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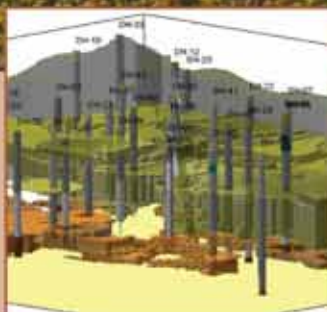
OCTOBER 2011

A Miocene river in northern Arizona and its implications for the Colorado River and Grand Canyon

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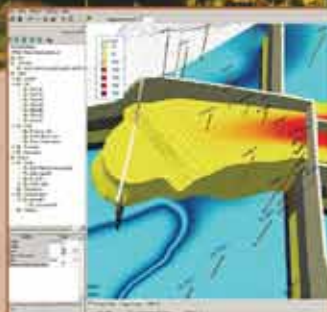


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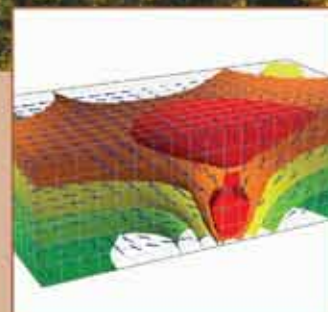


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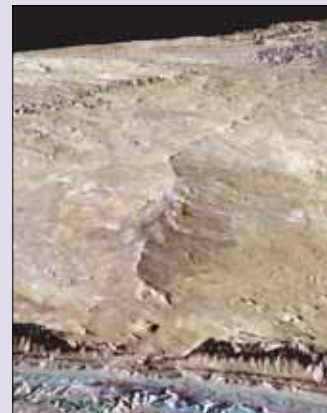
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Ivo Lucchitta, Richard F. Holm, and Baerbel K. Lucchitta

Cover: Oblique view looking NE along Crooked Ridge from The Gap, carved into the upturned Echo Cliffs, toward White Mesa in the distance. Darker part of the ridge in the foreground is mantled by river deposits. Image is composite of Landsat and shaded-relief DEM data with 10 m spatial resolution and 2x vertical exaggeration, obtained from the USGS Eros Data Center's seamless server. See related article, p. 4–10.



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ERRATUM: The Sept. 2011 *GSA Today* included a position statement draft on *Supporting Planetary Exploration* (p. 54–55) but did not include a Web link for comments or a comment deadline. The link is www.geosociety.org/positions/comments.asp?position=PlanetaryExploration and the deadline is 17 Oct. 2011. Read the draft at www.geosociety.org/gsatoday/archive/21/9/pdf/i1052-5173-21-9-54.pdf.

A Miocene river in northern Arizona and its implications for the Colorado River and Grand Canyon

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ABSTRACT

The southwesterly course of the pre-late Miocene Crooked Ridge River can be traced continuously for 48 km and discontinuously for 91 km in northern Arizona. It is visible today in inverted relief. Pebbles in the river gravel came from at least as far northeast as the San Juan Mountains. The river valley was carved out of easily eroded Jurassic and Cretaceous rocks, whose debris overloaded the river with abundant detritus, possibly steepening the gradient. After the river became inactive, the regional drainage network was rearranged twice, and the Four Corners region was lowered by erosion 1–2 km. The river provides constraints on the history of the Colorado River and Grand Canyon; its continuation into lakes in Arizona or Utah is unlikely, as is integration of the Colorado River through Grand Canyon by lake spillover. The downstream course of the river was probably across the Kaibab Arch in a valley roughly coincident with the present eastern Grand Canyon.

INTRODUCTION

A turning point in the long history of thought about the origin and age of the Colorado River and Grand Canyon came in the mid-1960s and 1970s when McKee et al. (1967) and Lucchitta (1975, 1989) proposed a polyphase history in which an old upper river flowing on the Colorado Plateau was captured by a young lower river that extended itself by headward erosion from the just-opened Gulf of California (Durham and Allison, 1960). This model implied a post-5–6 Ma age for the integrated Colorado River and the Grand Canyon.

Recent work mostly accepts a complex history, but some rejects a young age or the concept of integration through headward erosion. Data from Crooked Ridge River provide constraints on several of the new proposals, including (1) that an ancestral river flowed into or out of “Hopi Lake” in a north or northwesterly direction (see below); (2) that an ancestral river flowed northward along the present course of Marble and Glen Canyons; and (3) that the Colorado River was integrated through Grand Canyon by the spillover of Hopi Lake.

Scattered exposures of gravel in northern Arizona have long been known (e.g., Cooley et al., 1969; Hunt, 1969; R. Hereford, 1975, personal commun.), but integration of these observations into a coherent drainage system only became possible with the advent of detailed topographic maps, and especially satellite and digital elevation model (DEM) data. Such images presented here are composites of Landsat and shaded-relief DEM data with 10–30 m

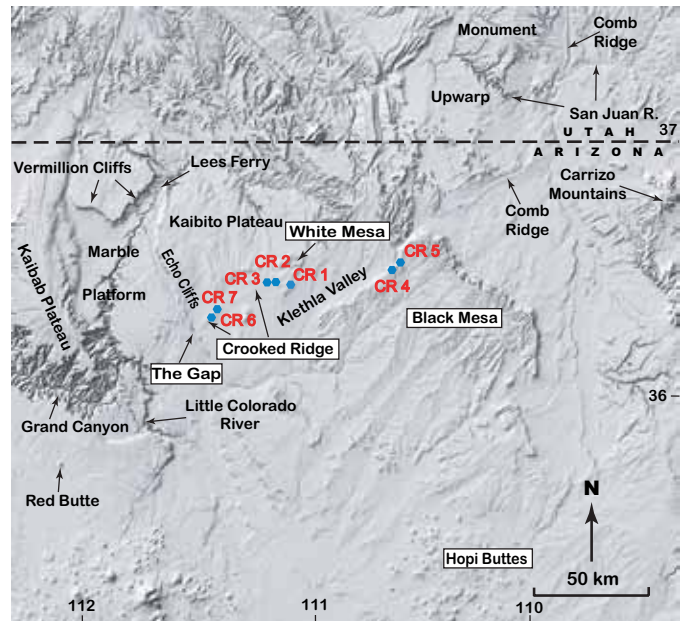


Figure 1. Digital elevation model image showing geographic features of the Kaibito Plateau–Black Mesa region in Arizona near Crooked Ridge. Blue dots show sample localities; red labels are sample numbers.

resolution and 2× vertical exaggeration, obtained from the U.S. Geological Survey Eros Data Center’s seamless server.

PHYSICAL CHARACTERISTICS OF CROOKED RIDGE

Crooked Ridge extends continuously across the Kaibito Plateau of northern Arizona from the eastern edge of White Mesa to The Gap, a large wind gap carved into the Jurassic Navajo Sandstone at the Echo Cliffs (Figs. 1 and 2). The ridge is 48 km long in a straight line, and 55 km long along its trace. An isolated remnant of river deposits with distinctive clasts similar to those on Crooked Ridge occurs near the northwest corner of Black Mesa, ~43 km from the nearest exposures on White Mesa and approximately on the same gradient and trend (Figs. 1 and DR1¹). The river course can thus be traced for 91 km.

The sinuous Crooked Ridge is an example of inverted relief that came about because deposits in the floodplain of an ancient river were protected by a cap of massive 1–2 m pedogenic Stage V calcrete, whereas the rest of the valley was not so protected and has been preferentially lowered by erosion (Figs. 3 and 4).

Remnants of the river deposits now occur on about a quarter of the ridge’s length westward from White Mesa and about a third of the length eastward from The Gap (Figs. 1, 2, and DR1). The intervening part has either fragmentary river deposits or none. The capped parts of the ridge rise as much as 110 m above the adjacent landscape, whereas the eroded bedrock parts are as much as 50–80 m above it. On satellite images, the preserved river deposits are as much as ~1000 m wide, though generally less.

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¹GSA supplemental data item 2011320, Tables DR1–DR3 and Figures DR1 and DR2, is available online at www.geosociety.org/pubs/ft2011.htm. You can also request a copy from *GSA Today*, P.O. Box 9140, Boulder, CO 80301-9140, USA; gsatoday@geosociety.org.

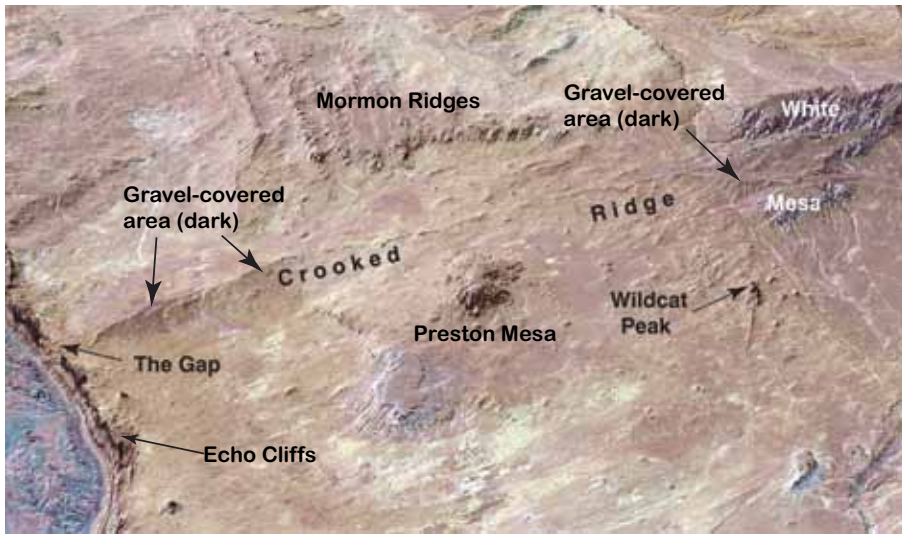


Figure 2. Oblique view of Kaibito Plateau with Crooked Ridge in center, looking north. Approximate straight-line length along the ridge from east edge of White Mesa to The Gap is 48 km. North side of old river valley is clearly visible. Wildcat Peak is a monchiquite intrusive probably 8–6 Ma. No monchiquite clasts were found in the gravel, even though the peak is less than 13 km from Crooked Ridge.

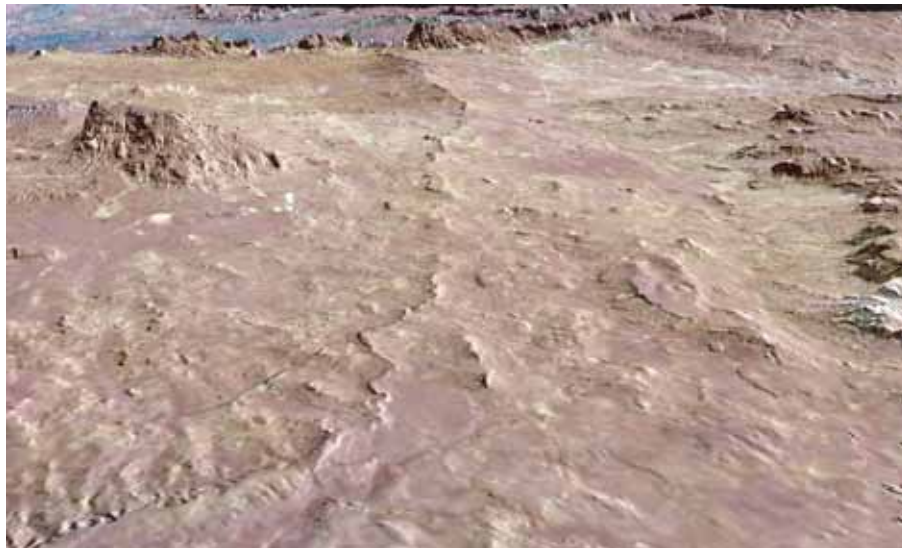


Figure 3. Oblique view looking SW along Crooked Ridge to The Gap 48 km away in a straight line. Ridge follows course of the ancient river in inverted relief. Wider parts of ridge in foreground and at far end are mantled with river deposits; parts in between are primarily bedrock.



Figure 4. Exposure of fluvial sediments on Crooked Ridge, 9 km northeast of The Gap. The exposure consists primarily of sand, with subordinate mud and clay. Gravel is common near top, also within light-colored calcrete cap. Channeling is common.

Along most of the Kaibito Plateau reach, the bedrock for the Crooked Ridge valley is the relatively weak upper part of the Navajo Sandstone and the easily eroded Carmel Formation at the base of the San Rafael Group. These rocks allowed formation of a wide river valley. Evidence for this is visible on satellite images, where the north edge of the old valley is marked by a south-facing 150 m scarp that parallels the trend of Crooked Ridge and truncates the south-southeast-trending Mormon Ridges (Figs. 2 and 3).

The ill-defined south edge of the valley probably is along the northern end of bedrock prominences such as Preston Mesa (Fig. 2) and the southern part of White Mesa. This alignment parallels both Crooked Ridge and the northern edge of the valley. If this alignment is taken as the south edge, the valley may have been as much as 5–10 km wide across most of the Kaibito Plateau.

At The Gap (Figs. 1 and 2), the valley crosses the Echo Cliffs ridge, formed by the resistant Navajo Sandstone upturned along the Echo Cliffs monocline. This defile is visible today in cross section. The present rim-to-rim width of the gap is 3.4 km and its depth is 290 m, as measured on satellite images and topographic maps.

STRUCTURAL AND STRATIGRAPHIC FEATURES

Between Black Mesa and White Mesa, the ancient drainage crosses Kletthla Valley at a low angle. This is a strike valley along the south continuation of the Tsegi–Comb Ridge system of monoclinical flexures, a part of a major structural trend that continues northward for ~250 km along Comb Ridge and separates the Monument upwarp to the northwest from structurally low areas to the southeast (Figs. 1, 5, and DR2 [see footnote 1]).

On Kaibito Plateau, Crooked Ridge crosses several down-to-the-east monoclinical flexures (Fig. DR2). West of Echo Cliffs, the Kaibab Plateau is a north- and south-plunging dome (Fig. 1) bounded on the east by the East Kaibab monocline, which also

has down-to-the-east displacement. The Colorado River forms a great bend that follows the strike of the strata around the south-plunging part of the dome. The effect of the various monoclines is to expose strata successively lower in the section toward the west.

The remnant of fluvial deposits on Black Mesa rests on the Wepo Formation in the middle of the Upper Cretaceous Mesaverde Group. The ancient valley sides are not preserved here but must have been composed of Upper Cretaceous rocks above the Mesaverde Group, perhaps correlating with the Wahweap Formation of the Kaiparowits Plateau ~110 km northwest in southern Utah. This unit probably also formed the valley floor and sides northeast of Black Mesa toward the San Juan Mountains.

The sides of the old valley between Black Mesa and White Mesa, now occupied by Kletthla Valley, were in the Mesaverde Group and the underlying Mancos Shale and Dakota Sandstone of Cretaceous age as well as the Morrison Formation and Entrada Sandstone of Jurassic age.

White Mesa is capped today by the Entrada Sandstone and thin remnants of the Cretaceous Dakota Formation (F. Peterson, 2010, personal commun.). The reach between White Mesa and The Gap is rimmed by the upper part of the Jurassic Navajo Sandstone and the Carmel Formation, capped locally by small remnants of Entrada. In Crooked Ridge time, Jurassic and Cretaceous rocks most likely rimmed all these parts of the valley.

The abundance of easily eroded rocks along the river course likely influenced the character of the river.

LITHOLOGIC CHARACTERISTICS AND PROVENANCE OF TRANSPORTED MATERIAL

A minimum of 20 m of fluvial material is exposed on Crooked Ridge. Good exposures show that the bulk of the deposits consist of sand containing stringers and interbeds of gravel, mud, and clay. Gravel is more abundant near the top of several exposures. Channeling at <1 to ~10 m scale is common (Fig. 4), as is cross bedding that shows a southwest flow direction (noted by us and by Hunt, 1969). The sand is weakly indurated, fine- to medium-grained but locally medium- to coarse-grained, and subrounded to subangular. A small percentage of grains are fine, very well rounded, and frosted, and were probably derived from Mesozoic eolianites. The scarcity of eolian sand suggests that the Oligocene Chuska erg of Cather et al. (2008) either was never present in the area traversed by Crooked Ridge River or was eroded by the time the river was active.

Composition, sampling methods, sampling locations, and inferred sources of gravel are shown in Tables DR1 and DR2 (see footnote 1). Clasts are considered distinctive or non-distinctive according to the level of confidence in assessing provenance; both locally derived and far-traveled or exotic clasts are present. Most locally derived clasts are quartz sandstones from the upper Mesozoic formations that formed the valley sides on the Kaibito Plateau, Black Mesa, and upstream from Black Mesa (Harshbarger et al., 1958; Page and Repenning, 1958; Cooley et al., 1969). Also common are petrified wood and fossiliferous limy sandstone, both derived from upper Mesozoic formations. Typically, these clasts are subangular to subrounded; maximum size generally is ~30 cm, but a few boulders, which probably rolled in from the valley sides, reach 100 cm in diameter. Exotic clasts are subrounded to rounded, mostly 1–3 cm in diameter, but reach 10 cm.

Exotic clasts include many types of volcanic, hypabyssal, plutonic, and metamorphic lithologies; petrographic characteristics link them with specific sources northeast of Crooked Ridge and

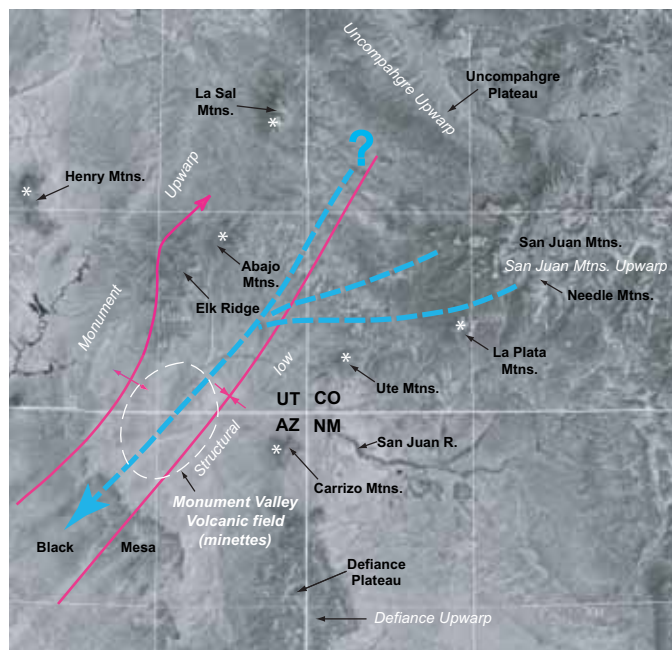


Figure 5. Thick dashed blue lines indicate inferred approximate courses of Crooked Ridge River and possible tributaries. Magenta anticline and syncline symbols denote structurally high and low areas, respectively. Thin dashed white line bounds Monument Valley minette volcanic field. White asterisks mark laccolithic mountains with hypabyssal porphyry exposed. White lettering denotes geologic features; black lettering, geographic features.

Black Mesa at least as far as the San Juan Mountains (Table DR2). Minettes came from the late Oligocene to early Miocene dikes and diatremes of the Navajo volcanic field, most likely from the Monument Valley section (Laughlin et al., 1986, and references therein) (Fig. 5). Clasts of granite, pegmatite, and perthitic microcline also probably came from intrusions in Monument Valley, where these lithologies are especially common as xenoliths.

The intermediate porphyries are strikingly similar to rocks reported in laccolithic centers of the Colorado Plateau, including the Abajo, Carrizo, Henry, La Plata, La Sal, and Ute Mountains (Friedman and Huffman, 1998, and references therein). The emplacement depth of these Laramide and middle Tertiary intrusions is uncertain, but probably <2400 m below the surface at the time of intrusion. Erosion of Upper Cretaceous and possibly early Tertiary strata unroofed these distinctive porphyries in the Crooked Ridge River drainage basin and fed pebbles into the river.

All the distinctive clasts of metamorphic rocks can be matched with Proterozoic rocks mapped in the Needle Mountains (Fig. 5), where today they crop out at elevations as high as 4000 m. The quartz metaconglomerate and metawacke are comparable with some of the lithologies in the Vallecito Conglomerate and the Irving Formation, and the fine quartzofeldspathic gneiss matches the Twilight Gneiss (Larson and Cross, 1956; Barker, 1969).

Felsic lava flows, welded tuffs, andesites, latites, and hydrothermal mineral deposits are widespread and abundant in the Oligocene San Juan volcanic field (Lipman et al., 1978). The distinctive clasts of these lithologies, as well as most if not all the non-distinctive clasts of the same type, are likely to have come from this region.

The pebbles of crystal tuff and altered rhyolite and andesite are not likely to be reworked from older gravel deposits because the former are friable and the latter are soft. Pebbles of rhyolitic vitrophyre are not likely to be reworked from the Chinle and Morrison Formations because they are glassy and not devitrified as are those from the Mesozoic formations (Cadigan, 1972; Thordarson et al., 1972; Dodge, 1973). Notably absent from the samples collected at Crooked Ridge and Black Mesa are clasts of limestone similar to the Kaibab Formation on the Kaibab Plateau, red sandstone similar to that of Triassic rocks on the Colorado Plateau, and monchiquite, a volcanic rock common in the Hopi Buttes to the south (Fig. 1) and also present at Wildcat Peak, not far south of Crooked Ridge on the Kaibito Plateau (Fig. 2).

AGE OF CROOKED RIDGE

We only have indirect methods for estimating the age of Crooked Ridge River. One is that the course of the river has no relation to the present drainage network. Instead, two distinct episodes of drainage arrangement have occurred since Crooked Ridge River time. The first of these is the development of Klethla Valley (Fig. 1), which cuts across the course of the ancient river. Klethla Valley is broad and mature and typical of many such valleys on the Colorado Plateau. This valley in turn is being beheaded by immature drainages of the canyon-cutting cycle that are tributary to the Colorado and San Juan Rivers. These two major rearrangements of the drainage network since Crooked Ridge time require an indeterminate but substantial time interval.

Another indirect method involves Wildcat Peak (Fig. 2), a monchiquite intrusive that is part of the Tuba volcanic field (Akers et al., 1971). Wildcat Peak has not been dated, but volcanic rocks of this composition have been dated in the Hopi Buttes at 6–8.5 Ma (Damon and Spencer, 2001), suggesting a similar age for this intrusive. No monchiquite clasts have been found in the gravel even

though Wildcat Peak is <13 km from Crooked Ridge, toward which tributary streams near Wildcat Peak presumably flowed. Therefore, we infer that the river became inactive before the intrusive was emplaced or unroofed in the late Miocene.

Finally, removal of 1–2 km of strata from the area of the laccolithic intrusives since they were first unroofed (see below), must have taken a substantial time. Such deep erosion is in agreement with results obtained by other techniques (e.g., Pederson et al., 2011).

On the basis of these considerations, we infer that the Crooked Ridge River was active in mid-Miocene (and perhaps earlier?) time, in keeping with Hunt's (1969) suggestions concerning the age of paleodrainages in the region. The river became inactive in the late Miocene.

LONGITUDINAL PROFILE OF THE RIVER

The farthest east and highest exposure of river deposits is on Black Mesa at 2240 m; the farthest west and lowest near The Gap is at ~1700 m. Over the 91 km that Crooked Ridge River can be traced from Black Mesa to The Gap, the river deposits drop 530 m, giving an average present-day gradient of 5.8 m/km. The gradient of individual reaches varies considerably (Fig. DR1), probably reflecting differences in the rocks into which the valley was carved, structural features such as monoclines, and constrictions such as The Gap in the river's path. The relatively high gradient can plausibly be ascribed to overloading by sediment derived from the easily eroded Jurassic and Cretaceous rocks that formed the valley sides upstream from The Gap. Internal structures of the river sediments suggest a braided stream and support this interpretation.

An alternative explanation for the steep gradient of the deposits is post-depositional tilting of the channel due to crustal warping such as a "bull's-eye" of isostatic unloading to the north (Lazear et al., 2011; Pederson et al., 2011) or mantle dynamics (Robert et al., 2011; Moucha et al., 2009). However, the inferred bull's-eye is in the Canyonlands country north to northwest of Crooked Ridge River, so the river's course is essentially tangential to the uplift contours and should be little affected by this unloading.

The mantle-dynamics studies suggest northeast tilting for nearly all the Miocene and southwest tilting since then. Therefore, the river would have been tilted first northeast and then southwest. It is currently not possible to evaluate the net effect of these tilting events on the gradient of Crooked Ridge River.

The erosional history of the Colorado Plateau in the eastern Grand Canyon region shows a wave of erosion starting in the southwest and progressing northeast with time, mostly through cliff retreat at 4–8 km/Ma (Lucchitta, 1975; Holm, 2001; Lucchitta and Jeanne, 2001). This erosion would cause northeast tilting of the region because of isostatic uplift and may have decreased the original gradient of the nearby Crooked Ridge River.

In conclusion, the steep gradient of the river deposits is plausibly explained by overloading, although tectonic adjustments can neither be proved nor ruled out at this time.

COMPARISON WITH OTHER RIVERS

It is useful to compare the characteristics of Crooked Ridge River with those of other present-day overloaded streams with similar configurations in order to estimate the gradient and possible discharge of the ancient river. Two such streams are a reach of the Animas River upstream from Durango and the San Juan River upstream from Pagosa Springs, both in southwest Colorado. Data for these streams and for Crooked Ridge River are in Table DR3 (see footnote 1).

The comparison suggests that a steep gradient for the overloaded Crooked Ridge River is not unreasonable, and that (together with the exotic clasts) the ancient river was not a minor local wash, but a river of regional extent whose discharge was at least comparable to those of today's Animas and upper San Juan Rivers.

EROSIONAL LOWERING

The relative scarcity of porphyry clasts in Crooked Ridge gravel contrasts markedly with their abundance in even the oldest terraces of the Colorado River. We infer that the laccolithic intrusives were less exposed when the Crooked Ridge River was active than they are today and that some were not exposed at all (Eckel et al., 1949). Today, a few of these rocks are exposed at altitudes as high as 4000 m, and many are at 3000–3500 m; in Crooked Ridge River time, only the highest would have been exposed. Hence, the scarcity of these clasts in the gravel suggests a topographic surface in the 3500+ m range. Today, the region in southwest Colorado and southeast Utah near the intrusives is at 1500–2000 m, suggesting that 1–2 km of strata has been removed since Crooked Ridge River time.

PERMISSIBLE AND IMPERMISSIBLE PALEODRAINAGES

The middle Miocene to lowermost Pliocene(?) Bidahochi Formation figures prominently in hypotheses on the history and integration of the Colorado River on the Colorado Plateau. The formation was deposited in Bidahochi basin, roughly centered in the Hopi Buttes (Fig. 1). The origin of the formation is controversial. Spencer et al. (2008) proposed that it was deposited in a deep “Hopi Lake” large enough to potentially extend into southern Utah. The postulated lake was the sump of a large drainage system that crossed the Colorado Plateau and headed in the Snake River basin, as inferred from fossil fish of Snake River affinities and adapted to swift-flowing rivers. The lake would eventually have spilled over into a drainage along the present Grand Canyon, initiating a top-down cascade of spillovers that integrated the Colorado River in its present course through Grand Canyon and the lower Colorado region (e.g., Meek and Douglass, 2001; Scarborough, 2001).

Others (e.g., Dallegge et al., 2001; Dickinson, 2011) propose that the formation was deposited not in a deep lake, but rather in shallow and ephemeral ones that at times probably were playas and were filled by fluvial aggradation.

Crooked Ridge River provides useful constraints on the Bidahochi Formation issue. The southwesterly course of the river from the San Juan Mountains to the Kaibab upwarp makes it impossible for rivers such as an ancestral Colorado to flow southward or southeastward from western Colorado or eastern Utah into “Hopi Lake” or, conversely northward or northwestward from “Hopi Lake” (Fig. 6).

It is difficult to reconcile the existence of a large lake near (let alone across) the well-established Crooked Ridge River, which presumably had a developed drainage network and had cut down to a lower elevation than the lake. It is also difficult to envision a sudden, catastrophic, and canyon-forming spillover of the lake in an area where the valley of the Crooked Ridge River already existed. Even had the spillover taken place, the resulting flow would have been along the course of Crooked Ridge River, not through western Grand Canyon.

As the current evaluations of tilting are speculative, we use the 1700 m altitude of Crooked Ridge River sediments near The Gap as a preliminary constraint on possible continuations of Crooked Ridge River downstream, where no deposits are preserved (Fig. 6).

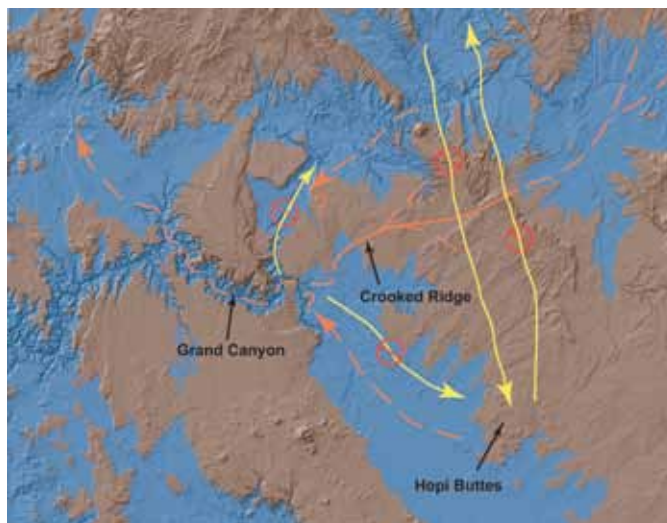


Figure 6. Digital elevation model image showing elevations above (brown) and below (blue) 1700 m, the elevation of Crooked Ridge gravel at The Gap. Brown areas are excluded from possible continuation of river; blue areas are permissible continuations assuming no gradient for the river (boundary condition). Hopi Buttes are mostly excluded. Headwaters of Little Colorado River (off image) are excluded. Orange lines are permissible river courses; yellow lines, impermissible. Orange lines with query denote possible ancestral Colorado and Little Colorado Rivers.

Accordingly, the Bidahochi basin is part of the excluded terrain, because the base of the Bidahochi Formation is at ~1750 m (Love, 1989; Cather et al., 2008). Thus, it is unlikely that the Crooked Ridge River would have filled the hypothetical Hopi Lake even in the absence of a gradient.

Figure 6 also shows that the only possible continuation beyond The Gap is southward along the alignment of the Echo Cliffs, then westward to near the present-day confluence of the Colorado and Little Colorado Rivers. From this point, the river could flow either north along the alignment of the present Marble Canyon, or west along the alignment of the present eastern Grand Canyon.

If the ancient river flowed north, possibly to a hypothetical and undocumented “Glen Lake” (Hill and Ranney, 2008), its current average gradient would place it at an elevation of 920 m at Lees Ferry, which is below even the present Colorado River elevation there. If the gradient had been only 3 m/km, the river would have been ~350 m above present river grade in the Miocene. However, the present river grade is much lower than it was in Crooked Ridge time because the Colorado was ~200 m higher just 525–600 ka ago (Lucchitta, unpub. field data, 1998; Lucchitta et al., 2000, 2001), giving an incision rate of 380–330 m/Ma. So even at 1 Ma the Colorado River grade would have been at that of the Crooked Ridge River or higher. The incision is the product of vigorous post-5 Ma downcutting by the Colorado River. Projecting the rate over this interval would bring the river elevation at Lees Ferry to 1600–1900 m above present river grade, or ~1 km above the elevation of the Crooked Ridge River at The Gap. Neither distant nor more local warping is likely to overcome such a topographic disparity.

We conclude that the Crooked Ridge River was unlikely to flow northward from the area of The Gap. On the other hand, our data do not preclude an ancient river such as the ancestral Colorado River flowing southwestward along approximately its present course but at a higher elevation, to join the Crooked Ridge River in the area of the present-day confluence of the Little Colorado River.

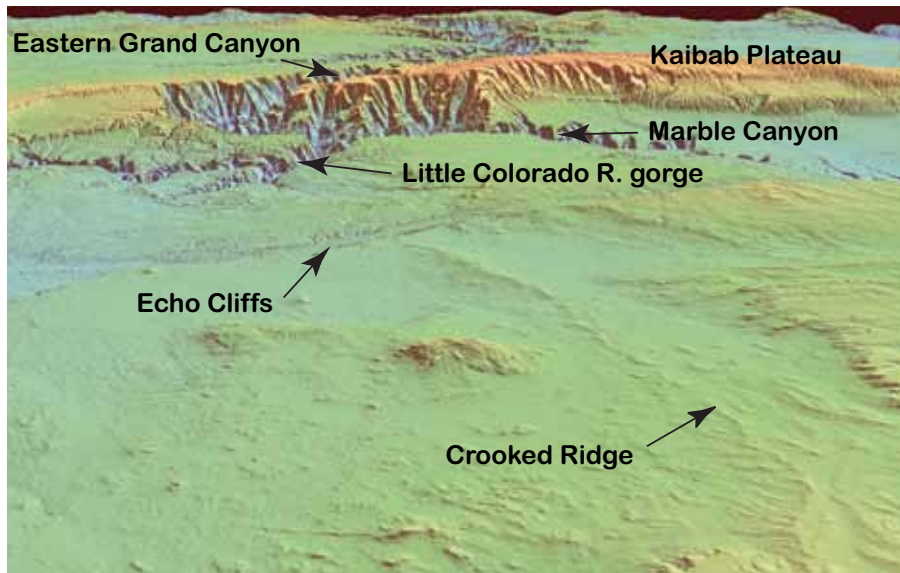


Figure 7. Oblique view to SW along Crooked Ridge (foreground) heading for eastern Grand Canyon (background).

A course westward is possible along the alignment of the present eastern Grand Canyon (Figs. 6 and 7). This potential route was proposed long ago by Babenroth and Strahler (1945) and Lucchitta (1975, 1989) and, more recently, by Scarborough (2001) and Flowers et al. (2008). The greater width and complexity of the Grand Canyon here supports an older age than for other parts of the canyon. Most likely, the old course was in a broad valley that followed the curving strike of strata around the south-plunging part of the Kaibab arch. Valley rims were in Mesozoic rocks and the floor was incised some hundreds of meters below the top of the Kaibab Limestone.

Regarding the continuation of the Crooked Ridge River beyond the Kaibab Plateau, a course along western Grand Canyon and the Lake Mead area is precluded by widespread and well documented Miocene interior-basin deposits at the mouth of the Grand Canyon (Longwell, 1936; Lucchitta, 1966, 1967, 1972, 1989). We offer instead the speculation that the river flowed northwestward (Fig. 6) to near St. George, Utah, then generally northward along the east flank of the Sevier orogenic belt, eventually reaching the Snake River basin. This would allow fish of Snake River affinities (Spencer et al., 2008) to reach the Colorado Plateau area near Crooked Ridge River.

CONCLUSIONS

1. Crooked Ridge River was a substantial stream of northern Arizona that headed at least as far northeast as the San Juan Mountains of Colorado. The age of the river is poorly constrained. In keeping with Hunt (1969) and our findings, we think it was of middle Miocene age, and possibly older. The river probably became inactive in late Miocene time.
2. The clasts of the river are not reworked from some older river because several of the clast lithologies would not survive recycling.
3. Channel characteristics and gradient compare favorably with two substantial present-day rivers in the region.
4. The ancient river bore no relation to the present-day drainage network. On the contrary, two entirely different drainage configurations have developed since Crooked Ridge River time.
5. The southwesterly course of the river from the San Juan Mountains to the Kaibab upwarp makes it impossible for other rivers

such as an ancestral Colorado to flow across the Crooked Ridge River into or away from northeast Arizona and lakes such as Hopi Lake, nor could it empty into these lakes.

6. The Crooked Ridge River could not flow northward along the present course of Marble Canyon.
7. A southwest- or south-flowing river (ancestral Colorado?), topographically much higher than the present river, could have joined Crooked Ridge River somewhere near the present mouth of the Little Colorado River.
8. A westward continuation of the river(s) along the alignment of the present eastern Grand Canyon around the Kaibab arch is possible and our favored alternative.
9. It is unlikely that a lake spillover would have integrated the Colorado River through the western Grand Canyon because an older and well developed river system was already in place that did not flow through the western Grand Canyon into the upper Lake Mead area.
10. Since the river became inactive, the Four Corners region has been lowered erosionally by 1–2 km.

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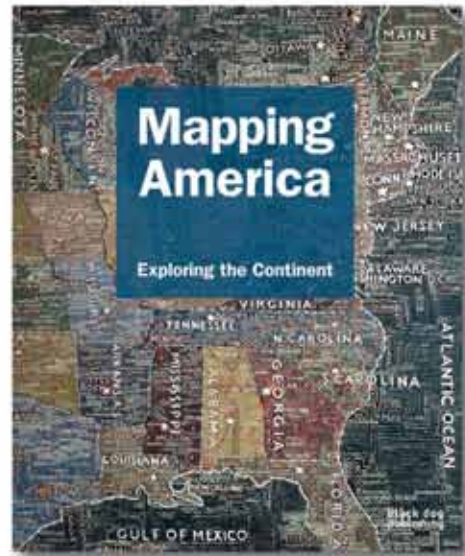
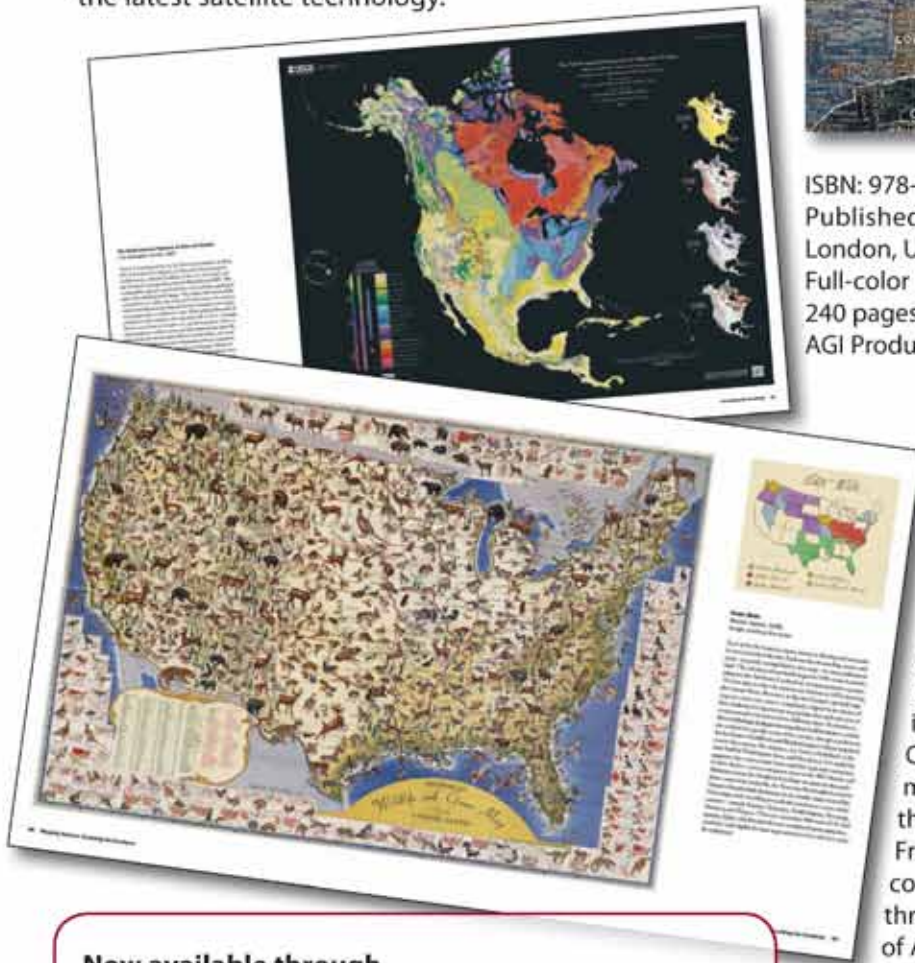
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2012 GSA Medals and Awards

**Nominations
due
1 February 2012**

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2012 GSA Medals and Awards

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The primary nominator is responsible for collecting the complete nomination packet (including letters of support), which should then be submitted as one e-mail (with supporting documents as attachments) or as one package via post.

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Criteria for Nomination

1. The paper must be selected from GSA or state geological survey publications;
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3. The nomination must include a paragraph stating the pertinence of the paper.

Basis for Selection

Each paper will be judged on its uniqueness or significance as a model of its type of work along with its overall worthiness. It is preferred that the paper be directly applicable to informed laypersons (e.g., planners, engineers). In addition, *nominated papers must:*

- establish an environmental problem or need;
- provide substantive information on the basic geology or geologic process pertinent to the problem;
- relate the geology to the problem or need;
- suggest solutions or provide appropriate land use recommendations based on the geology;
- present the information in a manner that is understandable and directly usable by geologists; and
- address the environmental need or resolve the problem.

2011 Award Named

The 2011 award will be bestowed during the 2011 GSA Annual Meeting & Exposition on Tues., 11 Oct., at the Hilton Minneapolis (Marquette VI, 7 a.m.–noon) for *Mapping of Holocene River Alluvium along the San Pedro River, Aravaipa Creek, and Babocomari River, Southeastern Arizona*, 2009, DM-RM-1, 6 sheets, map scale 1:24,000, 77 p., by Joseph P. Cook, Ann Youberg, and Philip A. Pearthree, Jill A. Onken, Bryan J. MacFarlane, David E. Haddad, Erica R. Bigio, and Andrew L. Kowler.

2012 National Awards

GSA members are encouraged to nominate colleagues for the following awards.

The William T. Pecora Award, sponsored jointly by NASA and the U.S. Dept. of the Interior, recognizes outstanding contributions by individuals or groups toward understanding Earth by means of remote sensing. The award recognizes the work of those in the scientific and technical community as well as those involved in the practical application of remote sensing. Consideration will be given to sustained or single contributions of major importance to the art and/or science of understanding Earth through observations from space. Learn more at <http://remotesensing.usgs.gov/pecora.php>.

The National Medal of Science is awarded by the President of the United States to individuals “deserving of special recognition by reason of their outstanding contributions to knowledge in the physical, biological, mathematical, engineering, or social and behavioral sciences.” The award committee gives special attention to younger U.S. scientists and engineers, who may now be reaching a point at which their contributions merit recognition, as well as to outstanding women and minority scientists. Learn more at www.nsf.gov/od/nms/medal.jsp.

The Vannevar Bush Award is presented periodically to a senior statesperson of science and technology who, through public service in science and technology, has made an outstanding contribution toward the welfare of humankind and

to the United States. Nominations should be accompanied by a complete biography and a brief citation summarizing the nominee’s scientific or technological contributions to our national welfare in promotion of the progress of science. Learn more at www.nsf.gov/nsb/awards/bush.jsp.

The Alan T. Waterman Award is presented annually by the National Science Foundation (NSF) and the National Science Board to an outstanding young researcher in any field of science or engineering supported by the NSF. Candidates must be U.S. citizens or permanent residents 35 years of age or younger OR not more than five years beyond receipt of a Ph.D. by 31 Dec. of the year in which they are nominated. Candidates should have completed sufficient scientific or engineering research to have demonstrated outstanding capability and exceptional promise for significant future achievement through personal accomplishments. The Waterman Award complements the Vannevar Bush Award; both are designed to encourage individuals to seek the highest levels of achievement in science, engineering, and service to humanity. Learn more at www.nsf.gov/od/waterman/waterman.jsp.

The G.K. Warren Prize is awarded by the National Academy of Sciences for noteworthy and distinguished accomplishment in fluvial geology and closely related aspects of the geological sciences. Learn more at www.nasonline.org/site/PageServer?pagename=AWARDS_warren.

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The Society recognizes the following members for their contributions and service as GSA Campus Representatives. As Campus Reps, these members on two- and four-year college and university campuses around the world provide valuable information regarding GSA programs, opportunities, and deadlines to geoscience students and their colleagues, and act as ambassadors for GSA.

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Alpine, Texas, USA

7–9 March 2012

www.geosociety.org/Sections/sc/2012mtg/



From the NASA Earth Observatory website: "Alternately known as a geologist's paradise and a geologist's nightmare, Big Bend National Park in southwestern Texas offers a multitude of rock formations. Sparse vegetation makes finding and observing the rocks easy, but they document a complicated geologic history extending back 500 million years." The Enhanced Thematic Mapper Plus on NASA's Landsat 7 satellite captured this natural-color image of Big Bend National Park on 10 May 2002; <http://earthobservatory.nasa.gov/IOTD/view.php?id=44670>.

CALL FOR PAPERS

Abstract deadline: 6 Dec. 2011

Please submit your abstract online at www.geosociety.org/Sections/sc/2012mtg/. An abstract submission fee of US\$10 for students and US\$15 for all others will be charged. If you cannot submit an abstract online, please contact Linda Battan, +1-303-357-1018, lbattan@geosociety.org. For any other questions, please contact the Technical Program Chair, Jim Whitford-Stark at jlwstark@sulross.edu.

Symposium

1. **Big Bend National Park and Vicinity: A Decade of Research.** Don Corrick, Big Bend National Park; Dee Ann Cooper, Texas Natural Science Center, The Univ. of Texas at Austin; Roger Cooper, Lamar Univ.

Theme Sessions

1. **Tectonic History of the Trans-Pecos Region.**
2. **The Rio Grande and Its Tributaries in the Big Bend Region: Hydrology, Water Quality, and Restoration Efforts.** Jeff Bennett and Joe Sirotnak, Big Bend National Park.
3. **Long-Term Biogeochemical Responses to Global Change.** John Zak, Texas Tech University
4. **The Permian of the Southwest.**
5. **Aquifers of West Texas.** James Ward, Angelo State University.
6. **Geoarchaeological Investigations in the Big Bend Region, Southwestern Texas.** Andy Cloud, Center for Big Bend Studies, Sul Ross State University.
7. **Issues in Earth Science Education.**

FIELD TRIPS

Please contact Field Trip Chair John White at john.white@eku.edu if you have questions.

1. **Geology of Big Bend National Park: A Decade of Research.** John White, Eastern Kentucky University.
2. **Geology of Colorado Canyon, Big Bend Ranch State Park.** Kevin Urbanczyk, Sul Ross State University.
3. **Permian of the Southwest.**
4. **Aquifers of West Texas.**

SHORT COURSE

Techniques in Field Hydrogeology and Hydrology. Joe Yelderman, Baylor University; Kevin Urbanczyk, Sul Ross State University.

REGISTRATION

Early registration deadline: 6 Feb. 2012

Cancellation deadline: 13 Feb. 2012

Registration opens in December. For further information or if you need special accommodations, please contact the general chair, Kevin Urbanczyk, at kevinu@sulross.edu.



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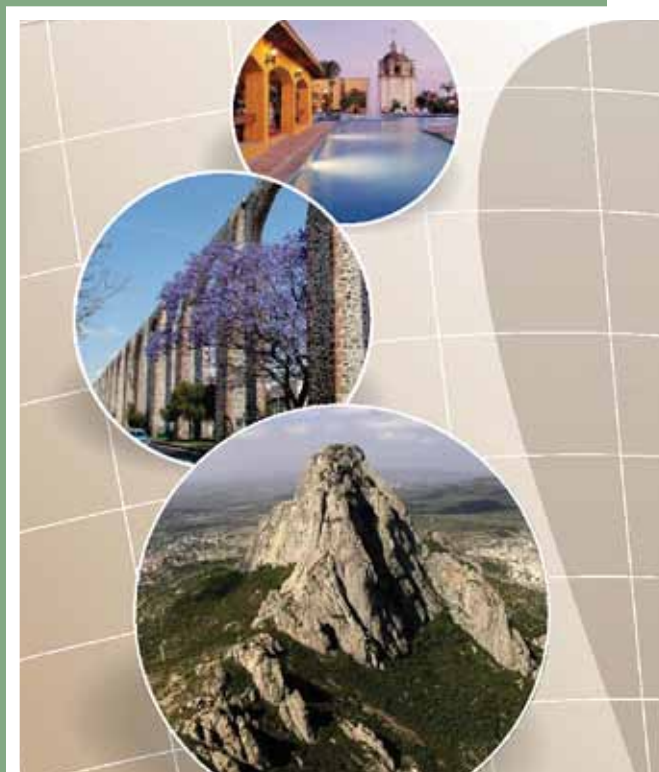
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CORDILLERAN

108th Annual Meeting
of the Cordilleran Section, GSA
Querétaro, México
29–31 March 2012

www.geosociety.org/Sections/cord/2012mtg/



Download poster at www.geosociety.org/Sections/cord/2012mtg/.

LOCATION

The Center of Geoscience and the Institute of Geology of the National Autonomous Univ. of Mexico (Universidad Nacional Autónoma de México; UNAM) are hosting the 108th meeting of the GSA Cordilleran Section in Querétaro, Mexico, at Hotel Misión Juriquilla. Querétaro is a modern industrial city built around a beautiful colonial center. It is located in the geographic center of country, ~140 miles northwest of Mexico City.

CALL FOR PAPERS

Abstract deadline: 12 Jan. 2012

Please submit your abstract online at www.geosociety.org/Sections/cord/2012mtg/. An abstract submission fee of US\$10 for students and US\$15 for all others will be charged. If you cannot submit the abstract online, please contact Linda Battan, +1-303-357-1018, lbattan@geosociety.org.

Symposium

51. **Amalgamation and Breakup of Pangea in the Americas.** *Cosponsored by IGCP 597 (Origin and Evolution of Pangea) and IGCP 574 (Bending and Bent Orogens, Continental Ribbons).* Brendan Murphy, St. Francis Xavier Univ., bmurphy@sfx.ca; Jarda Dostal, Saint Mary's Univ., Jarda.Dostal@StMarys.ca; Damian Nance, Univ. of Ohio, nance@ohio.edu.

Theme Sessions

- T1. **Silicic Volcanism.** Cathy Busby, Univ. of California, cathy@crystal.ucsb.edu; Graham Andrews, Univ. of California, gdma1977@gmail.com.
- T2. **Ore Deposits and Ore Genesis in the American Cordillera.** Antoni Camprubi, UNAM, camprubitaga@gmail.com.
- T3. **Convergent Margin of Western Pangea: Triassic-Jurassic Magmatism, Sedimentation, and Tectonics from Colombia to Oregon.** Timothy Lawton, New Mexico State Univ., tlawton@nmsu.edu; Rafael Barboza-Gudiño, Univ. Autónoma de San Luis Potosí, rbarboza@uaslp.mx; Roberto Molina-Garza, UNAM, rmolina@geociencias.unam.mx.
- T4. **Flat-Slab Subduction from Past to Present.** Vlad Manea, UNAM, vlad@geociencias.unam.mx; Marina Manea, UNAM, marina@geociencias.unam.mx.
- T5. **Mechanisms of Arc Magma Generation along the Cordillera.** Laura Mori, UNAM, lmori@geologia.unam.mx; Peter Schaaf, UNAM, pschaaf@geofisica.unam.mx; Arturo Gómez Tuena, UNAM, tuena@geociencias.unam.mx.
- T6. **Terrane Accretion, Flat Slab Subduction, and Convergence Rate Variations: What Caused the Cretaceous-Paleogene Shortening across the Mexican Cordillera?** Michelangelo Martini, UNAM, mmartini@geologia.unam.mx; Elisa Fitz Díaz, elisaf@geologia.unam.mx, UNAM; Timothy Lawton, New Mexico State Univ., tlawton@nmsu.edu.
- T7. **Structural Style, Timing, and Stratigraphy of the Laramide Orogeny in Mexico.** Mariano Cerca, UNAM, mcerca@geociencias.unam.mx; Gabriel Chavez-Cabello, Universidad de Nuevo León, gabchave@hotmail.com; Martín Valencia, UNAM, valencia@geologia.unam.mx.
- T8. **Lithosphere Stretching and Magmatism Leading to the Gulf of California.** Luca Ferrari, UNAM, luca@geociencias.unam.mx; Arturo Martín Barajas, CICESE, amartin@cicese.mx; Joann Stock, California Institute of Technology, jstock@gps.caltech.edu.
- T9. **What Do Fossil Ages and Distributions Tell Us about the History of the Ancient Gulf of California?** Judy Terry Smith, redcloud1@earthlink.net, Smithsonian Institution; Ana Luisa Carreño, UNAM, anacar@servidor.unam.mx; Javier Helenes, CICESE, jhelenes@cicese.mx.
- T10. **The Caribbean Plate and its Geologic Connections with North and South America.** Luigi Solari, UNAM,

solari@servidor.unam.mx; Uwe Martens, Tectonic Analysis Ltd., umartens@zoho.com.

- T11. **Developments in Geophysical Investigations of Volcano Hydrothermal Systems: Exploration and Hazards.** Jonathan M.G. Glen, USGS, jglen@usgs.gov; Shaul Hurwitz, USGS, shaulh@usgs.gov; Vyacheslav M. Zobin, Universidad de Colima, vzobin@ucol.mx; Robert A. Sohn, Woods Hole Oceanographic Institution, rsohn@whoi.edu.
- T12. **Limnogeology Studies and Paleoenvironmental Records from Ancient and Modern Lakes.** Beatriz Ortega, UNAM, bortega@geofisica.unam.mx; Margarita Caballero, UNAM, maga@geofisica.unam.mx; Socorro Lozano, UNAM, mslozano@servidor.unam.mx.
- T13. **Heterogeneous Geologic Formations: Modeling Spatial Variability.** Eric Morales Casique, UNAM, ericmc@geologia.unam.mx; Martín Díaz Viera, Instituto Mexicano del Petróleo, mdiazv@imp.mx.
- T14. **Ground Deformation Related to Anthropogenic Activities: Achievements in the Development of Geoscience Information System for Improved Management of Natural Resources.** Dora Carreon-Freyre, UNAM, freyre@geociencias.unam.mx; Mariano Cerca, UNAM, mcerca@geociencias.unam.mx; Devin Galloway, USGS, dlgallow@usgs.gov; Penelope Lopez-Quiroz, Centro de Investigación en Geografía y Geomática, penelope@centrogeo.org.mx.
- T15. **Pushing the Envelope: Recent Advances in Teaching Geoscience with Technology.** Ralph Dawes, Wenatchee Valley College, RDawes@wvc.edu.
- T16. **Undergraduate Research Posters.** Cosponsored by *Council on Undergraduate Research (CUR)*. Kathleen D. Surples, Trinity Univ., ksurples@trinity.edu.

FIELD TRIPS

To submit additional field trip proposals, contact Jorge Aranda, jjag@geociencias.unam.mx.

1. **Amalgamation and Breakup of Pangea: The Type Example of the Supercontinent Cycle—Acatlán Complex, Southern Mexico: The Geological Record of an Orogen on the Western Periphery of Pangea** (4 days). Duncan Keppie, UNAM, duncan@unam.mx, Brendan Murphy, Gonzalo Galaz, Moritz Kirsch, and María Helbig.
2. **The Late Cretaceous Mexican Fold-and-Thrust Belt and its Possible Relation with the Accretion of the Guerrero Terrane** (3 days). Michelangelo Martini,

mmartini@geologia.unam.mx, Elisa Fitz, and Timothy Lawton.

3. **Environmental Geochemistry of the Pozos Mining District, Guanajuato, East-Central Mexico** (1 day). Alejandro Carrillo, ambiente@geociencias.unam.mx, Juventino Martínez, and Gilles Levesse.
4. **Sierra de Catorce: Remnants of the Ancient Pacific Margin of Western Pangea in Central Mexico** (2–3 days). Rafael Barboza, rbarboza@uaslp.mx, Roberto Molina, and Tim Lawton.
5. **Geology of the Parícutin Volcano and of Los Azufres Geothermal Field, Michoacán** (3 days). Ignacio Torres Alvarado, ita@cie.unam.mx, Victor Hugo Garduño, Pedro Corona, and Eduardo González Partida.
6. **Ground Deformation Related to Anthropogenic Activities in Urbanized Areas of the Mexico Basin** (2 days). Mariano Cerca, mcerca@geociencias.unam.mx, and Dora Carreón.
7. **The Mid-Tertiary Volcanic Sequence Exposed at the Guanajuato Mining District and its Relation with Silver-Gold Mineralization.** José Jorge Aranda-Gómez, jjag@geociencias.unam.mx, Pablo Dávila-Harris, and Luis Vassallo.
8. **Recent Volcanism in the Eastern Trans-Mexican Volcanic Belt.** Gerardo Carrasco, gerardoc@geociencias.unam.mx, Pablo Dávila-Harris, Michael Ort, Nancy Riggs, and Lee Siebert.

REGISTRATION

Early registration deadline: 27 Feb. 2012

Cancellation deadline: 5 Mar. 2012

Online registration begins in January 2012. For further information, or if you have special requirements, please contact the local committee chair, Luca Ferrari, luca@geociencias.unam.mx.

ACCOMMODATIONS

A block of rooms has been reserved at Hotel Misión Juriquilla at the following rates: single/double w/breakfast: US\$127/\$132 (incl. tax) per night; single/double all inclusive (breakfast, lunch & dinner): US\$160/\$224 (incl. tax) per night. Reservations: 01-800-900-3800 or reserve@hotelesmision.com.mx; please mention the GSA Cordilleran Section. Hotel website: www.hotelesmision.com/mexico/queretaro/queretaro/hotels/Mision-Queretaro-Juriquilla/description.aspx.

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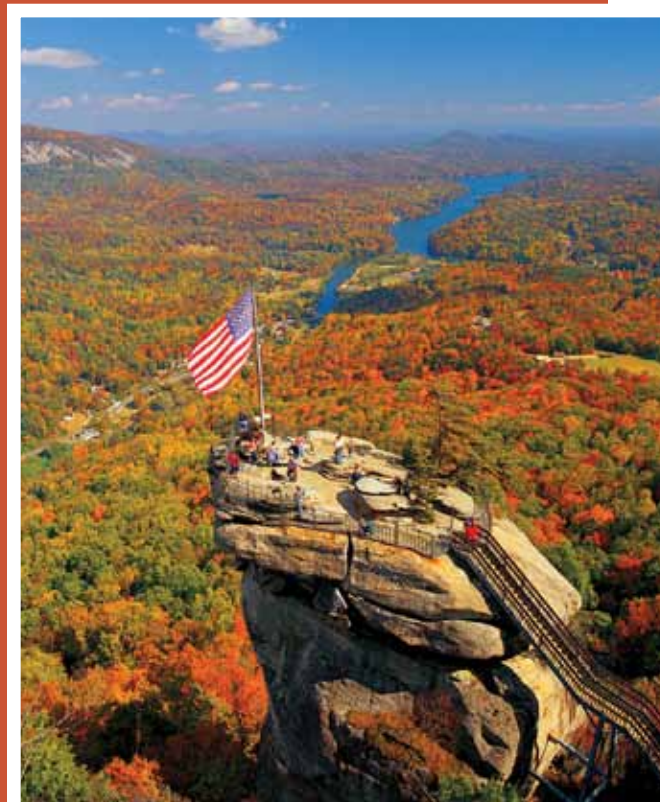


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LOCATION

The Dept. of Geosciences and Natural Resources at Western Carolina University is pleased to host the 61st Annual Meeting of GSA's Southeastern Section at the Renaissance Asheville Hotel, located in historic downtown Asheville, North Carolina, USA. Asheville offers easy access to the world renowned geology of the Blue Ridge, Piedmont, Valley and Ridge, and Cumberland Plateau, with geologic venues ranging from ancient orogenic belts and exotic mineral districts to active landslides, karst landscapes, and unique fossil sites.

CALL FOR PAPERS

Abstract deadline: 17 Jan. 2012

Submit online: www.geosociety.org/Sections/se/2012mtg/

Abstract submission fee: US\$10 for students; US\$15 for all others. Contact Nancy Wright, +1-303-357-1061, nwright@geosociety.org, if you cannot submit your abstract via the online system.

Symposium

1. **Transcurrent Motion in the Southern Appalachians: Comparing Kinematics and Timing across the Orogen.** Cheryl Waters-Tormey, Western Carolina Univ., cherylwt@wcu.edu; Jim Hibbard, North Carolina State Univ., jphibbar@ncsu.edu.
2. **Coastal Response to Sea Level and Climate Changes.** Cosponsored by *Western Carolina University Program for the Study of Developed Shorelines; Eastern Section, SEPM.* Katie McDowell, Western Carolina Univ., kmcdowell@wcu.edu; David Mallinson, East Carolina Univ., mallinsond@ecu.edu.
3. **Practical Applications of Engineering Geology.** Cosponsored by *AEG Carolinas Section.* Paul Weaver, Chair, AEG-Carolinas, paul.weaver@summit-engineer.com; Brad Worley, North Carolina Department of Transportation, bdworley@ncdot.gov.

Theme Sessions

1. **Terranes of the Southern Appalachian Blue Ridge and Piedmont: Insights into Their Tectonic Heritage and Incorporation into the Orogen from Recent Geochronologic, Isotopic, Provenance, and Field Studies.** Arthur J. Merschat, USGS, amerschat@usgs.gov; Brendan R. Bream, ExxonMobil Exploration Co., bbream@msn.com; Richard Tollo, George Washington Univ., rtollo@gwu.edu.
2. **Ancient and Modern Eolian Systems of Eastern North America.** Cosponsored by *Eastern Section, SEPM.* Chris Swezey, USGS, cswezey@usgs.gov; Rich Whittecar, Old Dominion Univ., rwhittec@odu.edu.
3. **Sedimentation and Stratigraphy of Fine-Grained Strata: Insights from Modern and Ancient Marine Systems.** Cosponsored by *Eastern Section, SEPM.* J.P. Walsh, East Carolina Univ., walshj@ecu.edu; Don Neal, East Carolina Univ., neald@ecu.edu.
4. **Hydrological Processes and Problems in the Southern Appalachians.** Mark Lord, Western Carolina Univ., mlord@wcu.edu; Dave Kinner, dkinner@wcu.edu; Western Carolina Univ.; Jerry Miller, Western Carolina Univ., jmiller@wcu.edu.
5. **Hydrogeology and Geomorphology of Carbonate Aquifers in the Southeastern United States.** Cosponsored by *Eastern Section, SEPM.* Lee J. Florea, Ball State Univ., mr_chaos@hotmail.com.
6. **Coastal Hydrogeology.** Samuel Mutiti, Georgia College and State Univ., samuel.mutiti@gcsu.edu; Alex Manda, East Carolina Univ., mandaa@ecu.edu.

7. **Building the Foundation for Geoscience Education, a Next Step: Working with Expert Earth Science Teachers to Create More Highly Qualified Earth Science Teachers.** Cosponsored by *National Association of Geoscience Teachers Southeastern Section*; *North Carolina Geological Survey*. Randy Bechtel, North Carolina Geological Survey, randy.bechteln@ncdenr.gov.
8. **Geologic Maps, Digital Geologic Maps and Derivatives (Poster Session).** Michael W. Higgins, The Geologic Mapping Institute, mhiggins@mindspring.com; Ralph F. Crawford, The Geologic Mapping Institute, crawford@sprintmail.com.
9. **Undergraduate Research (Poster Session).** Lee Phillips, Univ. of North Carolina, p.l.phillips@uncp.edu.
2. **Facilitating Classroom Innovation in the Geosciences: The TUES and Other NSF Educational Funding Programs, and Strategies for Successful TUES Proposals.** Jeff Ryan, Univ. of South Florida, ryan@mail.usf.edu; Jill Singer, Buffalo State College, singerjk@buffalostate.edu.
3. **Field Safety Leadership.** Amy Ruf, ExxonMobil Upstream Research Co., amy.s.ruf@exxonmobil.com; Stephen Oliveri, ExxonMobil Corp., stephen.r.oliveri@exxonmobil.com; Kevin Bohacs, ExxonMobil Upstream Research Co., kevin.m.bohacs@exxonmobil.com.

FIELD TRIPS

1. **Industrial Minerals of the Spruce Pine Mineral District.** Cosponsored by *SME-Carolinas*. Alex Glover, Active Minerals International, aglover@activeminerals.com; Bob Ganis, consultant, bobganis@mac.com.
2. **Central and Eastern Blue Ridge Tectonics.** Arthur Merschat, USGS, amerschat@usgs.gov; Robert D. Hatcher, Jr., Univ. of Tennessee, bobmap@utk.edu.
3. **Caves and Karst of the Cumberland Plateau in Southeast Kentucky.** Cosponsored by *Eastern Section, SEPM*. Lee J. Florea, Ball State Univ., mr_chaos@hotmail.com.

WORKSHOPS

1. **Creating Your Own Geological Maps, Models, and Geoscience Learning Resources Using Google Earth.** Declan De Paor, Old Dominion Univ., DDePaor@odu.edu; Steve Whitmeyer, James Madison Univ., whitmesj@jmu.edu.

ACCOMMODATIONS

A block of rooms has been reserved for meeting attendees at the Renaissance Asheville Hotel, 31 Woodfin Street, Asheville, NC, 28801, USA, + 1-800-266-9432. Room rate: US\$119 per night, plus tax.

LOCAL COMMITTEE

General Co-Chairs: Blair Tormey, btormey@wcu.edu; Cheryl Waters-Tormey, cherylwt@wcu.edu

Tech Program Chair: Kevin Stewart, kgstewart@email.unc.edu

Field Trip Chair: Chuck Trupe, chtrupe@georgiasouthern.edu

Short Courses & Workshops Chair: Eric Horsman, horsmane@ecu.edu

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Deformation, Fluid Flow, and Mass Transfer in the Forearc of Convergent Margins

25–31 March 2012

Il Ciocco, Castelvecchio Pascoli, Lucca, Italy

CONVENERS

Donald Fisher, *Dept. of Geosciences, Penn State University, University Park, Pennsylvania, USA, dmf6@psu.edu*

César Ranero, *Barcelona Center for Subsurface Imaging, Barcelona, Spain, cranero@cmima.csic.es*

Paola Vannucchi, *Dipto. di Scienze della Terra, Università degli Studi di Firenze, Firenze, Italia, paola.vannucchi@unifi.it*

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Cosponsored by the European Geosciences Union, the Italian Geological Society, the Spanish Ministry of Science and Innovation, and the U.S. National Science Foundation.

Description and Objectives

This Penrose Conference will explore recent developments related to deformation, fluid flow, and mass transfer in the forearc of convergent plate boundaries and their potential relationships to earthquake phenomena and seismogenesis. Numerous recent observations are potentially of great consequence to forearc behavior: (1) evidence for hydration of the oceanic mantle prior to subduction and its dehydration during subduction; (2) recognition of the oceanic crust as a zone of high permeability in the incoming plate; (3) evidence for complex subduction fault behavior, including slow slip within and adjacent to the seismogenic zone; (4) observations by seafloor

observatories of tectonically induced transient fluid flow events; (5) observations of complex structure for the forearc, including out-of-sequence faults and a wide array of fault types from extension to shortening; (6) extensive records of slope basin seismic stratigraphy and structure; (7) high-resolution multi-beam images of a significant number of margins that span the full range of convergent margin behavior; (8) discovery of pseudotachylyte (paleo-earthquakes) in accreted sediments; (9) records of coseismic and interseismic deformation from geodetic, especially GPS, measurements; and finally (10) 3-D seismic surveys of both an accretionary and an erosive margin. The recent Great Tohoku Earthquake of 11 March 2011 has thrown into doubt the paradigm that the plate boundaries of erosive convergent margins are too segmented to allow for great earthquakes. This conference will provide an opportunity for researchers to address these and other recent developments in a format that allows for discussion, integration of ideas, and development of collaborations and future directions.

The meeting is an opportunity for integration of onshore and marine observations, experiments on mechanics and fluid flow, and results of geodynamic modeling. Discussions will consider a range of time scales from the short-term secular variations of the seismic cycle to the long-term evolution of structure and topography. The topics that will be emphasized as part of the program include:

- Material balances—the processes and rates of accretion and erosion and their influence on seismogenesis;
- Interactions between the subducting and overriding plates, including continental slope and forearc basins;
- Wedge dynamics and links between seismic and geologic time scales;
- Fluid flow in the forearc and tectonics—evidence from direct observations and inferences from rock microstructures and geochemistry; and
- The timescales of the earthquake cycle—Is the magnitude and frequency of earthquakes influenced by forearc geology?

Preliminary Agenda

This five-day meeting will begin in Bologna, Italy, on 26 March 2012, with a two-day field trip that crosses the Ligurian forearc. Day one will involve observations of the External Ligurides; the second day will focus on a mélange interpreted as part of an erosive subduction channel. The field trip will end at Il Ciocco, a conference venue situated 500 m above sea level, 70 km north of Pisa airport. A short, half day field trip will be organized in the nearby Apuan Alps to visit the metamorphic rocks deformed during continental subduction of the Adria plate. Transportation to Pisa will be provided at the conclusion of the meeting.

Attendees and Estimated Costs

The registration fee will cover hotel lodging for six nights (double occupancy), all meals for five days, handouts, and transportation for the field trips to Il Ciocco. Airfare is not included; participants must make their own travel arrangements. Registration fees have not been finalized; please check www.geosociety.org/penrose/.

Applications and Registration

Application deadline: 30 Nov. 2011

Registration deadline: 30 Jan. 2011

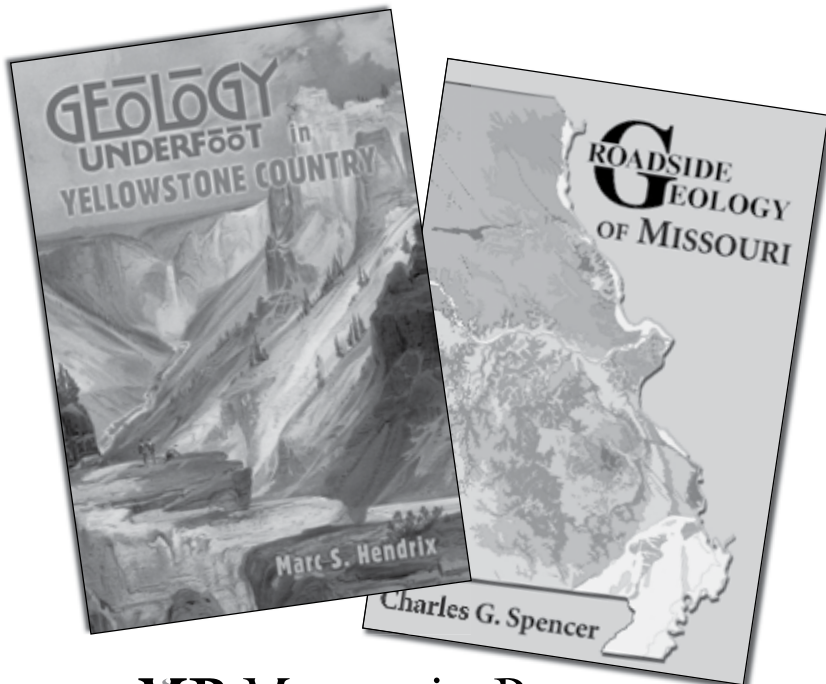
Participants will have to commit to attending the full five days of the conference. To apply, please contact the conveners at dmf6@psu.edu with a letter of intent that includes a brief

statement of interests, the relevance of your recent work to the themes of the conference, the subject of your proposed presentation, and contact information. Interested graduate students and early career faculty are strongly encouraged to apply. Once you have been selected to participate, you will be sent registration information.



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GSA Foundation Update

Donna L. Russell, Director of Operations

Supporting the GSA Foundation by Leaving a Lasting Legacy

The GSA Foundation has been the beneficiary of several "Planned Giving Gifts" since its inception. In just the past eleven years, the Foundation has received more than US\$3 million in estate and bequest gifts from GSA members and friends. The following is a list of those thoughtful GSA members:

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There are many ways you can provide a meaningful and special gift to the GSA Foundation in your estate plans. That special gift may be a charitable bequest, a gift of life insurance, or even retirement plan assets. Your financial planner can help you tailor and finalize a plan that will help meet your own personal situation.

The GSA Foundation has a free **Charitable Gift Planning Guidelines** brochure—just call the Foundation office at +1-303-357-1054 or e-mail Donna Russell at drussell@geosociety.org and we'll be happy to send a copy to you.



Most memorable early geologic experience:

I'll never forget eating 49 pancakes and still losing the pancake-eating contest to Hugh Wingerter on the last day of Northwestern's 1949 Lake Superior field trip.

—Henry James Dorman



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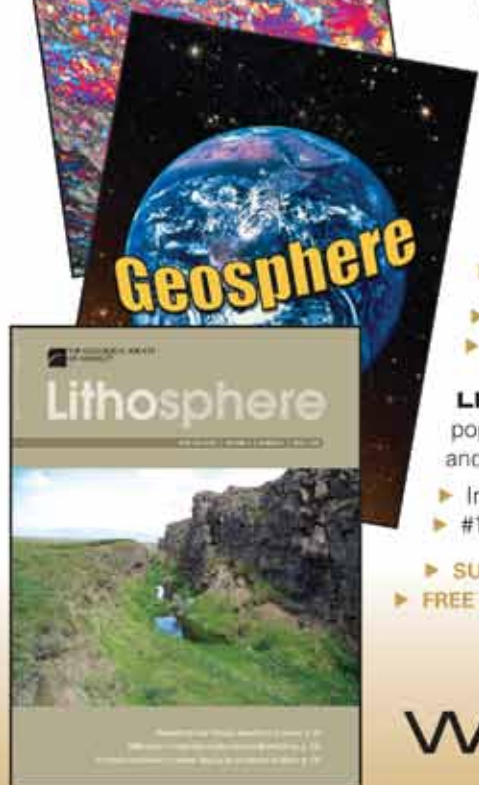
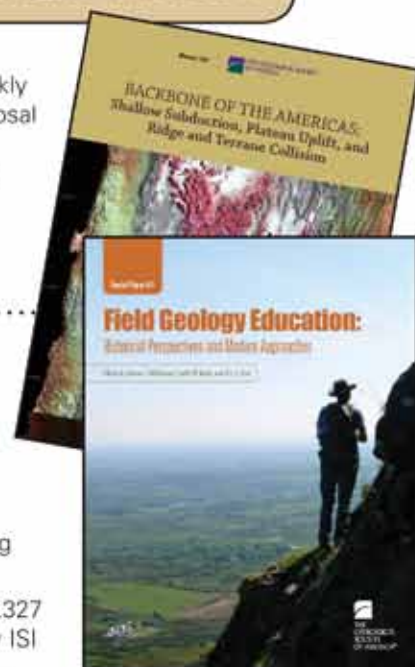
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www.geosociety.org/meetings/2011/fusion.htm

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Blog Roll: Follow various blogs that are posting information about the meeting.

GSA Meeting Bulletin Board: Find anything from rideshares to roommates for the meeting, as well as activity planning and science discussions. Go to the main fusion page to find out how to log in.

Local Geologists' Guide to Minneapolis

Written by geologists for geologists—use this guide to learn more about the hot spots in Minneapolis, including arts & culture, food & drink, shopping, nightlife, and parks & recreation, all within walking distance of the convention center.

www.geosociety.org/meetings/2011/documents/SSC-guide.pdf



Walker Sculpture Garden; photo used with permission from Meet Minneapolis.

GSA Lunchtime Lecture Series

Minneapolis Convention Center, Room 101DE

The GSA Lunchtime Lecture series offers four one-hour presentations (one for each day of the meeting) by high-profile speakers on broad topics relevant to geoscience and society. Bring your lunch and prepare to be challenged and inspired!



Harvey Thorleifson

Lunchtime Lecture 4

Harvey Thorleifson: The Role of Geoscience in our Society
Wed., 12 Oct., 12:15–1:15 p.m.

Harvey Thorleifson, this year's annual meeting chair, is State Geologist of Minnesota; Director, Minnesota Geological Survey; Professor, Dept. of Earth Sciences, University of Minnesota; President Elect, the Association of American State Geologists; and former president of both the Geological Association of Canada and the Canadian Federation of Earth Sciences. He holds a Ph.D. from the University of Colorado.

Lecture synopsis: This year's meeting theme captures the breadth and importance of what we as geologists do. We grasp the entire scope, in space and time, of our planet and its evolution. We explain earth materials, processes, and history; we outline the history of life; and we provide for human needs with respect to water, energy, materials, and security. The role we play as scientists, educators, consultants, and industry leaders is of escalating importance for human well-being and biodiversity maintenance worldwide. We therefore have a duty to optimize our efficiency and effectiveness, to maximize the benefits we bring to society.



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Ads (or cancellations) must reach the GSA advertising office no later than the first of the month, one month prior to the issue in which they are to be published. Contact advertising@geosociety.org, +1.800.472.1988 ext. 1053, or +1.303.357.1053. All correspondence must include complete contact information, including e-mail and mailing addresses. To estimate cost, count 54 characters per line, including punctuation and spaces. Actual cost may differ if you use capitals, bold-face type, or special characters. Rates are in U.S. dollars.

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Applicants should have at least 10 years of experience with stone and concrete petrography; meet the requirements of ASTM C856 and C295; and understand the use of supplemental testing and analytical techniques such as XRD, IR, SEM/EDS, and chemical testing. Exceptional communication skills, experience in research and investigations, and a demonstrated ability for managing and developing staff are also required skills.

To learn more about SGH and to apply for this position, please visit our website at www.sgh.com or e-mail your resume to Stella Mereves-Carolan, Corporate Recruiter at smereves-carolan@sgh.com or Apply online at www.sgh.com.

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TENURE-TRACK FACULTY POSITION SEDIMENTARY GEOLOGY/LOW-TEMPERATURE GEOCHEMISTRY, IOWA STATE UNIVERSITY

The Dept. of Geological and Atmospheric Sciences at Iowa State University invites applications for a tenure-track faculty position at the assistant professor level to begin August 2012. The position will be in one of two broad areas: sedimentary geology or low-temperature geochemistry, with particular emphasis placed on research relevant to paleoclimatology, environmental geochemistry, or contaminant hydrogeology. An essential requirement is the potential of applicants to establish a successful, externally funded research program. Ideally that program would complement existing strengths in the department, including climate modeling, paleoclimatology, glaciology, hydrogeology, geophysics, economic geology, tectonics, and geoscience education. We also encourage interactions with researchers and faculty in other units on campus, such as Agricultural and Biosystems Engineering; Agronomy; Chemistry; Civil, Construction and Environmental Engineering; Ecology and Evolutionary Biology; Natural Resources Ecology and Management; the Iowa Water Center; the Leopold Center for Sustainable Agriculture; and the National Laboratory for Agriculture and the Environment. A commitment to excellence in teaching at the undergraduate and graduate levels is also essential. Information about the department is online at www.ge-at.iastate.edu.

Candidates must hold a Ph.D. by the time of appointment. All applications must be submitted electronically at www.iastatejobs.com (search vacancy ID# 110650). Please be prepared to enter or attach a letter of application including concise teaching and research statements, curriculum vitae, and the names, addresses, e-mail addresses, and phone and fax numbers of at least three references.

The positions will remain open until filled. Full consideration will be given to those applications received by 13 Nov. 2011. We encourage applications from minori-



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ASSISTANT PROFESSOR GEOLOGY

DEPARTMENT OF CHEMICAL AND
PHYSICAL SCIENCES

The Department of Chemical and Physical Sciences at the University of Toronto Mississauga is seeking applications for a tenure-track position at the Assistant Professor level from scholars with research interests in Geochemistry, Geophysics, Sedimentology or related fields. The successful applicant will complement an Earth Sciences research cluster at UTM specializing in paleoclimatology, climate-tectonic interactions, and petrology. Candidates for this position should have received their Ph.D. by the starting date, and should demonstrate potential for excellence in teaching and research. The successful applicant will be expected to develop and maintain an active, externally funded program of research and to contribute to the education and training of undergraduates at UTM and graduate students in the Department of Geology, University of Toronto. The position will commence July 1, 2012 at a salary commensurate with qualification and experience.

We encourage you to submit your application online by visiting us at www.jobs.utoronto.ca/faculty.htm, and refer to job number 1100767. Please ensure that you include a current CV, statement of research and teaching interests, materials relevant to teaching experience, and copies of representative publications. Individuals lacking computer access may submit application materials to Chair of Earth Sciences Search Committee, Department of Chemical and Physical Sciences, University of Toronto Mississauga, 3359 Mississauga Road North, Mississauga, Ontario, Canada L5L 1C6. Three letters of recommendation should also be sent under separate cover. Materials must be received by November 1, 2011.

For more information about the Department of Chemical and Physical Sciences at the University of Toronto Mississauga, please visit our home page at www.utm.utoronto.ca/cps.

All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority. The University of Toronto is strongly committed to diversity within its community and especially welcomes applications from visible minority group members, women, Aboriginal persons, persons with disabilities, members of sexual minority groups, and others who may contribute to the further diversification of ideas.

ties, women, veterans, and persons with disabilities. Iowa State University is an equal opportunity/affirmative action employer.

TENURE-TRACK FACULTY POSITION WILLIAMS COLLEGE

The Geosciences Dept. at Williams College invites applications for a tenure-track appointment beginning 1 July 2012. We seek a colleague in the broad areas of paleontology, paleoecology, stratigraphy, and geobiology. The applicant must have a strong commitment to excellence in teaching at the undergraduate level, and is expected to develop a vigorous research program that engages undergraduate students. We especially welcome applications from individuals with a strong field component to their research, but will also consider more laboratory-oriented scientists. The successful candidate will teach three courses per year (lectures plus lab). Teaching responsibilities include historical geology and paleontology, as well as other specialized courses. Examples of such courses include, but are not limited to, sequence stratigraphy, basin analysis, biostratigraphy, paleoecology, evolutionary biology, life in extreme environments, or the interaction of organisms with the earth's crust and atmosphere. The Geosciences Dept. is committed to providing excellent training for future geoscientists, as well as teaching earth science as part of a balanced liberal arts education. Our department also contributes many courses to the Center for Environmental Studies at Williams College. Further information is online at <http://web.williams.edu/Geoscience/>.

Applicants should have a Ph.D. or dissertation completed by the time of appointment, some teaching experience, and a vigorous research program suitable for undergraduate student involvement. Appointment is normally at the beginning assistant professor level, although a more senior appointment is possible under special circumstances. Deadline for applications is 31 Oct. 2011.

Please send a letter of application, which should include a statement of teaching and research philosophy, curriculum vitae, and contact information for three references, to Paul Karabinos, Chair of Geosciences,

Williams College, 947 Main Street, Williamstown, MA 01267, USA; pkarabin@williams.edu.

Williams College is a coeducational liberal arts institution located in the Berkshire Hills of western Massachusetts with easy access to the culturally rich cities of Albany, Boston, and New York City. The College is committed to building and supporting a diverse population of approximately 2,000 students, and to fostering an inclusive faculty, staff and curriculum. Williams has built its reputation on outstanding teaching and scholarship and on the academic excellence of its students. Please visit the Williams College website (www.williams.edu). Beyond meeting fully its legal obligations for non-discrimination, Williams College is committed to building a diverse and inclusive community where members from all backgrounds can live, learn, and thrive.

TWO TENURE-TRACK POSITIONS PLANETARY SCIENCES INSTITUTE OF GEOLOGICAL SCIENCES POLISH ACADEMY OF SCIENCES

The Institute of Geological Sciences of the Polish Academy of Sciences is initiating the first planetary geology research program in Poland. The Research Centre in Wrocław is seeking highly qualified and motivated scientists to work on a range of fundamental topics in planetary geoscience. Two new tenure-track positions are now available in our group: one in Martian geoscience, one on the evolution of the early solar system, both starting 1 Jan. 2012 with a contract of duration 42 months. We hope you will be a part of this extraordinary opportunity to found a new center in planetology.

The successful candidates will develop a strong research program in their research area. The group, supported by the European Union and the Foundation for Polish Science, will develop in the context of preparations for affiliation of Poland to ESA. The lab is located in downtown Wrocław, one of the most dynamic cities of Poland, and offers pleasant working conditions at a short distance to the Sudetes Mountains. The candidates must have obtained a Ph.D. after 1 Jan. 2008. Remuneration amounts to 6400 PLN/month, which is

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very attractive on Polish standards. The deadline for applying is 25 Oct. 2011; details and how to apply can be retrieved from www.ling.pan.pl/PlanetaryScienceJobs.htm, or by contacting the project PI at daniel.mege@twarda.pan.pl.

HYDROGEOLOGY TENURE-TRACK POSITION AUSTIN PEAY STATE UNIVERSITY

The Dept. of Geosciences at Austin Peay State University invites applications for a tenure-track position in hydrogeology beginning Fall 2012. For details about the positions and information on how to apply please visit www.apsu.edu/human-resources/faculty/CurrentJobOpenings. Review of applications will begin 31 Oct. 2011 and will continue until the position is filled. Information about the department is online at www.apsu.edu/geosciences.

HYDROGEOLOGIST, BRIGHAM YOUNG UNIVERSITY

The Dept. of Geological Sciences at Brigham Young University invites applications for a continuing status track (BYU's equivalent of "tenure track") Professorial Faculty position in the area of hydrogeology to be filled as soon as Sept. 2012. A Ph.D. at the time of appointment is required. The department has a long history of expertise in physical and chemical hydrogeology, and a candidate is sought who can help maintain and expand existing programs. Implementation of a vigorous, externally funded research program is required. The successful candidate also must be able to teach hydrogeology to advanced undergraduates, graduate courses within his or her area of expertise, and introductory geology courses as assigned.

Excellent research infrastructure exists within the department. Relevant instrumentation supports solute, stable isotope, ^3H , and ^{14}C analysis. Shallow geophysical equipment enables ground penetrating radar, and high-resolution seismic reflection surveys.

The department consists of 13 professorial faculty and 3 professional faculty, and offers B.S. and M.S. degrees. In addition to hydrogeology, major research areas include petroleum geology, continental magmatism, shallow and deep geophysics, structure and tectonics, stratigraphy, paleontology, planetary geology, and mineral surface chemistry.

Applicants should complete an online faculty application and attach a current curriculum vita at <https://yjobs.byu.edu> (faculty position #110618) Graduate transcripts, a statement of research and instrument experience, a statement of teaching philosophy, and the names and contact information for 3 references should be sent to: Chair, Search Committee, Dept. of Geological Sciences, S-389 ESC, Brigham Young University, Provo, UT, 84602. The application deadline is January 31, 2012. You may obtain instructions for completing the online faculty application from Kris at kris_mortenson@byu.edu.

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.

ASSISTANT PROFESSOR, COASTAL GEOSCIENCES UNIVERSITY OF RHODE ISLAND

The University of Rhode Island anticipates a full-time, tenure-track Assistant Professor position beginning 1 Sept. 2012, in coastal geology and the coastal response to climate change. Visit <https://jobs.uri.edu> to apply and view complete details for job posting # (6000527). Review of resumes will begin 10/15/2011 and continue until the position is filled. Online applications will require three PDF attachments: (1) a cover letter of application; (2) a CV which includes the names and contact information of four referees; and (3) "other" document which elaborates your research and teaching interests and philosophy. The University of Rhode Island is an AA/EEO employer and values diversity.

ASSISTANT RESEARCH SCIENTIST/ STAFF SCIENTIST

INTEGRATED OCEAN DRILLING PROGRAM (IODP) TEXAS A&M UNIVERSITY

The Integrated Ocean Drilling Program (IODP) at Texas A&M University invites applications for the position of Assistant Research Scientist/Staff Scientist in our Science Operations section. A Ph.D. in geosciences or related field and demonstrated research experience is required. Applicants with expertise in organic geochemistry, microbiology, and sedimentary inorganic

geochemistry are encouraged to apply, but all fields of geosciences will be considered. Applicants must have a demonstrated fluency in written and spoken English. An experienced seagoing scientist, especially in scientific ocean drilling, is preferred.

The successful applicant will serve as the Expedition Project Manager to coordinate all aspects of cruise planning and implementation, and post-cruise expedition activities. These duties include sailing as the IODP scientific representative on an IODP expedition approximately once per year. Individual research, as well as collaboration with colleagues at Texas A&M University through the university's interdepartmental Ocean Drilling and Sustainable Earth Science initiative (ODASES), is expected. The applicant will also provide scientific advice on laboratory developments in their area of specialization. Applicants must be able to cooperate and work harmoniously with others and have the ability to be an effective team leader. The successful applicant will be required to pass a new employee physical exam and annual seagoing physical exams.

Salary will be commensurate with qualifications and experience of the applicant. This is a regular full time position, contingent upon continuing availability of funds for IODP. We will begin reviewing applications on **15 Nov. 2011** but will continue to accept applications until candidates are selected for interviews. Applicants may access the TAMU application at <http://tamujobs.tamu.edu> and apply online with reference to **NOV#111108**; attach a curriculum vita, including a list of published papers, statement of research interests, and names and addresses of three references: Integrated Ocean Drilling Program, U.S. Implementing Organization, Texas A&M University, College Station, Texas 77845.

Equal Opportunity/Affirmative Action Employer Committed to Diversity.

APPLIED GEOMORPHOLOGY DEPT. OF EARTH AND SPACE SCIENCES (ESS) UNIVERSITY OF WASHINGTON

The Dept. of Earth and Space Sciences (ESS) at the University of Washington invites applications for Program Coordinator of a new Masters track in Applied Geosciences.

This is a 100% FTE (12 months) faculty appointment at the rank of Lecturer or Assistant Professor (without tenure). This is a 12-month appointment and includes responsibility for coordinating the MS program and the development of a summer internship program for MS candidates, in addition to teaching duties appropriate to the appointed rank. University of Washington faculty engage in teaching, research and service. Appointment as Assistant Professor includes the expectation to develop and maintain a research program leading to peer-reviewed publications.

We seek candidates with expertise in applied geomorphology broadly defined, including: fluvial and/or hillslope geomorphology, engineering geology, earthquake geology, applied/environmental geophysics and/or GIS applications in surface processes. We are particularly interested in candidates who have demonstrated close ties with the private sector and/or governmental agencies.

Opportunities for collaboration exist with current departmental research in surface process, solid earth geology and geophysics, space physics, geobiology and planetary processes. The department is also part of an extended research community in the UW's College of the Environment, with interdisciplinary opportunities in forestry, fisheries, oceanography, Quaternary research, climate change, and civil engineering.

Applicants must hold a Ph.D. in geology/earth sciences or a closely related field at the time of appointment. Exceptional candidates with a MS degree in geology/earth sciences or a closely related field and more than 5 years experience as professional geologists may also be considered.

Applications must include: curriculum vitae and list of publication/significant technical reports; a statement of teaching experience and interests particularly with regard to training students for work as professional geologists; and three letters of reference, sent directly to the search committee by the referees. Electronic application is strongly preferred and must be in PDF format. Send to: applied-geomorph-search@ess.washington.edu, with subject line "Applied Geomorph Application, (your name)." Hard-copy applications and reference letters may be sent to Applied Geomorphology Search Committee, c/o Nathan Briley, Dept. of Earth and Space Sciences, University of Washington, Box 351310, Seattle, WA 98195-1310, +1-206-543-1190. The deadline for completed applications is 1 Nov.

The University of Washington is an affirmative action, equal opportunity employer.

ASSISTANT PROFESSOR, MINERALOGY AND STRUCTURAL GEOLOGY, GEOGRAPHY, GEOLOGY AND PLANNING, MISSOURI STATE UNIVERSITY SPRINGFIELD, MISSOURI

The Dept. of Geography, Geology and Planning invites applications for a tenure-track Assistant Professor with an emphasis in Mineralogy and Structural Geology to begin in August 2012. Ph.D. (or ABD) in Geology or closely related field required at time of appointment. Expertise in Mineralogy and Structural Geology at a level adequate to supervise master's level graduate students, an aggressive research agenda documented by a detailed research plan, and a commitment to both undergraduate- and master's-level teaching and service are required. Be able to facilitate a work environment that encourages knowledge of, respect for, and development of skills to engage with those of other cultures or backgrounds. Demonstrated knowledge and understanding of multicultural and diversity issues. Post-doctoral research experience and evidence of teaching effectiveness would be advantageous.

The department grants undergraduate degrees in geology, geography, planning, geospatial science, and earth science education and an M.S. in Geospatial Science in Geography and Geology. The successful applicant would have the opportunity to teach and advise in the undergraduate program in geology and in the department's graduate program.

Apply online at www.missouristate.edu/academicopenings. Attach a letter of application, curriculum vitae, detailed research plan, and contact information for 3-5 professional references to the electronic employment application. The evaluation of applications will begin 8 Nov. 2011 and will continue until a successful candidate is found. For further information, call +1-417-836-5800 or fax to +1-417-836-6006, e-mail GGP@missouristate.edu, or visit our website at geosciences.missouristate.edu. Missouri State University is an affirmative action/equal opportunity institution. The University is dedicated to the goal of building a culturally diverse and inclusive faculty and staff committed to teaching and working in a multicultural environment and strongly encourages applications from women, persons for underrepresented ethnic and racial groups, individuals with disabilities and covered veterans. Employment will require a criminal background check at University expense.

ASSISTANT PROFESSOR AQUEOUS GEOCHEMISTRY/BIOGEOCHEMISTRY UNIVERSITY OF SOUTH CAROLINA

The Dept. of Earth and Ocean Sciences invites applications for a tenure-track, assistant professor position in aqueous geochemistry or biogeochemistry. We seek an individual with outstanding research and teaching capabilities and broad interests related to the ways in which geochemical and biogeochemical processes mediate chemical exchange between the hydrosphere, lithosphere, and biosphere. Areas of interest may include characterization of natural systems over long (geologic) and short (environmental) time scales and the influences of climate change and human activity on elemental cycling.

The successful candidate is expected to teach undergraduate and graduate courses in earth science and to direct an active externally funded research program. Potential collaborative interactions exist within the department (www.geol.sc.edu); with other interdisciplinary programs housed within the School of the Earth, Ocean and Environment (www.cas.sc.edu/seoe/), including the Environment and Sustainability Program and the Marine Science Program; and with other departments, including Civil and Environmental Engineering, Geography, and Biological Sciences. Teaching responsibilities will likely include introductory earth or environmental science courses as well as upper-level undergraduate and graduate level courses related to the candidate's specialty. A Ph.D. is required at the time of appointment, and post-doctoral experience is desirable. Applicants should submit a CV, statements of research and teaching interests, and the names, addresses and phone numbers of at least three references (in a single pdf file) to geochem@geol.sc.edu. For more information please contact Alicia M. Wilson, Geochemistry Search Committee Chair, Dept. of Earth and Ocean Sciences, University of South Carolina, Columbia, SC 29208.

To ensure full consideration, applications should be received by 15 Nov. 2011. We will review files until a candidate is selected. The University of South Carolina is an affirmative action, equal opportunity employer. Women and minorities are encouraged to apply. The University of South Carolina does not discriminate in educational or employment opportunities or decisions for qualified persons on the basis of race, color, religion, sex, national origin, age, disability, sexual orientation or veteran status.

**ASSISTANT PROFESSOR OF GEOLOGY
MERCYHURST COLLEGE**

The Mercyhurst College Geology Dept. invites applications for a tenure track Assistant Professor position to begin August 2012. We seek a soft rock geologist with broad interests in the geosciences committed to teaching excellence in the liberal arts tradition. Teaching responsibilities will include introductory geology courses, Sedimentology, Stratigraphy, and GIS. A demonstrated interest and ability to also teach courses in hydrogeology and/or soils is a plus. The successful candidate will be expected to incorporate service learning in their teaching and develop a strong research program that involves undergraduates. Open opportunities exist for Great Lakes-related research as well as for collaborations with the Archaeology/Anthropology Dept., the Sustainability Studies program, and the college's teaching and research programs in Taos, New Mexico. Our class sizes are small, field-based learning is encouraged and supported, and the teaching facilities are exceptional. Completion of the PhD is required at the time of appointment. Applications, including a cover letter, a statement of teaching philosophy, a statement of research interests that includes how you foresee integrating undergraduates into your research, a curriculum vitae, and contact information for three referees, should be sent via e-mail to Dr. J.M. Adovasio (jadovasio@mercyhurst.edu). Review of applications will begin 1 Nov. 2011. Mercyhurst College is an equal opportunity employer. For more information about the college please visit www.mercyhurst.edu/.

**SUSAN CUNNINGHAM RESEARCH CHAIR
GEOLOGY, SCHOOL OF GEOGRAPHY AND
EARTH SCIENCES, MCMASTER UNIVERSITY**

The School of Geography and Earth Sciences (SGES) at McMaster University in Hamilton, Ontario, Canada, invites applications for a full-time tenure track position in geology at the Assistant or Associate Professor level beginning 1 July 2012.

McMaster University is among leading Canadian universities with 24,000 full time undergraduate and 3,000 graduate students. SGES has 29 full time faculty members, and has a long tradition of excellence in research and teaching in geology. For more information about SGES, please visit www.science.mcmaster.ca/geol/.

At the time of appointment, the successful candidate must have a Ph.D. in earth or environmental sciences, geology, or geophysics and a record of publishing in academic journals. We are particularly interested in a geologist or exploration geophysicist with a strong background and research experience in sedimentary basin analysis, petroleum geology, and/or seismic/sequence stratigraphy. Experience in the application of remote sensing and 3-D subsurface modeling, and their use in field-based research is desired. The candidate is expected to develop a well-funded, externally recognized, research program. The applicant should have a strong commitment to undergraduate/graduate teaching and supervision.

All qualified candidates are encouraged to apply; however Canadians and permanent residents will be considered first for this position. McMaster University is strongly committed to employment equity within its community, and to recruiting a diverse faculty and staff. The University encourages applications from all qualified candidates, including women, members of visible minorities, Aboriginal persons, members of sexual minorities, and persons with disabilities.

Applicants should send a cover letter outlining their research interests, a copy of their curriculum vitae, a brief teaching dossier including a statement of teaching philosophy (max. 2 pgs.). These materials may be sent as hard copy or electronic copy as a pdf file. Electronic (PDF) copies of no more than three published reprints or works in progress may also be sent to the Chair of the Search Committee by the closing date 30 Nov. 2011. Candidates are required to ensure that three references send letters of recommendation to the Search Committee Chair by the closing date. Evaluation of files will begin on their receipt.

Dr. Bruce Newbold, Chair, Search Committee, School of Geography and Earth Sciences, General Science Building, Room 206, McMaster University, 1280 Main Street West, Hamilton, Ontario, Canada, L8S 4K1; (905) 525-9140, Ext. 27948, Fax: (905) 546-0463, e-mail: newbold@mcmaster.ca.

**TENURE-TRACK POSITION: ASSISTANT
PROFESSOR AND CURATOR OF PALEONTOLOGY
CALIFORNIA STATE UNIVERSITY, FULLERTON**

The Dept. of Geological Sciences at California State University, Fullerton, seeks a full-time, tenure-track Assistant Professor with expertise in vertebrate pale-

ontology to join the faculty in Fall 2012 and serve as the Curator of Paleontology for the newly established John D. Cooper Archaeology and Paleontology Curation Center. The successful candidate will have the following credentials and capabilities:

- Ph.D. in Geology or a related field with emphasis in Vertebrate Paleontology;
- experience in vertebrate fossil curation, accession, and management;
- a vigorous research program in vertebrate paleontology that can involve undergraduate and graduate students;
- strong interest in teaching and achieving excellence in teaching; and
- the interest and ability to interact effectively with an ethnically and culturally diverse campus community.

An important responsibility of the successful candidate's will be performing and directing research and curation of the paleontology collection at the Cooper Center, including oversight of an Associate Curator of Paleontology, interns, students, and volunteers. The Collection contains fossils in various stages of curation, from large jacketed specimens to fully curated fossils. Known strengths of the collection include Miocene marine mammals and reptiles, many from previously unrecognized taxa; numerous unprepared, jacketed blocks from an Eocene non-marine bone bed; and a paleobotanical collection of unknown extent. Learn more about the Cooper Center at <http://coopercenter.fullerton.edu/>.

The successful candidate is expected to develop an externally funded research program focusing on specimens curated at the Cooper Center and resulting in peer-reviewed publications in refereed journals. Teaching responsibilities may include some of the following: physical geology, historical geology, paleontology, and upper-division and graduate courses in the new faculty member's area of expertise. Expected service activities include promotion of the Collection within the scientific community and outreach to the regional educational community.

CSU Fullerton is a large urban university dedicated to the preeminence of learning. A designated Hispanic-Serving Institution, CSU Fullerton is noted both for the diversity of its student body and its engagement of undergraduate students in research. Located 22 miles southeast of metropolitan Los Angeles, Fullerton is a full-service city renowned for its unique mix of residential, commercial and industrial, educational, and cultural environments that provide residents with an outstanding quality of life. The department has thirteen full-time faculty members with expertise in traditional and applied areas of the geological sciences. The nearby geological provinces provide abundant opportunities for field-based research, which the department emphasizes in its curriculum. There are over 100 undergraduate geology majors and ~20 MS students in the department. Additional information is online at <http://geology.fullerton.edu/>.

To apply, please send the following:

1. A detailed curriculum vita including a record of your past external funding;
2. A letter of application that explains how you meet the qualifications outlined above and specifically addressing your qualifications as Curator of Paleontology for the Cooper Center;
3. A statement of your future research plans and goals as they relate to the collections in the Cooper Center;
4. A statement of your teaching philosophy including a list of courses you would feel comfortable teaching;
5. Letters of recommendation from at least three references familiar with your research, curation, and teaching experience—referees should send their letters directly to the address below.

Send application to Dr. Nicole Bonuso, Search Committee Chair, Dept. of Geological Sciences, California State University, P.O. Box 6850, Fullerton, California 92834-6850. Review of completed applications will begin 18 Nov. 2011. Applications received after this date will be reviewed only if the position is not filled from the original pool of applicants.

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

**CRUSTAL MATERIALS
UNIVERSITY OF WASHINGTON**

The Dept. of Earth and Space Sciences at the University of Washington invites applications for a full-time (100% FTE) 9-month tenure-track faculty position in the area of crustal materials. The successful candidate will have expertise in the theoretical, experimental or observa-

tional study of crustal materials. We encourage applicants with interests in integrating chemical/physical understanding with quantitative models of crust dynamics, surface processes and field geology. Collaboration with current departmental research is desirable.

Faculty members are expected to develop their own independent, externally funded research program and participate in departmental research, undergraduate and graduate teaching and independent research, and service.

Applicants must hold a Ph.D. in geology/earth sciences or a closely related field at the time of appointment. It is anticipated the position will be filled at the Assistant Professor level.

Applicants should send a curriculum vitae, bibliography, description of research and teaching interests, and the names of four references. All materials should be sent to: Crustal Materials Search Committee, c/o Nathan Briley, Dept. of Earth and Space Sciences, University of Washington, Box 351310, Seattle, WA 98195-1310, +1-206-543-1190. Preference will be given to applications received prior to 1 Nov. 2011.

The University of Washington is an affirmative action, equal opportunity employer.

**TENURE-TRACK APPLIED GEOPHYSICIST
DEPT. OF GEOLOGY, BAYLOR UNIVERSITY**

The Dept. of Geology at Baylor University invites applications for a tenure-track Assistant Professor in Applied Geophysics, beginning August 2012. Applicants must hold a Ph.D. in geophysics, physics, or geology with an emphasis in geophysics at the time of appointment. The department currently consists of 15 geoscientists (www.baylor.edu/Geology/).

Preference will be given to a candidate with a strong background in quantitative sciences whose research interests complement those of existing geophysical strengths in our department. Current strengths include earthquake seismology, potential field methods, geodynamics, and petroleum geology. Research involving processing and interpretation of seismic reflection data, and integrated interpretation with other geophysical and geological data, is desirable, although other research areas in applied geophysics would be considered. The successful candidate should have the potential to attract external funds and to build a strong research program involving graduate students. Research space is available in the state-of-the-art, 500,000 ft² Baylor Sciences Building.

The successful candidate should have the potential to build a vibrant teaching program involving graduate students, as well as teach undergraduate courses in geophysics and/or petroleum geology.

Application Process: Send letter of application, including statement of teaching and research interests, curriculum vitae, copies of transcripts, and the names and contact information for three references to Dr. Jay Pulliam, Chair, Search Committee, Dept. of Geology, Baylor University, One Bear Place #97354, Waco, TX 76798-7354 (+1-254-710-2361; e-mail: Jay.Pulliam@baylor.edu). The review of applications will begin 15 Dec. 2011 and will be accepted until the position is filled. To ensure full consideration, application must be completed by 15 Jan. 2012. Baylor is a Baptist university affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Opportunity employer, Baylor encourages minorities, women, veterans and persons with disabilities to apply.

**TENURE-TRACK MINERALOGIST/PETROLOGIST
DEPT. OF GEOLOGY, BAYLOR UNIVERSITY**

The Dept. of Geology at Baylor University invites applications for a tenure-track Assistant Professor in Mineralogy or Petrology, beginning August 2012. Applicants must hold a Ph.D. in geology at the time of appointment. The department currently consists of 16 geoscientists (www.baylor.edu/Geology/).

Research: We seek an individual with research interests in mineralogy, igneous or metamorphic petrology or high-temperature geochemistry who is capable of building a strong, externally funded research program. Research space is available in the 500,000 ft² "state-of-the-art" Baylor Sciences Building. Research equipment current available includes a Siemens D5000 X-ray diffractometer, a Rigaku Primus wavelength-dispersive X-ray fluorescence spectrometer, a Thermo Finnigan Delta V IRMS and sample preparation facilities including a strong-acid-rated fume hood and high-temperature furnace. A shared ICP-MS instrument is also available, as well as a SEM, TEM, and confocal microscopy in a shared lab facility.

Teaching: We seek an individual with a strong commitment to excellence in teaching, and require that he/she contribute significantly to the undergraduate program, by teaching undergraduate mineralogy

and petrology courses, as well as contributing to the graduate (M.S. and Ph.D.) programs in Geology by teaching graduate courses or seminars in his/her areas of specialization.

Application Process: Send letter of application, including statement of teaching and research interests, curriculum vitae, copies of transcripts, and the names and contact information for three references to Dr. Steve Dworkin, Chair, Search Committee, Dept. of Geology, Baylor University, One Bear Place #97354, Waco, TX 76798-7354 (+1-254-710-2361; e-mail Steve_Dworkin@baylor.edu). The review of applications will begin 15 Dec. 2011. To ensure full consideration, application must be completed by 1 Jan. 2012. Baylor is a Baptist university affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Opportunity employer, Baylor encourages minorities, women, veterans and persons with disabilities to apply.

**VISITING ASSISTANT PROFESSOR IN GEOLOGY
PALEONTOLOGY/SOFT-ROCK GEOLOGY
COLBY COLLEGE**

The Dept. of Geology invites applications for a one-year, non-tenure track, Visiting Assistant Professor in paleontology and soft-rock geology beginning 1 Sept. 2012. The successful applicant will be expected to teach a core-curriculum Paleontology course (200-level: Record of Life) with laboratory and an upper division course of his/her choice for geology majors during the academic year. The upper division course should complement those already offered in the department. The remainder of the teaching assignment will be an introductory course offering (100-level) for potential majors and non-majors. Additionally, the candidate may have the opportunity to direct one or more independent research projects. Colby is a highly selective liberal arts college recognized for excellence in undergraduate education and for close student-faculty interaction. Ph.D. with teaching experience at time of employment preferred; ABDs encouraged to apply. Applicants should submit a letter of application, curriculum vitae, statements of teaching and research interests, and three letters of reference to Dr. Robert A. Gastaldo, Chair, Dept. of Geology, 5807 Mayflower Hill Drive, Waterville, ME 04901. Review of applications will begin 14 Nov. 2011 and will continue until the position is filled. Colby is an Equal Opportunity/Affirmative Action employer, committed to excellence through diversity, and strongly encourages applications and nominations of persons of color, women, and members of other under-represented groups. For more information about the college, please visit www.colby.edu.

**EARTH SYSTEMS SCIENTIST
STRUCTURAL GEOLOGY/TECTONICS
TENURE-TRACK POSITION, DEPT. OF EARTH AND
ENVIRONMENTAL SCIENCES, BOSTON COLLEGE**

The Dept. of Earth and Environmental Sciences at Boston College invites applications for a tenure-track position in the area of Structural Geology/Tectonics to start Fall 2012. The successful candidate will be expected to develop an externally-funded research program integrated with excellence in teaching within the geological sciences and environmental geoscience curriculum at both the undergraduate and graduate levels. Teaching responsibilities include courses in structural and field geology as well as others in the candidate's area of expertise. Specific research subfields of the successful applicant could include crustal dynamics, thermochronology, tectonic history of orogenic belts, tectonic-climate interactions, paleoseismology, and/or active deformation/geodesy. The department is equipped with a mineral separation laboratory including Wilfley table, heavy liquids separation lab, Franz magnetic separator, and stereomicroscope. Other labs in the

department include state-of-the art petrographic microscopes, a laser Raman micro-spectroscopic imaging system, and an isotope ratio mass spectrometer for light stable isotope analyses. Information on the department, its faculty and research strengths can be viewed at www.bc.edu/eesciences. Applicants should send a curriculum vitae, statements of teaching and research interests, and the names and contact information of at least three references as a single PDF-file-mail attachment to tectonics-position@bc.edu. Review of applications will begin 28 Oct. 2011. Department faculty will be available at the GSA and AGU fall meetings to meet with applicants. Boston College is an academic community whose doors are open to all students and employees without regard to race, religion, age, sex, marital or parental status, national origin, veteran status, or handicap.

**FACULTY POSITION, PALEOCEANOGRAPHY/
OCEAN SCIENCE, UNIVERSITY OF ROCHESTER**

The Dept. of Earth and Environmental Sciences invites applications for a tenure-track faculty position in paleoceanography and ocean science. The rank of the position is open, with a start date on 1 July 2012. We are interested in a dynamic educator and researcher who can build an externally funded program through strong links to the international ocean science and global change communities. Preference will be given to applicants who can contribute to the development of a new program in global sustainability and can build cross-disciplinary programs involving undergraduate and graduate students that complement the University of Rochester's existing programs in climate change, geodynamic-climate interactions, geohazards, and Earth and planetary evolution. See www.ees.rochester.edu for more information about the department's strengths in climate science, geochemistry, geophysics, petrology, sedimentology, and tectonics. The University of Rochester is a highly ranked research university, and Rochester's cultural, educational, and recreational assets consistently place the city in the top 10 places to live within the U.S. Applicants should submit materials via the following web site: <https://www.rochester.edu/fort/ees/>. Materials include a curriculum vitae, select reprints, statements of research and teaching goals, and the names and contact information of four references. An additional statement is requested that describes your view of sustainability education in Earth science and how it can be integrated with broader education in sustainability. The review of applicants will begin 15 Dec. 2011 and will continue until the position is filled. The University of Rochester, an equal opportunity employer, has a strong commitment to diversity and actively encourages applications from candidates from groups underrepresented in higher education.

Opportunities for Students

4 Ph.D. grants in planetary sciences. The Institute of Geological Sciences of the Polish Academy of Sciences is initiating the first planetary geology research program in Poland. The Research Centre in Wrocław is seeking dynamic and motivated candidates for 4 Ph.D. grants to contribute to implementing this program, supported by the European Union and the Foundation for Polish Science. We hope you will be a part of this extraordinary opportunity to found a new center in planetology.

The contracts are for 3.5 years, starting 1 Jan. 2012. The research topics are in the field of comparative planetology, with emphasis on how Mars can help solve general geoscience issues, relating to e.g. mass wasting processes, lithosphere mechanics, and early planetary environments.

The candidates must hold a master's degree in geology, geophysics, geography, or physics. Stipend is 3500 PLN/month, which is well above mean Ph.D. grants in Poland, and excellent for a student's life in the country. The deadline for applying is 25 Oct. 25, 2011; details and how to apply can be retrieved from www.ing.pan.pl/PlanetaryScienceJobs.htm or by contacting the project PI at daniel.mege@twarda.pan.pl.

C-DEBI Graduate Student Fellowships for Deep Subseafloor Biosphere Research. The Center for Dark Energy Biosphere Investigations (C-DEBI) Graduate Fellow Program supports graduate student research in C-DEBI community laboratories. Candidate fellows are encouraged to examine the IODP Expedition Schedule prior to developing their research proposal as all fellowship research is expected to align with the objectives of an IODP Expedition that involves research into the deep biosphere. C-DEBI encourages women and minorities to apply. This funding is only available to graduate students sponsored in US institutions. The next deadline for this semi-annual call is 10/31/11. For details, visit the C-DEBI Graduate Fellowship website: www.darkeenergybiosphere.org/education/graduatefellowships.html.

The **Minorities in Scientific Ocean Drilling Fellowship** is funded through the U.S. Implementing Organization (USIO) for the Integrated Ocean Drilling Program (IODP) to encourage minority graduate students studying geoscience or engineering to complete research in topics related to scientific ocean drilling. The Spring 2012 Fellowship will award \$20,000 to an outstanding student whose research is using data and/or materials obtained from scientific ocean drilling or who is developing technology that will help advance science or engineering in scientific ocean drilling research. Projects that are the applicant's own endeavor will be more favorably viewed.

The fellowship is open to graduate students that are a member of a racial or ethnic minority group and who are enrolled in a geoscience or engineering program at any U.S. university or college. The deadline to apply is **31 Oct. 2011**. For details, visit www.oceanleadership.org/education/diversity/minorities-in-scientific-ocean-drilling-fellowship/.

Graduate Research Opportunity, Nanogeoscience, Baylor University. The geology department at Baylor University anticipates a graduate research position starting January 2012. The graduate student will work with Dr. Bill Hockaday (analytical/organic geochemistry) and Dr. Boris Lau (nanogeoscience) studying the fate and transport of mineral nanoparticles in aquatic systems. Highly motivated candidates with a BS/MS degree in relevant science and/or engineering disciplines will be considered. Successful applicants must possess excellent English communication skills. Qualified applicant will be funded with competitive stipend, benefits, and travel support to attend professional meetings. Review of applicants will continue until the position is filled. However, full consideration will be given to those applications submitted by 30 Sept. 2011.

Prospective candidates are encouraged to submit their CVs to Dr. Boris Lau (boris_lau@baylor.edu) or Dr. Bill Hockaday (william_hockaday@baylor.edu). Please use "Lau-Hockaday Research Opportunities" in the subject line.

Baylor is a Baptist university affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Employment Opportunity employer, Baylor encourages minorities, women, veterans, and persons with disabilities to apply.

2012 GSA ANNUAL MEETING & EXPOSITION

CHARLOTTE

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CALL FOR PROPOSALS

TECHNICAL SESSIONS

Deadline: 10 Jan. 2012

<http://gsa.confex.com/gsa/2012AM/sessionproposal.epl>

Help ensure that your area of research and expertise is represented in next year's technical program. Individuals, groups, and geosciences organization are welcome to suggest topics and submit proposals for both Topical Sessions and Pardee Keynote Symposia. Pardee Symposia are high-profile sessions on significant scientific developments, with invited speakers only. Topical Sessions are a combination of invited and volunteered papers. Unique formats are allowed, but they must be outlined in the proposal, along with the technical support needs. Sessions that promote discussion are encouraged.

FIELD TRIPS

Deadline: 1 Dec. 2011

Know of a great geoscience excursion near Charlotte, North Carolina, USA? Teach your colleagues and peers about the ground-breaking research in this region. Submit your idea for a fun, interesting, and educational field trip for the 2012 Annual Meeting online at <http://gsa.confex.com/gsa/2012AM/fieldtrip.htm>. Trips can be anywhere from a half day to 5 days long. **Questions?** Please contact Beth Engle, +1-303-357-1006, bengle@geosociety.org.

SHORT COURSES

Deadline: 1 Feb. 2012

Have something that your peers need to know? Then lead a Short Course at the 2012 GSA Annual Meeting in Charlotte! Proposals for Short Courses are now being accepted. Courses can be run to develop professional, teaching, and research skills at all levels. Proposal guidelines are available online or by contacting Jennifer Nocerino at jnocerino@geosociety.org.



Looking ahead to 2012

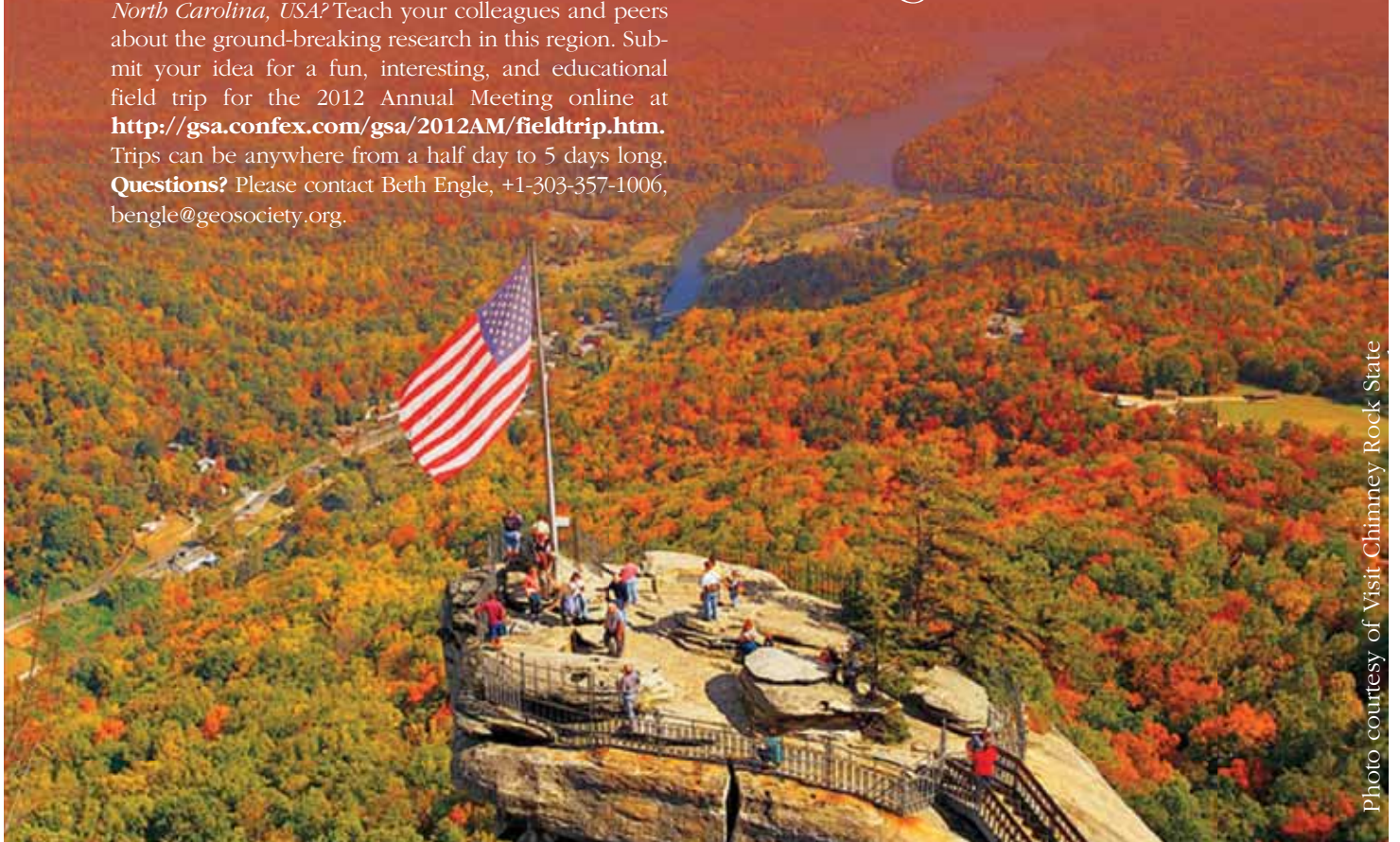
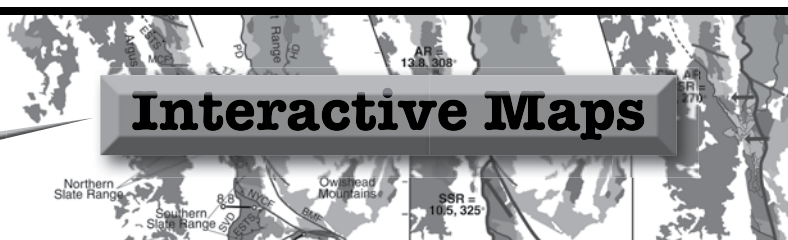


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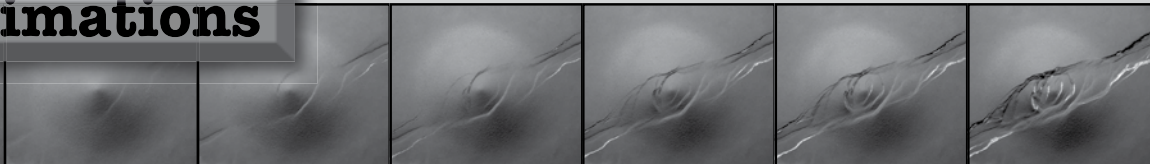
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Animations



Submissions welcomed from all geoscience disciplines

Publications Highlights

Can You Read Me Now?

GSA Launches Mobile-Optimized Publications Sites

Over the past two years, the percentage of visitors accessing GSA's publications sites from mobile devices has doubled, doubled again, and nearly doubled again.

In response, GSA is pleased to announce mobile-optimized publications sites for the journals at www.gsapubs.org. Visit any of the journal pages with a mobile phone and you'll be automatically redirected to a slimmed-down version of the website. You'll be able to access the same great content, although with fewer graphics for faster browsing. Larger buttons and finger scrolling allow you to read, skim, search, and e-mail yourself articles for a closer read later.

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