunity for research, scholarly pursuits, and service and initiatives related to the integration of technology and learning. The successful applicant should be proficient in teaching the following; an introductory course in physical geology, field school; and, senior courses in ore deposits/igneous petrology/exploration geophysics or hydrogeology/geomorphology. For more information, visit our Web site at www.mtroyal.ca.

classified ads continued on p. 22

MULTIPLE HIRES IN ENERGY GEOSCIENCE

The Jackson School is building a premier education and research program in Energy Geoscience. Over the next three years, we seek six or more scientists at the forefront of their disciplines to complement our existing strengths. We seek people attracted to challenging areas of scholarship that require collaboration across disciplines and programs, aimed at the following goals:

- Improve quantitative understanding of sedimentary basins by integrating on all scales classically separated disciplines such as stratigraphy and sedimentology, structural geology and tectonics, geomechanical and diagenetic modeling, geochemistry, basin modeling, petrophysics, and geophysical imaging.
- Determine fluid-rock interactions and the interplay between mechanical and chemical processes influencing fluid flow and storage in the subsurface, especially for carbon sequestration and unconventional sources of fossil energy, such as shale gas and tight gas reservoirs.
- Enhance identification and recovery of energy resources by comprehensive integration of information at all scales, using numerical modeling, and innovative automated monitoring, such as time-lapse seismic and instrumented oil fields.

We encourage applications from innovative scientists working in all fields of energy geoscience. We are building a body of faculty and scientists to place the school at the forefront of energy geoscience research and teaching for the coming century. Appointments include full-time faculty, full-time research, and mixtures of the two in any Jackson School unit— the Bureau of Economic Geology, the Department of Geological Sciences, or the Institute for Geophysics. For more information on the school and its hiring program visit us online at www.jsg.utexas.edu/hiring.

A PhD is required for appointment. An application should note the title of the specific advertisement you are responding to and include a cover letter, CV, list of publications, list of references, statements of teaching and/or research interests, sent to: Randal Okumura, Office of the Dean / Jackson School of Geosciences, The University of Texas at Austin / PO Box B, University Station / Austin, TX 78713 or jobs@jsg.utexas.edu.

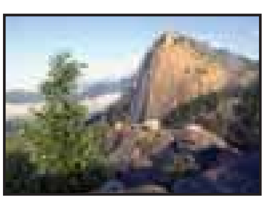
THE UNIVERSITY OF TEXAS AT AUSTIN IS AN AFFIRMATIVE ACTION / EQUAL OPPORTUNITY EMPLOYER

THE UNIVERSITY OF TEXAS AT AUSTIN
JACKSON
SCHOOL OF GEOSCIENCES
CHANGING THE WORLD OF GEOSCIENCES

Philmont Scout Ranch Volunteer Geologist Program

Cimarron, New Mexico, USA

Sponsored by the Rocky Mountain Association of Geologists



The Tooth of Time, New Mexico.

Volunteer for one-week opportunities to teach and demonstrate area geology to high-school–age scouts in back-country New Mexico (French Henry mining camp, Baldy Town, or Cypher's Mine). The 2008 program begins on Sunday, 15 June, and the last week for volunteering starts 10 August. Only 54 spots are available this summer, so **sign up early!**

For information and to sign up, contact Ed Warner, P.O. Box 480046, Denver, CO 80248-0045, USA, +1-720-904-0560, ewarn@ix.netcom.com. Alternate contact: Bob Horning, P.O. Box 460, Tesuque, NM 87594, USA, +1-505-820-9290, rrhorning@cybermesa.com.

LSU

LOUISIANA STATE UNIVERSITY

CHAIR AND PROFESSOR

(TENURED) DEPARTMENT OF GEOLOGY AND GEOPHYSICS

The faculty of the Department of Geology and Geophysics at Louisiana State University is seeking an outstanding research-oriented geologist to serve as Department Chair. This tenured appointment will be at the level of full professor. Our department has 17 faculty members and is one of the top Geology programs in the Southeastern US. It has benefited from our highly supportive alumni who have generously endowed our field camp, faculty chairs, and graduate research programs. We seek an outside candidate with an international reputation to serve as chair to further build the department by bringing a new perspective. That individual will need experience and a vision on how to strengthen the department's two primary research focus areas: 1. Evolution of sedimentary systems and 2. Earth materials and solid earth processes. **Required Qualifications:** Proven record of scholarship and external research funding. **Responsibilities:** oversees planning and administration of undergraduate and graduate programs in Geology and Geophysics; supports and facilitates collaborative multidisciplinary research programs across the university and with the outside community; maintains and builds upon our traditional strong relationship with industry; oversees the continuing development of alumni relations; manages the significant and still growing department endowment; reports to the Dean of the College of Basic Sciences.

LSU is the Flagship University, a public and comprehensive institution serving the State and the entire nation. The candidate may also be considered to occupy one of the three endowed chairs currently available in the department. These include the: John Franks Endowed Chair in the Department of Geology and Geophysics, Charles T. McCord, Jr. Endowed Chair of Geology (Petroleum), Billy and Ann Harrison Endowed Chair in Geology and Geophysics (Sedimentology).

An offer of employment is contingent on a satisfactory pre-employment background check. Application deadline is March 17, 2008 or until a candidate is selected. Desired start date is September 2008. We welcome nominations of potential candidates. Letters of application, including a curriculum vitae (including e-mail address), a statement of research and teaching activities, a description of administrative positions and philosophy, and the names of five potential references should be sent to:

Dr. Louis J. Thibodeaux, Department Chair
Chair of Search Committee
Department of Geology and Geophysics
E235 Howe-Russell Bldg
Louisiana State University, Ref: Log #1115
Baton Rouge, LA 70803-4101

LSU IS AN EQUAL OPPORTUNITY/EQUAL ACCESS EMPLOYER

classified ads continued from p. 20

DIRECTOR, THE UNIVERSITY OF TEXAS INSTITUTE FOR GEOPHYSICS (UTIG) JACKSON SCHOOL OF GEOSCIENCES

The University of Texas Institute for Geophysics (UTIG), one of the three principal units in the Jackson School of Geosciences at The University of Texas at Austin, seeks nominations and applications for the position of Director. UTIG is an international leader in marine geology and geophysics, seismology, and climate research. With externally funded research expenditures of approximately $4 million annually, its staff of 74 conducts and supports a broad variety of investigations, with particular emphasis on ocean basins, plate margins, polar regions, and climate modeling. Information about UTIG and the Jackson School of Geosciences can be found at www.jsg.utexas.edu/. Several UTIG research scientists hold faculty appointments in the Department of Geological Sciences and both graduate and undergraduate students play an important role in the UTIG research mission. Should the successful candidate desire an academic appointment, he/she will be expected to possess the necessary qualifications for a senior faculty position in the Department of Geological Sciences.

The ideal candidate will have a substantial record of research and publications, experience in the administration of complex research projects and organizations, and good people management skills. Involvement in international programs and leadership in academic and professional activities are desired qualifications. The Jackson School of Geosciences is undergoing dramatic growth in programs and personnel. The UTIG Director is a member of the leadership team directing these efforts.

Applications and nominations will be accepted until the position is filled. The target date for the new Director to assume the position is September 1, 2008. A letter of application providing the applicant's perspectives on UTIG and its future directions, a resume, and the names and email and surface mail contact information for four references should be sent to Dr. Charles G. Groat, Chair, UTIG Director Search Committee, Jackson School of Geosciences, The University of Texas at Austin, P.O. Box B, Austin, TX 78713 or, electronically, to utigdirectorsearch@jsg.utexas.edu. Screening of applications will begin as they are received.

The University of Texas at Austin is an Equal Opportunity/Affirmative Action employer.

KANSAS GEOLOGICAL SURVEY UNIVERSITY OF KANSAS

Research Associate—Groundwater model construction, calibration, sensitivity analysis, parameter estimation, and software development for new direct-push characterization techniques. Strong background in data analysis, groundwater modeling, and computer programming. This position is initially for up to 3 years, with longer-term employment possible subject to job performance and the availability of funds.

Start approx. 05/01/08. Salary US$40K–US$45K + benefits, commensurate with qualifications. Required: Advanced degree in the geosciences, experience with regional groundwater flow systems and stream-aquifer interactions.

First consideration given to application material received by 03/31/08.

For complete description go to www.kgs.ku.edu/General/jobs.html; to apply go to jobs.ku.edu (search by position number 00206611) or contact Annette Delaney at +1-785-864-2152, hr@kgs.ku.edu. For additional information about the section, www.kgs.ku.edu/Hydro/hydroProj.html.

EO/AA Employer.

Opportunities for Students

Visiting Fellowships—Institute For Rock Magnetism. Applications are invited for visiting fellowships (regular and student) lasting for up to 10 days during the period from July 1 through December 31, 2008. Topics for research are open to any field of study involving fine particle magnetism, but preference will be given to projects relating magnetism to geological or environmental studies, or to fundamental physical studies relevant to the magnetism of Earth materials.

A limited number of travel grants of up to US$750 are available to cover actual travel costs. No funds are available for per diem expenses. Application forms and information necessary for proposal preparation may be obtained from IRM manager Mike Jackson at the address below, or online at www.irm.umn.edu.

Short proposals (two pages, single-spaced text plus two forms and necessary figures and tables) are due by April 30, 2008, for consideration by the IRM's Review and Advisory Committee. Successful applicants will be notified in June, 2008. Proposals should be sent by e-mail to irm@umn.edu, or by post to: Facilities Manager, Institute for Rock Magnetism, University of Minnesota, 291 Shepherd Laboratories, 100 Union St. SE, Minneapolis, MN 55455-0128, USA.

Scholarships for Students for EBSD Workshop. The Microbeam Analysis Society will hold a 3-day workshop on electron backscatter diffraction at Univ. of Wisconsin–Madison, May 20–22. It will start with a one-day tutorial for beginners. With support from NSF, we have 10 scholarships of up to US$500 each for travel and lodging. Information and applications at www.microbeamanalysis.org or contact John Fournelle, johnf@geology.wisc.edu.

Research and Teaching Assistantships available for Fall 2008 at Temple University. Research and Teaching Assistantships are available for the Fall term (September 2008) in our Masters Program in Geology at Temple University. The 2-year Masters Program offers advanced courses and thesis research opportunities in **environmental geology, hydrogeology, geochemistry, environmental geophysics, planetary geology, paleopedology, stratigraphy, sedimentology, structural geology, vertebrate paleontology, and materials science.** Research funding is currently available for specific projects focused on enhanced geothermal systems, petroleum fault traps and seals, rock mechanics, studies of Martian sedimentary geology, Archean meteorite impacts, groundwater-lake interactions, and geochemical vertebrate taphonomy and paleosols. Financial support for every student includes stipend and full tuition for 2 years. Graduates of our program have an excellent record of employment in consulting and education professions and acceptance into doctoral programs. Graduate stipends are awarded on a competitive basis. Completed applications and supporting materials must be received by March 15 to ensure full consideration for Fall 2008 admission and stipends. Please visit our Web site at www.temple.edu/geology for additional information.

Graduate Assistantship (M.S., Ph.D.) opportunities, Geological Oceanography, Department of Marine Science, University of Southern Mississippi. Opportunities for research and teaching assistantships are available for qualified graduate students for the 2008–2009 academic year at the USM Department of Marine Science (see www.usm.edu/marine/). Current annual stipends range from US$20,400 for Master Students to US$21,600 for first year Ph.D. students, with full tuition waivers, health insurance coverage and other university fees paid. The department has active ongoing basic and applied research programs in all emphasis areas (biological, chemical, geological and physical oceanography and hydrographic science), with strong field- and lab-based interdisciplinary research components. We particularly seek students with interests in geological oceanography. Departmental resources include extensive laboratory and state-of-the-art analytical and computational facilities. The location of the department at the NASA John C. Stennis Space Center provides ready access to coastal systems and collaborative opportunities with a myriad of federal agencies (NASA, NOAA, NRL, NAVO, USGS, EPA). Potential students are encouraged to contact the Department at marine.science@usm.edu or to contact individual faculty members (see www.marine.usm.edu/faculty/dms_fac.html), and should visit www.usm.edu/marine/ for additional information and application instructions.

Graduate Assistantship (M.S., Ph.D.) opportunities, Department of Marine Science, University of Southern Mississippi. Opportunities for research and teaching assistantships are available for qualified graduate students for the 2008–2009 academic year at the USM Department of Marine Science (see www.usm.edu/marine/). Current annual stipends range from $20,400 for Master Students to $21,600 for first year Ph.D. students, with full tuition waivers, health insurance coverage and other university fees paid. The department has active ongoing basic and applied research programs in all emphasis areas (biological, chemical, geological and physical oceanography and hydrographic science), with strong field- and lab-based interdisciplinary research components. Departmental resources include extensive laboratory and state-of-the-art analytical and computational facilities. The location of the department at the NASA John C. Stennis Space Center provides ready access to coastal systems and collaborative opportunities with a myriad of federal agencies (NASA, NOAA, NRL, NAVO, USGS, EPA). Potential students are encouraged to contact the Department at marine.science@usm.edu or to contact individual faculty members (see www.marine.usm.edu/faculty/dms_fac.html), and should visit www.usm.edu/marine/ for additional information and application instructions.

2008 Graduate Student Grant Program: The Spackman Award. The Society for Organic Petrology (TSOP) invites applications for graduate student research grants, the Spackman Award. The purpose of the grants is to foster research in organic petrology by providing support to graduate students who demonstrate the application of organic petrology concepts to research problems.

Monetary awards up to a maximum of US$1,000.00 will be granted. The program awards a maximum of two grants each year. All applicants are invited to enjoy a year's free student membership in TSOP.

Grants are to be applied to expenses directly related to the student's thesis work, such as summer fieldwork, laboratory analyses, etc. A portion (not to exceed 25%) of the funds may be used to attend TSOP Annual Meetings. Funds should not be used to purchase capital equipment, to pay salaries, tuition, room, or board and must be spent within 18 months of receipt.

TSOP Spackman Award application deadline is May 15, 2008 and award is in September, 2008. An application form is on the TSOP Web site, www.tsop.org/grants.htm, or from Suzanne J. Russell, 2218 McDuffie St. Houston, TX 77019-6526, USA; sjruss@sbcglobal.net.

Fellowship Opportunities

VISITING FELLOWSHIPS INSTITUTE FOR ROCK MAGNETISM

Applications are invited for visiting fellowships (regular and student) lasting for up to 10 days during the period of July 1–December 31, 2008. Topics for research are open to any field of study involving fine particle magnetism, but preference will be given to projects relating magnetism to geological or environmental studies, or to fundamental physical studies relevant to the magnetism of earth materials.

A limited number of travel grants of up to US$750 are available to cover actual travel costs. No funds are available for per diem expenses. Application forms and information necessary for proposal preparation may be obtained from IRM manager Mike Jackson at the address below, or online at www.irm.umn.edu.

Short proposals (two pages, single-spaced text plus two forms and necessary figures and tables) are due by April 30, 2008, for consideration by the IRM's Review and Advisory Committee. Successful applicants will be notified in June 2008. Proposals should be sent by e-mail to irm@umn.edu or by post to Facilities Manager, Institute for Rock Magnetism, University of Minnesota, 291 Shepherd Laboratories, 100 Union St. SE, Minneapolis, MN 55455-0128, USA.

GSA Maps & Charts Series

Quaternary fault and lineament map of Owens Valley, Inyo County, eastern California

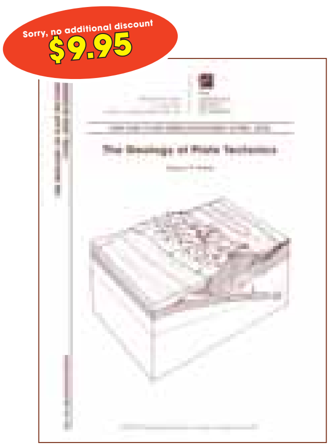
D.B. Slemmons, E. Vittori, A.S. Jayko, G.A. Carver, and S.N. Bacon, 2008

This study investigates the active tectonic setting of the Owens Valley graben in the area of the great 1872 earthquake rupture along the Owens Valley fault zone. The area is critical for understanding the tectonics of the southern Walker Lane at the boundary between the Sierra Nevada block and Basin and Range Province. The report compiles known mapped Quaternary faults, provides a context for identifying fault sections, and rational for delineating major structural blocks in the graben. Many new Late Pleistocene and Holocene faults, particularly west of the 1872 Owens Valley rupture are identified by special low-sun angle photography. These structures accommodate part of the late Quaternary strain within the eastern California seismic belt.

MCH096F, 1 folded sheet (27″ × 55″), 25 p. text
In Press, call for pricing—folded

MCH096R, 1 rolled sheet (27″ × 55″), 25 p. text
In Press, call for pricing—rolled

MAPS & CHARTS Series of large-sheet publications encompassing a great variety of geologic information for use in the classroom or laboratory, including geologic maps, cross sections, structure sections, bathymetric charts, stratigraphy charts, gravity maps, and magnetic maps. Most feature color and include texts. Published irregularly.



The Geology of Plate Tectonics

by Gregory R. Wessel

This chart belongs in every geology classroom and lab! Printed in full-color, it attempts to organize the types of plate boundaries and displays them in a useful graphic form. The chart describes geologic features with each type. Sheet is 36" × 53" (folded only).

MCH059REV,
1 folded sheet (36" × 53"), 7 p. text

$9.95 (sorry, no additional discount)

An Earth Scientist's Periodic Table of the Elements and Their Ions

by L. Bruce Railsback

An Earth Scientist's Periodic Table of the Elements and Their Ions is a new periodic table designed to contextualize trends in geochemistry, mineralogy, aqueous chemistry, and other natural sciences. First published as an insert in the September 2003 issue of *Geology*, this version is updated and supersized—36" × 76"!

MCH092F, 1 folded sheet (36" × 76"),
7 p. text, **Reduced price $10.00**

(sorry, no additional discount)

Sorry, no additional discount
$10.00

Geologic map and cross sections of the Flynn Creek impact structure, Tennessee

compiled by Jonathan C. Evenick and Robert D. Hatcher Jr., 2007

The Flynn Creek impact structure is located in northeastern central Tennessee, on the northeast flank of the Nashville dome. Remapping the structure has better delimited the depositional history and impact structure evolution. The structure contains many features characteristic of complex impact structures: concentric normal faults, central uplift, shatter cones, impact breccia, and a modern internal drainage system. In addition, it contains some distinctive impact-related compressional structures, such as thrust faults and buckle folds in the modified crater rim.

MCH095F, 1 folded sheet (36" × 66"),
$50.00, **member price $35.00—folded**

MCH095R, 1 rolled sheet (36" × 66"),
$55.00, **member price $40.00—rolled**

www.geosociety.org/bookstore

THE GEOLOGICAL SOCIETY OF AMERICA®
The Geological Society of America, 3300 Penrose Place, P.O. Box 9140,
Boulder, CO 80301-9140, USA • +1-303-357-1000, option 3, or +1-888-443-4472