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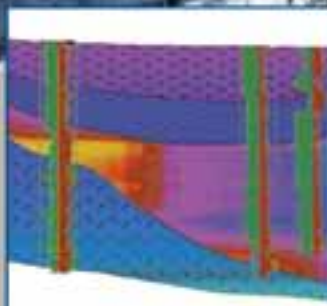
NOVEMBER 2010

***Tropical shoreline ice in the late Cambrian:
Implications for Earth's climate between the
Cambrian Explosion and the Great Ordovician
Biodiversification Event***

Inside:

- ▲ **First Announcement and Call for Papers:** 2011 Joint Meeting of GSA's Rocky Mountain and Cordilleran Sections, p. 14
- ▲ **Groundwork:** A Contribution to Our Dialogue on Energy Choices, p. 34

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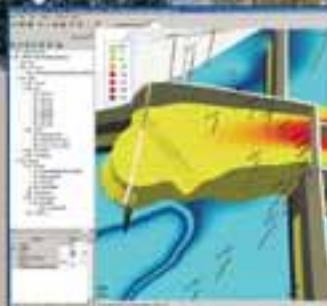
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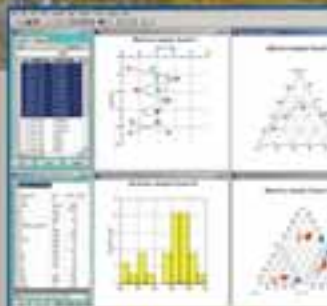
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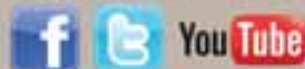
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SCIENCE ARTICLE

4 **Tropical shoreline ice in the late Cambrian: Implications for Earth's climate between the Cambrian Explosion and the Great Ordovician Biodiversification Event**

Anthony C. Runkel, Tyler J. Mackey, Clinton A. Cowan, and David L. Fox

Cover: The partly frozen, sandy shore of Lake Superior at Park Point, Minnesota, USA. Ice-cemented sand is brecciated into large blocks as it is undercut by waves in the swash zone; an analogy to conditions that occurred at least episodically along the equatorial late Cambrian shoreline of Laurentia. See "Tropical shoreline ice in the late Cambrian: Implications for Earth's climate between the Cambrian Explosion and the Great Ordovician Biodiversification Event," p. 4–10.



12 **Upcoming Deadlines**

13 **GSA Mentor Programs**

13 **2011 GSA Section Meeting Schedule**

14 **First Announcement and Call for Papers:** 2011 Joint Meeting of GSA's Rocky Mountain and Cordilleran Sections

16 **GSA Publications**

18 **GSA Divisions**

19 **Call for Applications:** 2011–2012 GSA-USGS Congressional Science Fellowship

20 **2011 GSA Student Research Grants**

22 **Congressional Science Fellow Report:** Conflict Minerals

24 **GSA Foundation Update**

26 **2010 GeoCorps™ America Participants**

29 **Classified Advertising**

34 **Groundwork:** A Contribution to Our Dialogue on Energy Choices

37 **Call for Proposals:** Minneapolis 2011

Tropical shoreline ice in the late Cambrian: Implications for Earth's climate between the Cambrian Explosion and the Great Ordovician Biodiversification Event

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ABSTRACT

Middle to late Cambrian time (ca. 513 to 488 Ma) is characterized by an unstable plateau in biodiversity, when depauperate shelf faunas suffered repeated extinctions. This poorly understood interval separates the Cambrian Explosion from the Great Ordovician Biodiversification Event and is generally regarded as a time of sustained greenhouse conditions. We present evidence that suggests a drastically different climate during this enigmatic interval: Features indicative of meteoric ice are well preserved in late Cambrian equatorial beach deposits that correspond to one of the shelf extinction events. Thus, the middle to late Cambrian Earth was at least episodically cold and might best be considered a muted analogue to the environmental extremes that characterized the Proterozoic, even though cooling in the two periods may have occurred in response to different triggers. Such later Cambrian conditions may have significantly impacted evolution preceding the Ordovician radiation.

INTRODUCTION

Understanding the paleoclimatic context within which major evolutionary events have occurred is one of the most critical, yet most elusive, aspects of interpreting the history of life on Earth. Between the Cambrian Explosion and the Great Ordovician Biodiversification Event (GOBE) is a ~25 m.y. period of subdued diversification, variously termed the “Late Cambrian Plateau” (Bambach et al., 2004) or the “Dead Interval” (Miller et al., 2006). Middle and late Cambrian marine fauna had low diversity, dominated by trilobite, phosphatic brachiopod, and conodont communities, yet these faunas experienced high turnover rates (Bambach et al., 2004; Miller, 2004). Viewed from the perspective of calcareous seafloor sediments and their non-uniformitarian rheological properties, this time interval is remarkable in its resemblance to the Proterozoic (Sepkoski, 1982; Cowan and James, 1992; Grotzinger and James, 2000; Knoll, 2003). The similarity in seafloor character suggests that at least some environmental conditions that typified the Proterozoic, and that existed prior to the Cambrian radiation of

metazoa, might have reemerged in middle to late Cambrian time, preceding the GOBE.

This resemblance may not be restricted to the nature of the seafloor. In this paper, we describe upper Cambrian features that indicate the presence of fresh-water ice at the Laurentian equator, suggesting that, like the Proterozoic, the latter half of the Cambrian was at least episodically globally cold.

Ice is indicated by extraordinary intraclasts in ancient beach deposits of the Furongian (501.0–488.3 Ma) Jordan Formation in the cratonic interior of North America (Fig. 1) (Runkel et al., 2007). The intraclasts preserve evidence of brittle-ductile-brittle changes in rheological behavior during their residence time in the paleo-swath zone—features identical to those caused by freeze-thaw-freeze cycles in modern beach sands at temperate latitudes. This evidence for freezing meteoric conditions near the Furongian paleoequator is in a stratigraphic interval that corresponds in timing to a global extinction that has long been postulated to have been triggered by a cryptic cold-water oceanographic event (Palmer, 1984).

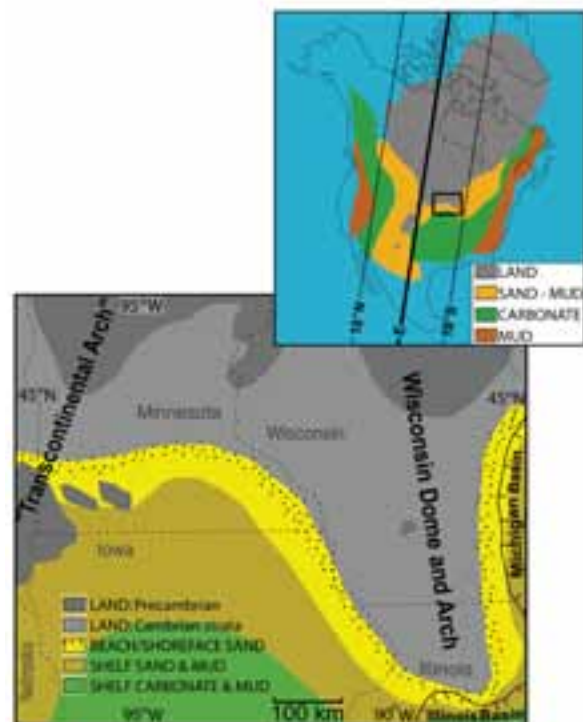


Figure 1. Location maps showing Laurentian late Cambrian facies belts and position relative to the equator (E) and regional tectonic and physiographic features of the cratonic interior. Modified from Runkel et al. (2007) with paleogeography of Laurentia from Cocks and Torsvik (2002).

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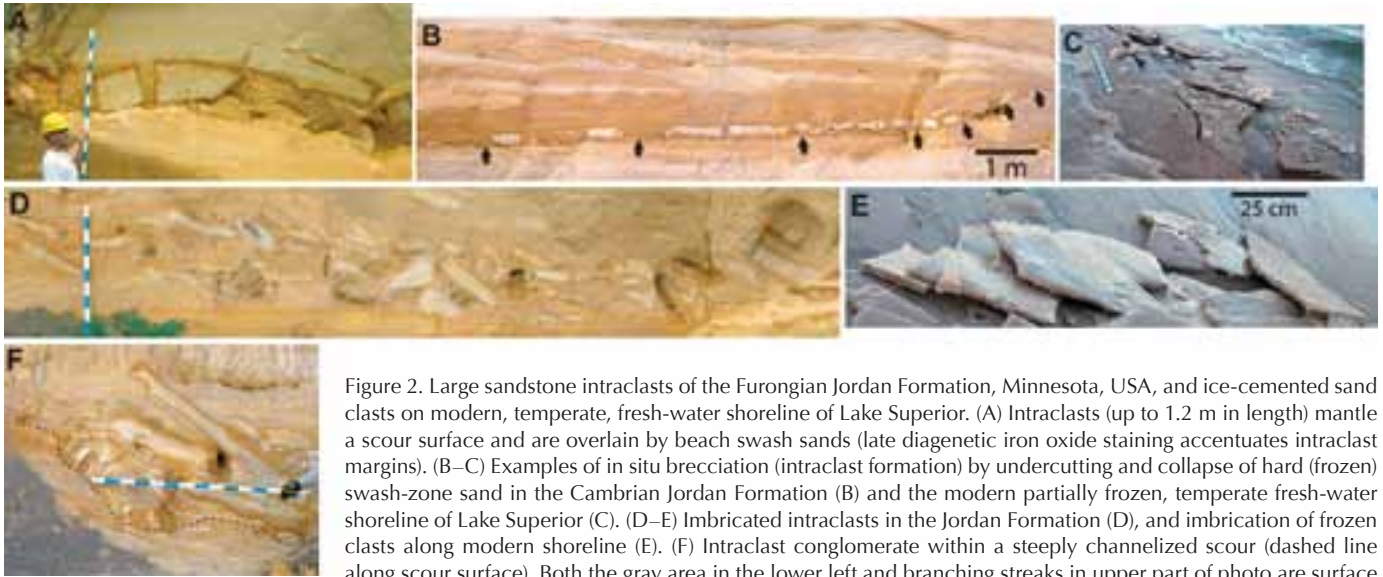


Figure 2. Large sandstone intraclasts of the Furongian Jordan Formation, Minnesota, USA, and ice-cemented sand clasts on modern, temperate, fresh-water shoreline of Lake Superior. (A) Intraclasts (up to 1.2 m in length) mantle a scour surface and are overlain by beach swash sands (late diagenetic iron oxide staining accentuates intraclast margins). (B–C) Examples of in situ brecciation (intraclast formation) by undercutting and collapse of hard (frozen) swash-zone sand in the Cambrian Jordan Formation (B) and the modern partially frozen, temperate fresh-water shoreline of Lake Superior (C). (D–E) Imbricated intraclasts in the Jordan Formation (D), and imbrication of frozen clasts along modern shoreline (E). (F) Intraclast conglomerate within a steeply channelized scour (dashed line along scour surface). Both the gray area in the lower left and branching streaks in upper part of photo are surface coating of dried, modern mud. Blue and white staff has 10 cm increments. Jordan Formation intraclasts in this and other figures are from section 12 of Runkel (1994), with UTM NAD83, Zone 15 coordinates 595174.486453 (UTME), 4872859.43211 (UTMN). Photographs and descriptions of modern ice-cemented sand are from the shoreline of Lake Superior at Park Point, Duluth area, Minnesota, USA. UTM NAD83, Zone 15 coordinates 572476.465496 (UTME), 5175832.45352 (UTMN).

Invocation of extreme cold, however, contradicts the long-held view that the middle to late Cambrian represents a sustained Greenhouse Earth episode (Bernier, 1990). The greenhouse interpretation is based, in large part, on traditional paleoecological assumptions about shallow marine carbonate sediments, models of atmospheric carbon dioxide levels (Bernier, 1990), and, recently, by extrapolation of controversial biogenic oxygen isotope data from the Lower Ordovician (Trotter et al., 2008). We revisit the applicability of characteristic middle through late Cambrian carbonate sediments to paleoclimatology and suggest that this interval of time was, at least episodically, and perhaps persistently, much colder than is commonly assumed. We also posit that this extraordinary climate mode may have had profound impacts on the evolution of Earth's early Paleozoic biosphere.

EVIDENCE FOR ICE

Unusual tabular sandstone intraclasts (Figs. 2A and 2B; Supplemental Data Fig. DR1A¹) up to 1.5 m in length occur within a discrete stratigraphic interval of the Jordan Formation. These intraclasts resulted from syndimentary cementation of intertidal sands in beach and tidal inlet environments (surf-swash zone and intertidal dune fields) that comprise the shallowest marine and estuarine facies preserved in this progradational cratonic sandstone (Runkel et al., 2007). Intraclasts typically occur in situ but can also occur ex situ: Rare pinstripe lamination of some intraclasts represents shore-adjacent aeolian lithofacies not otherwise preserved locally. Intraclasts of shallow-water origin also occur in deeper-water, finer-grained swaley cross-stratified facies deposited at fair-weather wave base, representing seaward transport of clasts by storms.

In surf- and swash-zone lithofacies of the Jordan Formation, intraclasts mantle low-angle, intrastratal truncation surfaces (Fig. 2B), locally displaying imbrication (Fig. 2D), or form conglomerates that fill steeply channelized storm scours (Fig. 2F). Where resting on low-angle scour surfaces, many intraclasts can be matched to their pre-brecciation original bed configuration, revealing an origin through undercutting and collapse (i.e., storm removal of loose sand from beneath a lithified sand layer) (Figs. 2B and 2C). Where filling steep-sided scours, intraclast orientations and compositions are typically more varied than in other settings. In intertidal dune lithofacies, intraclasts rest on foreset or set-bounding surfaces of decimeter to meter-scale dune cross-sets.

Intraclast abundance shows that syndimentary cementation of sand was locally common along the paleo-coastline during deposition of this part of the Jordan Formation. However, none of that original cement remains. This interval of the Jordan is friable, and late diagenetic Fe-oxide cements (Fig. 2A) locally accentuate or cross-cut original depositional interfaces, including intraclast margins. Cross-bedding and lamination within intraclasts show that they started as centimeter- to decimeter-thick cemented horizons, whose tops were primary sedimentary interfaces, and whose sides resulted from brecciation. We refer herein to the "sides" of an intraclast as representing these broken edges, regardless of present-day orientation.

Intraclast aspect ratios range from 1:1 to 1:12 and their sides may be smooth or irregular, displaying wedge-shaped gaps that narrow toward intraclast interiors, or with intricate, highly rugose, millimetric filigree (Figs. 3A–3C, 3G, and 3H). Rare intraclasts are curviform with internal laminae that are concordant to overall intraclast morphology (Figs. 3J–3L). The host sandstone for

¹GSA Supplemental Data item 2010290, supplemental photographs of modern and ancient ice-cemented intraclasts, is available online at www.geosociety.org/pubs/ft2010.htm. You can also request a copy from *GSA Today*, P.O. Box 9140, Boulder, CO 80301, USA; gsatoday@geosociety.org.

these curviform intraclasts is undeformed and cross-bedded, which reveals that the curviform shape was imparted to the intraclasts as the result of ductile deformation prior to the intraclasts being covered by migrating bedforms at the sediment-water interface (Fig. 4). Additionally, downward-branching burrows, similar to those made by polychaetes in modern coastal settings (Hertweck et al., 2007), pass from the host cross-bedded lithofacies into, and through, intraclasts (Fig. 5).

From these observations, we can reconstruct the synsedimentary and shallow subsurface rheological behavior of the

intraclasts, and thus constrain characteristics of the occult cementing agent. Both brittle brecciation of intraclasts with high aspect ratios and preservation of delicate filigree edges under swash and storm conditions on a sandy beach require a strong, hard cementing agent. In contrast, curviform (bent) intraclasts are evidence of ductile behavior at the sediment surface. Likewise, burrows that pass from host sediment into and through buried intraclasts necessitate that the cementing agent had essentially disappeared (presenting no resistance to Cambrian burrowers) when the clasts were still within centimeters of the sediment-water interface. Bent intraclasts with wedge-shaped gaps that formed post-bending suggest that intraclast rheological behavior could evolve from brittle (initial brecciation) to ductile (bending) to brittle again (gap formation and preservation) during its time on the shoreline (Fig. 4).

These characteristics are indicative of ice as the cementing agent for this ancient sand, a relatively routine interpretation for sand intraclasts in glaciogenic deposits (Browne and Naish, 2003), but less commonly recognized in other ancient settings (Illich et al., 1972). Intraclast rheology, size and aspect ratios, and recurring features such as bent clasts, wedge-shaped gaps, and filigree are consistent with published descriptions of frozen sand clasts along modern temperate shorelines (Nielsen, 1988; Dillon and Conover, 1965) and are identical to examples we studied along today's Lake Superior shoreline (Figs. 2, 3, and Supplemental Data Fig. DR1 [see footnote 1]). Solidly frozen sand has a similar strength to weak Portland cement concrete (Andersland and Ladanyi, 2004), which accounts for brittle characteristics. During incipient freezing or thawing, however, thin films of water surround sand grains and allow for ductile behavior (Andersland and Ladanyi, 2004) that results in draping and deformation of clasts. Complex intraclast rheological histories, repeated transitions between ductile and brittle behavior, and, ultimately, the complete disappearance of the cement, even just below the sediment surface, would be expected in ice-cemented sediment, which is susceptible to small fluctuations in temperature near its freezing point.

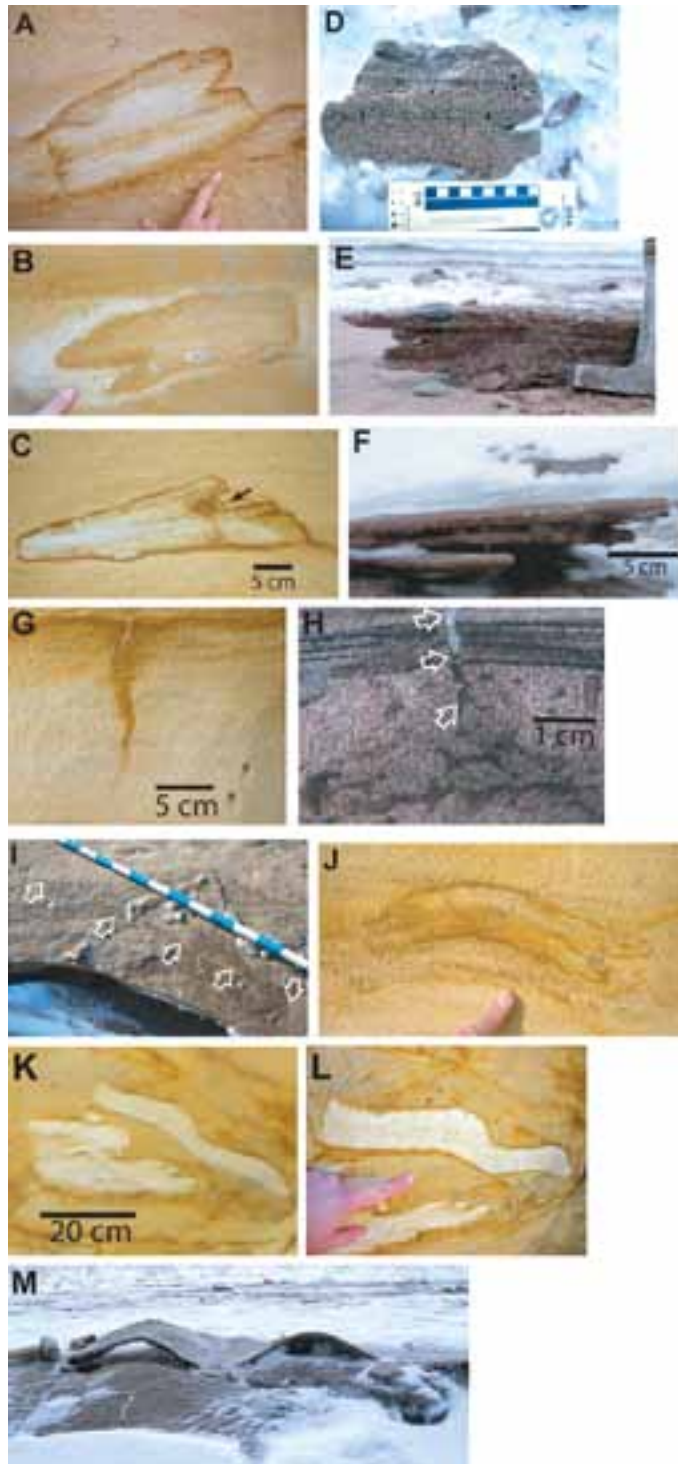


Figure 3. Comparison of morphologies that characterize Furongian intraclasts (left) with ice-cemented clasts on the modern partially frozen shoreline. (A–F) Lamination-parallel wedge-shaped gaps that taper toward clast interiors. Clast in (C) also displays preservation of fine-scale, delicate, millimetric filigree (arrow). Furongian clast-edge filigree follows foresets of a frozen toe of a paleodune form; modern clast-edge filigree follows frozen swash laminations; left edge of hammer handle in (E) is 2 cm vertically. (G–I) Lamination-perpendicular, partly penetrating cracks: (G–H) cross-sectional views of clast interior and upper margin of clasts; (I) plan view for modern example only (10 cm increments on staff). Such cracks form on the modern shoreline where a thawing, undercut, frozen sand layer partly fails and subsequently refreezes. (J–M) Curvilinear clasts: (J) intraclast with wedge-shaped gaps that opened up along laminations; (K–L) intraclast with contiguous curves. Oblique, closer view (L) shows that laminae within clast conform to clast margins, indicating curviform shape resulted from deformation (bending or folding) of an originally tabular clast, rather than having originated as a curviform-outlined cemented area of cross-laminated sand. Relationships of such deformed intraclasts to host sandstone matrix show that deformation occurred prior to burial by Furongian swash action. Clasts along modern shoreline (M) deform similarly in the swash zone by freeze-thaw processes. Circular end of hammer on left is 4 cm in diameter.

The strandline and estuarine paleoenvironments of intraclasts in the Jordan Formation implicate frozen fresh-water as the cementing agent; there is no evidence of frozen Furongian sea water (e.g., “freeze-up” or “break-up” deposits from nearshore ice; Reinson and Rosen, 1982). Instead, it appears that these intraclasts formed as a result of local conditions specific to the interface between the marine and terrestrial realms, where near-surface sand was saturated with fresh (or perhaps brackish) water. Fresh or brackish-water saturation of intertidal sands would have permitted freezing at temperatures far above those required for saltwater. A frozen sandy shore adjacent to an ice-free surf or open estuary would be an ideal setting to generate and preserve storm-wave induced brecciation of large blocks of the frozen beach sand (Dillon and Conover, 1965) (Figs. DR1B and DR1C [see footnote 1]).

A LINK TO MASS EXTINCTION

The intraclasts indicative of frozen shoreline conditions appear to have a restricted distribution both spatially and temporally within lower Paleozoic deposits of the Laurentian cratonic interior. Among thousands of exposures of Cambrian and Ordovician sandy shoreline deposits in the region, spanning ~50 m.y., they are present only in a discrete interval of the Jordan Formation that encompasses parts of just two biozones (upper *Eoconodontus* and lowermost *Cordylodus proavus* conodont zones). They are common to abundant only in several outcrops representing the upper *Cambrooistodus minutus* to lowermost *Hirsutodontus hirsutus* conodont sub-zones (Runkel et al., 2007). This biostratigraphic position corresponds to the boundary between the Sunwaptan and Skullrockian Laurentian Stages, which records the initiation of the last of at least three middle and late Cambrian global mass extinction events that decimated shelf communities (Loch et al., 1993). In North America, these recurring extinction events are used to define biostratigraphic units known as “biomeres” (Palmer, 1984; Taylor, 2006). The cause of biomere mass extinctions has been debated for decades, but among the most enduring hypotheses for the “kill mechanism” is incursion of cold water

onto continental shelves (Taylor, 2006; Loch et al., 1993). The persistence of the cold water theory is due largely to recognition that (1) “olenimorph” trilobites, otherwise known mostly from deep-water and high-latitude paleoenvironments, repopulated shelves after extinctions, presumably having migrated up from cold-water continental slope environments; and (2) sedimentary facies and geochemical analyses encompassing biomere intervals leave little room for other interpretations, such as eustatic sea level changes (with or without associated changes in water chemistry) or impact events (Taylor, 2006). The cold water hypothesis, however, has suffered from lack of widespread, unambiguous, direct or proxy evidence in the rock record, although coeval diastems and facies changes in carbonate sections (Loch et al., 1993) and

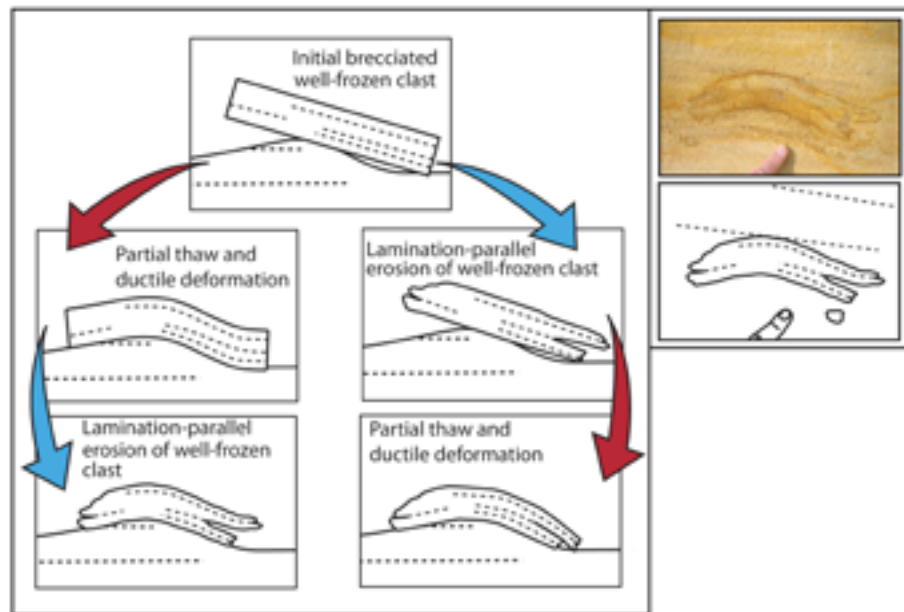


Figure 4. Constraints on evolution of intraclast rheological behavior shown by curviform intraclast with wedge-shaped gap (red arrows—partial thawing; blue arrows—refreezing). The sequence shown at left is the only way to achieve the ultimate configuration of deformed clast with observed wedge-shaped gap. Bending must occur prior to gap formation, because gap orientation requires a competent, but already curviform, clast. This evolution is suggestive of freeze-thaw-freeze (freeze to create original tabular clast that survives transport, partial thaw to then bend clast, and subsequent refreeze to create a competent clast that can support gap formation in this new position).

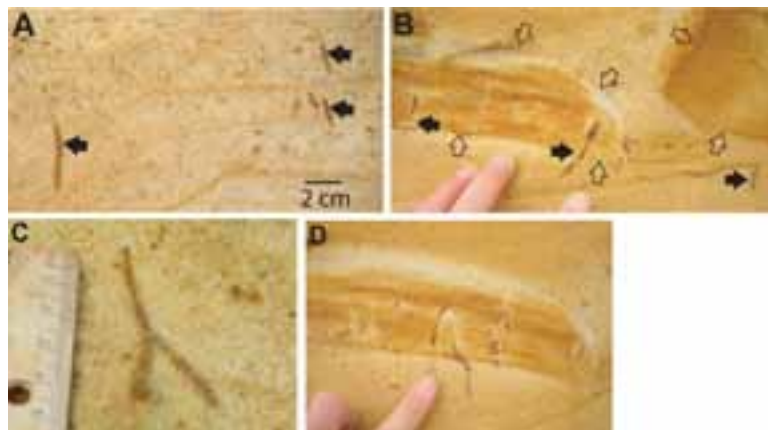


Figure 5. *Skolithos*(?) burrows (arrows) from intraclast host facies (diagenetic iron staining accentuates burrow) (A) and cutting intraclast margins (B) (solid arrows—burrows; open arrows—edges of intraclasts). (C–D) Branched burrows with similar relationships. Burrows that cross intraclast margins demonstrate that the cementing agent was no longer present after the clast was buried by sand in the swash zone but was still within reach of Cambrian shallow-depth burrowers.

negative carbon isotope excursions (Perfetta et al., 1999) at bioterm boundaries have been cited as physical evidence for incursions of cold water onto shelves. Additionally, a mechanism to raise the oceanic thermocline without apparently changing sea level has been elusive. The freezing shoreline conditions we document here provide not only important physical evidence linking extinction to cold conditions, but also provide insight into the magnitude of their influence. Expression of freezing conditions on the Furongian beach requires atmospheric cooling, not simply a rise in the thermocline or a shift in ocean currents. Cold could have penetrated shelf waters from above, bringing freezing temperatures across well-circulated, wave-agitated vast epicontinental shelves and thus exterminating endemic faunas.

DISCUSSION

The former presence of ice cement is a routine interpretation for known glacial paleoenvironments, but it is much more problematic in the context of middle to late Cambrian paleogeographic and inferred paleoclimatic conditions that place Laurentia in tropical latitudes during a presumed Greenhouse Earth episode. Several lines of evidence are consistent with the widely held characterization of sustained warmth during later Cambrian time. This evidence, however, is more equivocal than that used to characterize paleoclimate in younger rocks. Temperature tolerances of Cambrian organisms are not well understood, and the relatively few measures of paleotemperature based on isotopes are highly controversial (Land, 1995; Shields and Kasting, 2007), as is the correlation between modeled atmospheric carbon dioxide levels and paleotemperature (Veiser et al., 2000). A paucity of confirmed glacial deposits, and overall rising and ultimately high sea level, indicate merely that the Cambrian Earth apparently did not experience the climatic conditions necessary for development of continental ice to the extent as seen in other times in Earth's history.

Perhaps the most commonly cited evidence for sustained warmth during the middle and late Cambrian is the observation that the Laurentian craton, at least at times, was fringed by extensive carbonate platforms with features such as ooids and microbial reefs (stromatolites and thrombolites) (Lochman-Balk, 1971) that are traditionally regarded as indicative of tropical or near-tropical conditions. Recent studies, however, have cast doubt on the requisite warm-water origin for ancient ooids (James et al., 2005a); modern microbialites are not restricted to tropical climes, and modern marine stromatolites bear only scant resemblance to their ancient counterparts (Riding, 1991; Grotzinger and Knoll, 1999). Investigation of modern cool-water carbonate sediments and early seafloor diagenetic processes (James et al., 2005b) shows that many middle and late Cambrian oolites bear some hallmarks of cool-water deposition: original calcitic mineralogies (Heller et al., 1980) and syndepositional dissolution of aragonite on the seafloor (Wilkinson and Landing, 1978). Furthermore, irrespective of the possibly contentious re-interpretation of the paleoclimatological usefulness of oolite and stromatolite proposed here, such lithofacies are present only in discrete stratigraphic intervals of Cambrian sections, and, if "tropical" carbonate facies were indeed warmth-dependent, we suggest that relatively brief cooling events would be represented by other lithofacies,

equivocal in their temperature tolerance (e.g., calcisiltites and thrombolites), or by diastems when carbonate production ceased. Such diastems and lithofacies changes are ubiquitous in strata that correlate to the sandstone intraclasts we describe herein, and several authors have suggested they reflect cold water conditions (e.g., Loch et al., 1993).

Unlike coeval pericratonic carbonate depositional systems that are prone to climate-controlled stratal hiatuses (Bathurst, 1987), progradation of the quartzose Jordan Formation would be little-affected by cold temperature. It was fed by a nearly limitless supply of sand from the deeply weathered Laurentian craton, resulting in an exceptionally complete record of time (Runkel et al., 2008). Furthermore, the cratonic strandline setting had a rare set of conditions favorable to capturing and preserving evidence of even brief episodes of freezing temperatures: Intraclasts were deposited in facies where (1) percolating shoreface fresh or brackish water would have frozen at temperatures much higher than those required for coeval seawater; (2) exposure of frozen sand along the paleo-beachface would have permitted alternating freeze-thaw conditions that provide distinctive evidence for the former presence of ice (i.e., syndepositional alternating changes in clast rheology); and (3) wave-induced brecciation and rapid post-storm burial by wave processes would have preserved the frozen intraclasts before cement loss (melting or sublimation) (Figs. DR1B and DR1C [see footnote 1]).

A global-scale climatic phenomenon triggering this discretely preserved equatorial freezing event is favored by paleomagnetic data that place the Laurentian cratonic interior in sustained southern tropical latitudes throughout middle and late Cambrian time (e.g., Cocks and Torsvik, 2002), rendering unlikely the possibility that freezing conditions are the result of rapid continental drift to high latitudes (i.e., true polar wander) (Kirschvink et al., 1997). This poses the question of whether middle and late Cambrian time was consistently much colder than previously recognized, with relatively minor cooling episodes leading to freezing equatorial conditions, or, instead, whether the equatorial ice interpreted here represents an episode of drastic cooling during an otherwise Greenhouse Earth. Oxygen isotopic studies of slightly younger (Lower Ordovician) conodont apatite (Trotter et al., 2008), as well as modeled atmospheric carbon dioxide levels (Bernier, 1990), would appear to suggest the latter, if the debated use of those data as a measure of paleotemperature is regarded as reliable. We favor the former scenario and note that a number of reports have cited evidence from Laurentia and other continents consistent with a colder global Cambrian climate than widely assumed. This includes indications of continental glaciation specifically during the middle and late Cambrian, based on the magnitude and rate of eustatic sea level changes (e.g., Miller et al., 2005), and reputed, poorly dated glaciogenic sediments on some continents (Evans, 2003).

An overall cooler, later Cambrian Earth, or an unstable climate with dramatic swings, considered together with characteristic properties of carbonate seafloor sediment, is indicative of a reprise of select Proterozoic environmental conditions. However, the conditions that could have led to a cool later Cambrian Earth are no more apparent than they are for the Proterozoic, and the two periods may well have responded to

different climatic drivers. Globally significant tectonic and paleogeographic boundary conditions that might have triggered Proterozoic “Snowball Earth” events (Evans, 2003) are inconsistent with Cambrian plate reconstructions and known tectonic activity. High obliquity (Williams, 2008) appears to be contraindicated by reconstructions of global paleoenvironments (e.g., Evans, 2006) and the necessity for a subsequent reduction in obliquity prior to the onset of exclusively circum-polar glaciation in the Late Ordovician. Furthermore, unlike the relatively long durations of global cooling required to produce a Proterozoic Snowball Earth, the Cambrian conditions we have documented require cooling only to the extent that tropical latitudes were briefly subjected to diurnal temperatures that varied a few degrees around freezing. This allows for consideration of short-term climate drivers, such as cometary impacts (Bendtsen and Bjerrum, 2002), which might leave little geochemical or sedimentologic evidence. Whatever the primary controls on Cambrian climate, global cooling may have been subdued compared to during the Proterozoic, because the Cambrian likely experienced higher solar luminosity, less-efficient burial of organic carbon due to greater Cambrian bioturbation, and more limited primary productivity due to lower levels of bioavailable iron and phosphorus (Hoffman et al., 1998).

Ice at the late Cambrian equator suggests that the climate can be more accurately characterized as a muted analogue to the episodically globally cold conditions of the Proterozoic, rather than as the first of several sustained Greenhouse Earth events of the Phanerozoic. Such an interpretation has significant implications for understanding interactions between climatic and biologic evolution during this critical part of Earth’s history. It provides physical evidence for the long-postulated cold-water event that initiated a late Furongian global mass extinction and suggests the possibility that cooling events of this nature could have triggered earlier Cambrian mass extinctions. From a broader perspective, recognition of a cooler Earth during this time can provide additional constraints on recent hypotheses that link the climatic conditions of the Proterozoic and early Paleozoic to the origin and early evolution of metazoans. The reversion to Proterozoic-like conditions in the middle and late Cambrian is coincident with plateaued biodiversification and high extinction intensity following the Cambrian Explosion (Bambach et al., 2004), and the ultimate reemergence into the climate style of the Paleozoic is coincident with the GOBE and development of the shelly, filter-feeding benthic fauna that dominates the remaining Paleozoic record.

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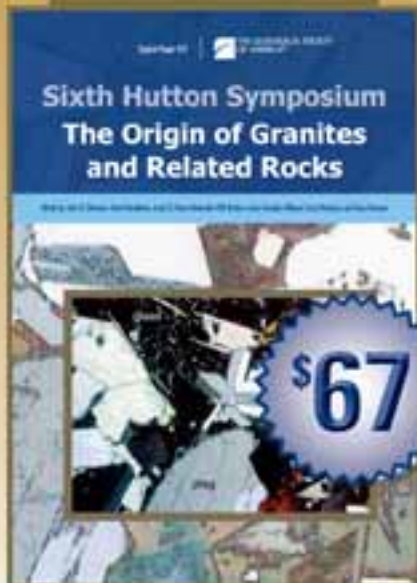


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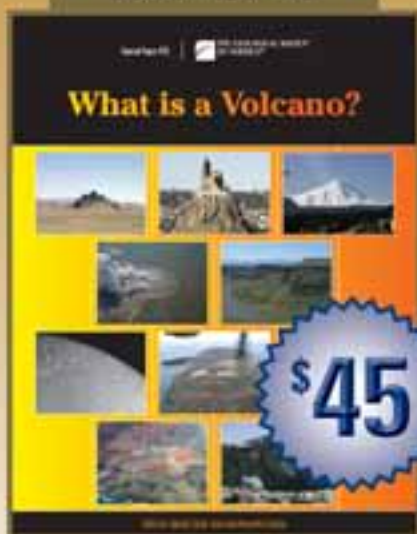
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Section, GSA

107th Annual Meeting of the Cordilleran
Section, GSA

Logan, Utah, USA

18–20 May 2011



Bear Lake, northeast of Logan, Utah, USA; image courtesy BearLake.com.

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TECHNICAL SESSIONS

- 1. From Contraction to Extension: The Mesozoic to Cenozoic Tectonic Evolution of the Northern Great Basin.** Joseph P. Colgan, USGS, jcolgan@usgs.gov; Chris Henry, University of Nevada–Reno, chenry@unr.edu; Victoria E. Langenheim, USGS, zulanger@usgs.gov; Allen J. McGrew, allen.mcgrew@notes.udayton.edu; David M. Miller, USGS, dmiller@usgs.gov; Michael L. Wells, michael.wells@unlv.edu.
- 2. Interactions of Climate, Tectonics, and Sedimentation in Cenozoic Basins of the Basin and Range.** Thomas Hickson, University of St. Thomas, tahickson@stthomas.edu; Melissa Lamb, University of St. Thomas, malamb@stthomas.edu; Paul Umhoefer, Northern Arizona University, paul.umhoefer@nau.edu.
- 3. Deep Crustal Perspectives on Cordilleran Orogenesis.** Chris G. Mattinson, Central Washington University, mattinson@geology.cwu.edu; Thomas D. Hoisch, Northern Arizona University, thomas.hoisch@nau.edu.
- 4. Neoproterozoic–Early Paleozoic Tectonic and Climatic Evolution of the Cordilleran Margin.** Carol Dehler, Utah State University, carol.dehler@usu.edu; Paul Link, Idaho State University; Adolph Yonkee, Weber State University.
- 5. Assembling North America: Precambrian Basement Tectonic and Geochemical Evolution of Laurentia (Oral and Poster).** David A. Foster, University of Florida, dafoster@ufl.edu; Darrell J. Henry; David W. Mogk; Paul A. Mueller.
- 6. Geology and Hydraulic Properties of Reservoir–Seal Systems with Implications for CO₂ Sequestration and Hydrogeology.** Alvar Braathen, UNIS, Norway, and Utah State University, alvarb@unis.no; Jim Evans, Utah State University, jim.evans@usu.edu; Elizabeth Petrie, Utah State University.
- 7. Petrologic and Geodynamic Perspectives on Non-Arc Volcanism in the Western United States.** John Shervais, Utah State University, john.shervais@usu.edu; Tony Lowry, Utah State University, tony.lowry@usu.edu.
- 8. Geochemistry of Igneous Rocks: From Small Scales to Big Pictures.** Adam Kent, Oregon State University, adam.kent@science.oregonstate.edu.

9. **The Mammalian Fossil Record of Utah.** Beth Townsend, Midwestern University, btowns@midwestern.edu; Paul Murphey, South Dakota Natural History Museum, pmurphey@sdnhm.org; Anthony Friscia, University of California—Los Angeles, tonyf@ucla.edu.
10. **Lake Bonneville and Beyond: Glacial-Pluvial Records of the Great Basin.** Paul W. Jewell, University of Utah, paul.jewell@utah.edu; Benjamin J.C. Laabs, SUNY Geneseo; Jeffrey S. Munroe, Middlebury College; Charles G. “Jack” Oviatt, Kansas State University, joviatt@ksu.edu.
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12. **Reading Landscapes and Dirt: Understanding Past Environmental Change.** Tammy Rittenour, Utah State University, tammy.rittenour@usu.edu; Shannon Mahan, USGS, smahan@usgs.gov.
13. **Human Impacts to Fluvial Systems and Restoration Approaches.** Sara Rathburn, Colorado State University, rathburn@warnercnr.colostate.edu; Ellen Wohl, Colorado State University, ellenw@warnercnr.colostate.edu.
14. **Water Resources of the Densely Populated Alluvial Valleys of the Western States—Processes.** Erick R. Burns, USGS Oregon Water Science Center, eburns@usgs.gov; Sue C. Kahle, USGS Washington Water Science Center, sckahle@usgs.gov.
15. **Water Resources of the Densely Populated Alluvial Valleys of the Western States—Water Budgets and Water Management.** Sue C. Kahle, USGS Washington Water Science Center, sckahle@usgs.gov; Erick R. Burns, USGS Oregon Water Science Center, eburns@usgs.gov.
16. **When Water Conveyances Are Breached: Causes and Impacts.** Jerome DeGraff, U.S. Forest Service, jdegraff@fs.fed.us; Richard Giraud, Utah Geological Survey, richardgiraud@utah.gov.
17. **New Geologic Maps for a Changing World—Research, Methods, Products, and Interpretations (Posters).** Grant Willis, Utah Geological Survey, grantwillis@utah.gov; Bob Biek, Utah Geological Survey, bobbiek@utah.gov.
18. **Undergraduate Research (Posters).** Kathleen Surpless, Trinity Univ., kathleen.surpless@trinity.edu; K. Hannula, Fort Lewis College, hannula_k@fortlewis.edu.
19. **Idea Blast: Sharing Incidental Findings (Posters).** Susanne Janecke, Utah State University, susanne.janecke@usu.edu. **Note:** A second meeting abstract submission is allowed for this session only.

MAP BLAST

You're invited to participate in this informal evening session—no abstract needed! Bring your in-progress geologic map and post it for comments and discussion. Maps should fit on poster boards. *Cash bar provided.*

FIELD TRIPS

Premeeting

1. **Karst Hydrogeology of the Bear River Range in the Logan Canyon Area, Northern Utah.** Larry Spangler, USGS.
2. **Tectonomagmatic Evolution of Distinct Arc Terranes within Blue Mountains Province, Oregon and Idaho.** Three days. C.J. Northrup, Mark Schmitz, and Gene Kurz, Boise State University.
3. **Cryogenian (“Sturtian”) Diamictite, Cap Carbonate, and Volcanic Rocks of Southeastern Idaho.** One day. Josh Keeley, Carol Dehler (carol.dehler@usu.edu), Paul Link, Adolph Yonkee, and Katie Kirkham.

Postmeeting

4. **New Investigations of Pleistocene Glacial and Pluvial Records in Northeastern Nevada.** Three days. Jeffrey S. Munroe, Middlebury College; Benjamin J.C. Laabs, SUNY Geneseo.
5. **Timing, Distribution, Amount, Style, and Causes of Early to Middle Cenozoic Extension in the Northern Great Basin.** Three days. Christopher D. Henry, Joseph P. Colgan, and Allen J. McGrew.
6. **Miocene to Recent Drainage Development of the Big Lost River System and Marsh Creek Adjacent to the Active Snake River Plain, Eastern Idaho.** Two days. Paul K. Link, linkpaul@isu.edu; David W. Rodgers; Glenn T. Thackray, Idaho State University; Mary K.V. Hodges, USGS.
7. **Impacts of Lava and Landslide Dams on the Evolution of the Owyhee River Canyon.** Four days. Lisa L. Ely, Central Washington University, ely@cwu.edu; Kyle House, USGS, pkhouse@gmail.com; Cooper Brossy, Fugro William Lettis & Associates Inc., c.brossy@fugro.com; Duane Champion, USGS, dchamp@usgs.gov.
8. **Paleontology and Stratigraphy of Middle Eocene Rock Units in the Bridger and Uinta Basins, Wyoming and Utah.** Three days. Beth Townsend, Paul Murphey, and Tony Friscia.
9. **New Insights into the Outlet of Lake Bonneville and Deltas of the Bear River.** One day. Susanne Janecke and Bob Oaks.



Wellsville Mountains, Utah, USA. Photo credit: Becky Blankenship; courtesy U.S. Forest Service.

GSA PUBLICATIONS

Did You Know?

Along with *GSA Today*, GSA publishes four journals: *GSA Bulletin*, *Geology*, *Geosphere*, and *Lithosphere*; several books series: *Memoirs*, *Special Papers*, *Reviews in Engineering Geology*, and *Field Guides*; and the sectional and annual meeting *Abstracts with Programs* volumes. GSA also co-edits and publishes the journal *Environmental & Engineering Geoscience*.

The *Geological Society of America Bulletin* is the Society's premier scholarly journal, published continuously since 1890. Fully refereed, the bimonthly journal reports major research in the traditional research-paper style. *GSA Bulletin* papers from 1945 to present are archived online.

Geology, published monthly since 1973, features short, up-to-the-minute articles covering all earth-science disciplines, including new investigations and provocative topics. An online forum section facilitates author-reader dialog. *Geology* papers from 1973 to present are archived online.

Geosphere, published online since 2005, is a peer-reviewed, bimonthly e-journal covering all geoscience disciplines and featuring animations, sound, and movie files.

Lithosphere, also peer-reviewed and bimonthly, was launched in 2009. True to its name, its research articles address how the surface, crust, and mantle interact to shape the physical and chemical evolution of the lithosphere at all spatial and temporal scales.

Environmental & Engineering Geoscience (E&EG), published quarterly for more than 30 years as the *Bulletin of the Association of Engineering Geologists (AEG)*, is co-edited and published jointly by GSA and AEG. E&EG contains new theory, applications, and case histories illustrating the dynamics of the fast-growing environmental and applied disciplines.

Memoirs & Special Papers: Both books series issued their first publications in 1934 after a generous bequest by R.A.F. Penrose Jr. **Memoirs** are sought and vetted by GSA science editors for comprehensive coverage of a topic and lasting value to researchers worldwide. **Special Papers** present state-of-the-art treatments of rapidly evolving subjects, the results of which may be altered or augmented by subsequent research, and are sought and vetted by GSA science editors for their high quality, broad interest, and coverage of wide-ranging topics.

Reviews in Engineering Geology, published since 1962, summarizes geological theory or case histories pertaining to engineering practice. This books series is produced in cooperation with the GSA Engineering Geology Division, which is responsible for the selection, review, and acceptance of manuscripts.

Field Guides compile detailed guides for field trips held during GSA annual and sectional meetings, as well as specialty meetings, and are published under the guidance of experienced scientists who serve as ad hoc volume editors.



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GSA Today reaches over 22,000 readers, with high international visibility and regular media coverage. Find article submission information and length guidelines at www.geosociety.org/pubs/gsatguid.htm.

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GSA's 17 Divisions provide avenues for you to stay connected with your colleagues worldwide and share news and information related to your scientific interests. Divisions also provide opportunities for leadership and service, specialty meetings, awards and recognition, and student support, and are instrumental in developing the GSA Annual Meeting Technical Program. To learn more, go to www.geosociety.org and click on "Divisions & Associated Societies."

■ **Archaeological Geology** (est. 1977) provides a forum for the presentation and discussion of papers on archaeological geology in order to stimulate and promote research and teaching within this field. Division awards include the *Rip Rapp Archaeological Geology Award*, the *Richard Hay Student Paper/Poster Award*, and the *Claude C. Albritton, Jr., Award* memorial fund.

■ **Coal Geology** (est. 1954) encourages coal research and disseminates coal geology information to all interested parties by actively participating in thought-provoking symposia and technical sessions at GSA's meetings and through scientifically pertinent publications. The Division sponsors the *Gilbert H. Cady Award* for outstanding contributions to the field of coal geology and also recognizes the volunteered contributions of its members through its *Distinguished Service Award*. For students, the Division offers the *Antoinette Lierman Medlin Scholarship*, the *Antoinette Lierman Medlin Laboratory and Field Awards*, and a *Best Student Paper Award*.

■ **Engineering Geology** (est. 1947) promotes education, research, outreach, and application of engineering geologic knowledge to the betterment of human society by adopting sound design of structures and facilities that assure public safety and a healthy environment. Each year, this Division honors geologists with the *E.B. Burwell, Jr., Award* and, along with the Association of Environmental and Engineering Geologists, commissions the *Richard H. Jahns Distinguished Lecturer*. Other Division awards include the *Meritorious Service Award*, the *Distinguished Practice Award*, and *Roy J. Shlemon Scholarship and Meeting Awards*.

■ **Geobiology & Geomicrobiology** (est. 2001) brings together scientists working at the interface of biology and geology to encompass the integration of these disciplines by simultaneously promoting both the broad scope and detailed disciplinary work demanded of rigorous interdisciplinary research. Fields currently represented within this Division include biogeochemistry, biomineralogy, geochemical ecology, paleontology, micropaleontology, origins of life and co-evolution of planets and life, paleobiology and paleoecology, molecular paleontology and ecology, systems modeling and informatics, and astrobiology. This Division sponsors an *Outstanding Contributions to Geobiology & Geomicrobiology Award* and an *Outstanding Student Research Poster Award*.

■ **Geoinformatics** (est. 2006) works to advance "Data to Knowledge" by providing GSA members with an opportunity to participate in the emerging field of cyberinfrastructure. The Division actively promotes and sponsors short courses, symposia, and books that emphasize information technology-supported discovery and the integration of geoscience data for a more comprehensive understanding of Earth and the planets as complex systems. The Division sponsors the *Geoinformatics Award*.

■ **Geology and Health** (est. 2005) focuses on the intersection of natural or anthropogenic geological conditions with health, disease, pathology, and death in modern and fossil humans, animals, and plants and fosters collaboration among scientists and health practitioners with an emphasis on the interdisciplinary relationship of geology to medicine, biology, chemistry, and other sciences. The Division sponsors a *Best Student Contribution Award*.

■ **Geology and Society** (est. 2003) follows the motto "Geology working for society" by increasing the geoscience community's knowledge of societal issues and improving the community's overall communication skills, thus ensuring accurate and intelligent dissemination of geologic information to society as a whole. This Division sponsors a *Best Student Presentation Award*.

■ **Geophysics** (est. 1971) facilitates discussion and presentation of the ideas and challenges of scientists interested in geophysics, fosters communication among geophysicists and other earth scientists, and promotes research and publication. This Division sponsors the *George P. Woollard Award* and lecture for outstanding contributions to geology through the application of geophysics as well as the *Allan V. Cox Student Research Award* and the *GSA Geophysics Division Student Research Award*.

■ **Geoscience Education** (est. 1991) fosters the active participation of GSA members in all aspects of earth-science education. The Division complements and expands on the contributions of GSA's Education & Outreach group, the National Earth Science Teachers Association (NESTA), the National Association of Geology Teachers (NAGT), the National Science Teachers Association (NSTA), and other similar organizations, and sponsors the *Biggs Earth Science Teaching Award* and a *Distinguished Service Award*.

■ **History of Geology** (est. 1976) encourages the study and communication of the history of geology. The Division sponsors technical sessions at GSA meetings and honors geologists for their research, writing, and historical work through the *Mary C. Rabbitt History of Geology Award*, the *Gerald M. and Sue T. Friedman Distinguished Service Award*, and the *History of Geology Student Award*. The Division occasionally submits "Rock Stars" articles to *GSA Today*, highlighting the life and work of "giants in geology."

■ **Hydrogeology** (est. 1959) focuses on the geologic aspects of hydrology, the role of geology in the hydrologic cycle, and the importance of hydrogeology to society and science. The Division has a well-established mentor program for students

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looking at careers in hydrology or hydrogeology, the John Mann Mentors in Applied Hydrogeology Program. *Birdsall-Dreiss Distinguished Lecturer* honorees are named by this Division, along with the *O.E. Meinzer Award*, the Division's *Distinguished Service Award*, and the *Hydrogeology Division Student Research Grant Awards*.

■ **Limnogeology** (est. 2002) encourages research on both ancient and modern lakes around the world, the collaboration of scientists from all disciplines on lake research, and the fostering of student research and careers in lake studies. The Division sponsors the *Kerry Kelts Student Research Awards* and in 2010 will present its inaugural *Israel C. Russell Award*.

■ **Mineralogy, Geochemistry, Petrology, and Volcanology** (est. 2009) provides a mechanism by which GSA members with interests in these areas can organize and partner with like-minded Associated Societies to promote awareness, teaching, study, and research within these disciplines. The Division offers a *Distinguished Geologic Career Award*.

■ **Planetary Geology** (est. 1981) operates under two mottos: "One planet just isn't enough!" and "The GSA Division with the biggest field area!" Awards sponsored by the Division include the *G.K. Gilbert Award*, the *Eugene M. Shoemaker Impact Cratering Award* for students, the *Stephen E. Dwornik Student Awards*, and (jointly with the Meteoritical Society) the *Pellas-Ryder Award* for the best student paper in planetary science.

■ **Quaternary Geology and Geomorphology** (est. 1955) facilitates communication among scientists in these fields and the presentation of their research and ideas to the wider scientific community. Several awards are given by this Division: the *Distinguished Career Award*, the *Kirk Bryan Award*, the *Gladys W. Cole Memorial Award*, the *Farouk El-Baz Award for Desert Research*, the *Don J. Easterbrook Distinguished Scientist Award*, and the *J. Hoover Mackin*, *Arthur D. Howard*, and *Marie Morisawa* student research awards.

■ **Sedimentary Geology** (est. 1985) works to ensure the presentation of related topics and sessions at GSA meetings and actively nurtures the work of students by offering the *Sedimentary Geology Division Student Research Grant Award* and *Student Poster Awards* and by providing financial aid for students to attend Division-sponsored short courses and field trips. Additionally, the Division sponsors the *Stephen E. Laubach Research in Structural Diagenesis Award* (alternating with the Structural Geology and Tectonics Division) and the *Laurence L. Sloss Award* for outstanding accomplishments in sedimentary geology and contributions to GSA.

■ **Structural Geology and Tectonics** (est. 1980), which focuses on the geometry and mechanisms of natural and experimental deformation at all scales, works to promote the research of scientists in these fields and to facilitate communication and discussion at all levels of the earth sciences. This Division offers a *Career Contribution Award* for advancement of the science of structural geology and tectonics, an *Outstanding Publication Award*, and a *Division Student Research Grant Award*. Additionally, the Division sponsors the *Stephen E. Laubach Research in Structural Diagenesis Award* (alternating with the Sedimentary Geology Division).



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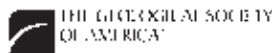
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The GSA student research grant application process is available online only; no paper applications or letters will be accepted. Apply online at www.geosociety.org/grants/gradgrants.htm starting late November 2010. Online submission must be completed by Tuesday, 1 February 2011, at 11:59 p.m. MST.

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Penrose Conference and Field Forum Proposals Encouraged

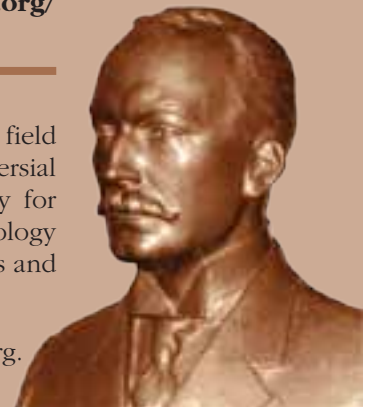
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GSA's Penrose Conferences were established in 1969 to provide opportunities for the exchange of current information and exciting ideas in geology and related fields and to stimulate and enhance individual and collaborative research. Go to www.geosociety.org/Penrose/ for guidelines and a proposal form.

FIELD FORUMS

Have a great idea for a Penrose Conference that would be much more effective in a field setting or a field trip idea that captures the essence of new discoveries or a controversial topic? Then submit a Field Forum proposal! Field Forums provide an opportunity for the exchange of current knowledge and ideas that are well expressed by the geology of a specific area. Go to www.geosociety.org/fieldforums/ for proposal guidelines and more information.

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Publish with GSA

The Numbers Are In

The 2009 ISI impact factors are up from 2008 for *Geology*, *GSA Bulletin*, and *Geosphere*, according to the ISI Journal Citation Reports, and GSA was recently notified that *Lithosphere* has been accepted into the Science Citation Index and Web of Science.

GSA Bulletin has published definitive geoscience works since 1890—and it's as timely, relevant, and whip-smart as ever. Join a top-notch roster of international contributors; submit a paper to *GSA Bulletin*. 2009 impact factor: 3.101; 5-year: 4.324; cited half-life: >10 years. Submit online: <http://www.editorialmanager.com/gsabulletin/>

Geology articles are innovative, provocative, and timely. Of interest to a broad audience, papers in *Geology* often describe a significant advance in the field. 2009 impact factor: 4.368; 5-year: 4.843; cited half-life: >10 years. Submit online: <http://www.editorialmanager.com/geology/>

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Mark G. Little

Conflict Minerals

On 21 July 2010, President Obama signed into law a broad financial regulations bill intended to help prevent and manage the kind of recession that has handicapped the world economy since 2006. Of the hundreds of pages of text, six are intended to provide relief to a population far from Washington, D.C., and far removed from the financial crisis—the people of the Democratic Republic of Congo (DRC) and the Great Lakes Region of central Africa.

The Second Congo War that raged from 1998 to the early 2000s and the conflict that now simmers in the DRC have claimed the lives of more than two million people and damaged the bodies and spirits of tens of thousands terrorized by sexual violence. This war has caused more loss of human life than any other conflict on this planet since WWII; however, the outside world has remained sclerotic and slow to act. In November 2009, the Conflict Minerals Trade Act (H.R. 4128) was introduced in the House of Representatives. The bill was designed to help end the illicit sale of “conflict minerals,” which would, in turn, cut off a major revenue stream to the armed factions responsible for the current violence. Mineral resources such as cassiterite (tin), columbite-tantalite (niobium, tantalum), wolframite (tungsten), and gold in the eastern DRC are often controlled by a shadowy network of rebel groups, wayward government troops, and smugglers. The profits of this illicit trade allow the killing and rape to continue; however, the minerals are vital ingredients in many important devices manufactured and consumed across the world, from tantalum capacitors in pacemakers to tungsten filaments in halogen lights. Fortunately, there are other sources of these minerals outside of the conflict areas and outside of the DRC altogether. H.R. 4128 would require that manufacturers using these resources publicly reveal their supply chain, thus allowing U.S. consumers to make informed decisions about where their dollar is ultimately going.

Because the bill has an international focus, it was referred to the House Committee on Foreign Affairs, where I have been working for the past year. The chair of the committee agreed with the goals of the legislation and threw the power of his position and the resources of the committee squarely behind the bill.

The most important of those resources is staff. I was fortunate to be in a position to assist the professional staff working on H.R. 4128 by offering my perspective as an earth scientist. During the ensuing months, we met with non-governmental organizations working on the ground in DRC; technical experts from the mining and jewelry industries; sympathetic hi-tech electronics companies that are dependent on these minerals; and State Department officials who would be tasked with creating and maintaining conflict-zone maps. This exchange of information and ideas occurred in parallel to regular meetings with other congressional offices and committees—both majority (Democratic) and minority (Republican). All of these conversations helped to create a bill that improved on each iteration.

Like most legislation, the Congo Conflict Minerals Trade Act was subject to a “mark-up,” the formal committee amendment process. In the days preceding the mark-up, the final bill language was tweaked through a series of telephone calls, meetings, and

many e-mails between majority and minority offices of multiple committees. Each time there was any change—including grammatical and syntactical—the bill was reviewed by all interested offices. On 28 April, the day of the mark-up, the bill passed through committee with unanimous, bipartisan support.

By 20 May, the Senate had passed a Wall Street reform bill amended with the Congo Conflict Minerals Act. While passage was great news for the prospect of reducing financial support for the conflict in DRC, the Senate-passed bill was substantially different from the House Committee-passed version. Thus began a new series of meetings, this time with a heightened sense of urgency and importance because there was a real hope of getting the legislation enacted—the bill was also placed on a strict timeline by senior congressional leadership. Senate and House, Republican and Democratic, personal and committee offices were now involved, all working to craft a compromise between the two versions. Again, the meetings went down to the last minute and, again, the final product was stronger for the collaborative work and commitment of the members of Congress and their staff.

The effectiveness of this legislation may be ambiguous for many years; however, Congress and President Obama have made a strong statement about the value of human life. In doing so, they have also recognized the relationship between the global demand for natural resources and conflict in developing countries. The U.S. government has chosen to promote peace by empowering consumers with the kind of information that can lead to a safer world.

This manuscript is submitted for publication by Mark G. Little, 2009–2010 GSA-USGS Congressional Science Fellow, with the understanding that the U.S. government is authorized to reproduce and distribute reprints for governmental use. The one-year fellowship is supported by GSA and by the U.S. Geological Survey, Department of the Interior, under Assistance Award No. G09AP00158. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. government. Little is working on the staff of the House Committee on Foreign Affairs, and he can be reached at MarkGabriel.Little@mail.house.gov.

2011 Calendar

Visions of the Dynamic Landscape 2011

This 12-month calendar features images of places or processes important to understanding and witnessing the changing landscape, especially in the Pacific Northwest. Photographs were selected from award-winning submissions to the 2009 GSA Annual Meeting photo exhibition in Portland, Oregon. Showcasing stunning photographs of Jokulsarlon glacial lake, Iceland; Grand Canyon Chockstone, Arizona; Bosumtwi Crater, Ghana; Rialto Beach, Olympic National Park; and many other landscapes, this useful calendar will spruce up your office or study.

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GSA Foundation Update

Donna L. Russell, Director of Operations

GSA Foundation Fiscal Year 2010 (FY10) Report

The GSA Foundation was incorporated in 1980 as an independent not-for-profit corporation with a mission to raise contributions from all sources to provide funding for GSA programs and projects.

During FY10, the Foundation received 5,824 gifts totaling US\$1,382,434. Seven of these were bequests with a combined total of US\$765,914. In turn, the Foundation was able to transfer US\$620,999 to GSA programs and projects during FY10.

Thank you so much to all the donors who made FY10 a success for the Foundation! Your support is sincerely appreciated.

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GSA FOUNDATION FY10 BALANCE SHEET

(as of 30 June 2010; all funds are listed in U.S. dollars)

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Pledge Receivable	\$61,954
Unitrust Receivable	\$221,619
Gifts in Kind	\$8,625
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TOTAL	\$10,664,782
Liabilities	
Due to GSA: Awards/Programs	\$106,240
Other Misc. Liabilities	\$35,559
TOTAL	\$141,799
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—George A. Thompson

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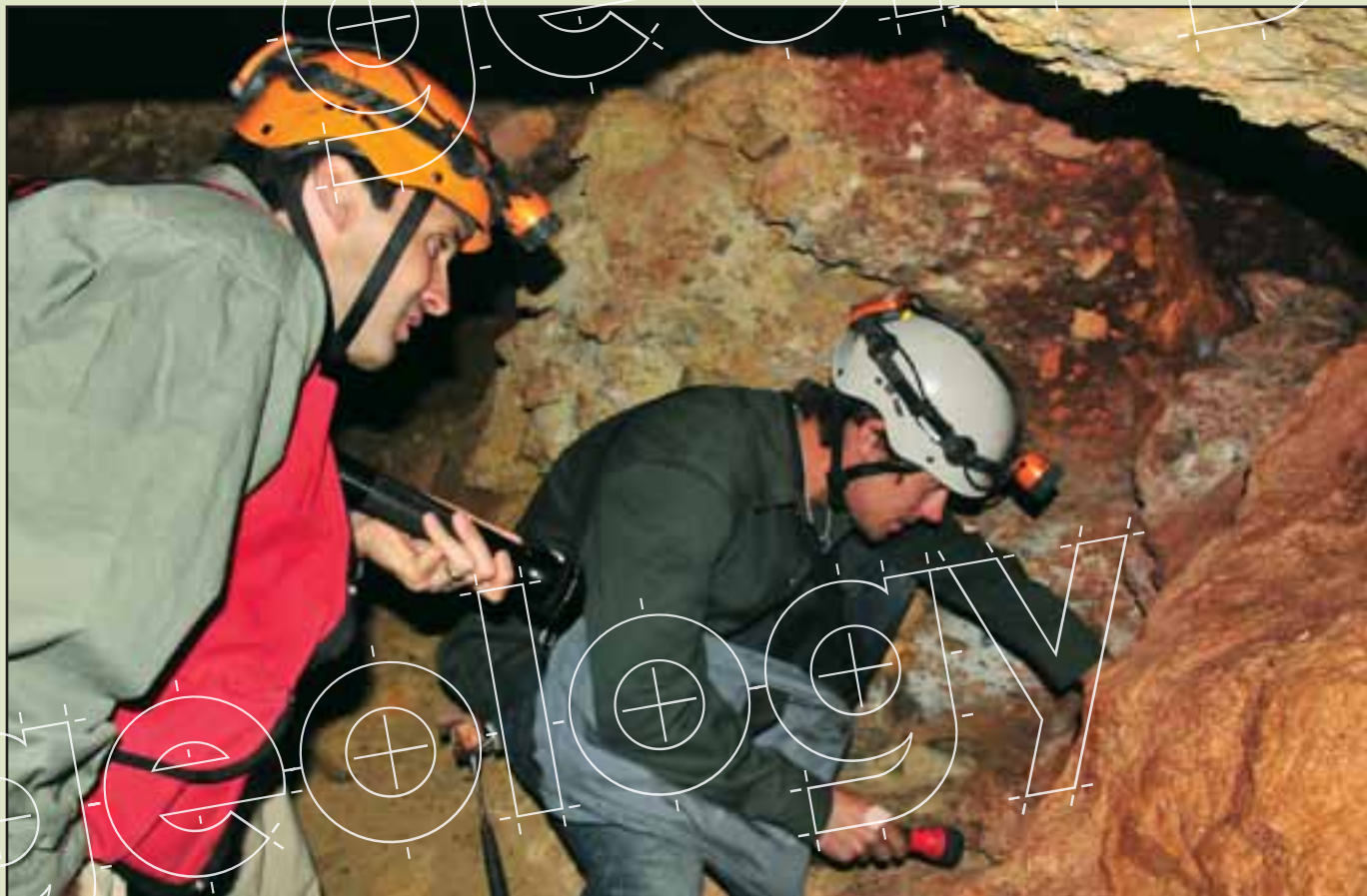
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Robert Haselwander, Custer and Shoshone National Forests, Montana, USA.

GeoCorps™ America places geoscientists of all levels—university students, teachers, professionals, and retirees—in short-term geoscience projects on public lands throughout the United States. GeoCorps projects are hosted by three major federal partners—the National Park Service (NPS), the U.S. Department of Agriculture (USDA) Forest Service, and the Bureau of Land Management (BLM). Projects cover a wide variety of subjects related to the geosciences, including geology, hydrology, paleontology, soils, geohazards, mapping, GIS, education, and interpretation. GeoCorps positions are sponsored by individual donors and the organizations listed below. Most GeoCorps employment is during the spring/summer season, but this year features, for the first time, eight positions running during the fall and winter.

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- Discover Your Northwest
- Grand Canyon Association
- Provincetown Center for Coastal Studies
- Rocky Mountain Nature Association
- The Friends of Florissant Fossil Beds
- The Friends of Voyageurs National Park

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1 December 2010

Positions for fall/winter 2011 will be posted 2 May 2011

www.geosociety.org/geocorps/

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2010 GEOCORPS PARTICIPANTS**

Bureau of Land Management

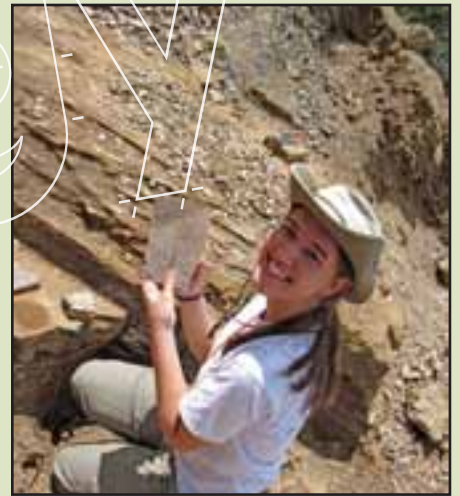
Alex Eddy, National Landscape Conservation System
Allison Vitkus, Royal Gorge Field Office
Carla Whittington, Price Field Office
Elise Weldon, King Range National Conservation Area
Hester Mallonee, Craters of the Moon National Monument
Jessica Fenn, Jarbidge Field Office
John Underwood, Royal Gorge Field Office
Katherine Loughney, Gunnison Gorge National Conservation Area & Wilderness
Laura Bochner, El Camino Real de Tierra Adentro National Historic Trail
Madeline O'Campo, National Historic Oregon Trail Interpretive Center
Maureen Kertes, Fairbanks District Office
Megan Crocker, Price Field Office
Mitra Sartipi, Arizona Strip District
Robin Canavan, Upper Missouri River Breaks National Monument
Tajeev Patel, Grand Staircase-Escalante National Monument



Adam Brown, Routt National Forest, Colorado, USA.

National Park Service

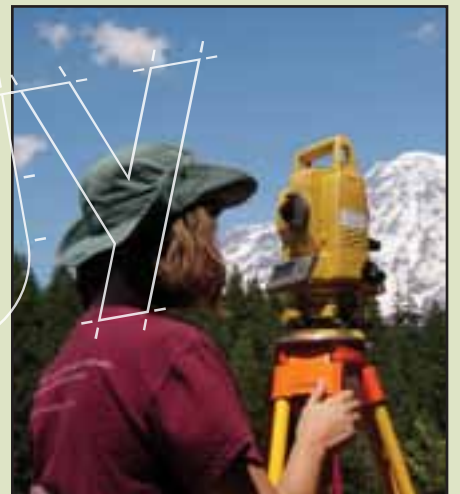
Alexander DeMoor, Denali National Park and Preserve
Allison Platsky, Florissant Fossil Beds National Monument
Andrea Johnson, Rocky Mountain National Park
Andrew Walters, Mount Rainier National Park
Ariel Demarest, Florissant Fossil Beds National Monument
Bree McClenning, Mount Rainier National Park
Chris Hemstad, Voyageurs National Park
Christina Carr, Mount Rainier National Park
Christina Forbes, Denali National Park and Preserve
Christine McDougal, Geologic Resources Division
Dana Smith, Mount Rainier National Park
Daniel Soda, Northeast Coastal and Barrier Network
Deborah Slawson, Harpers Ferry National Historical Park
Elizabeth Waite, Florissant Fossil Beds National Monument
Elliot Dale, Natural Resource Program Center
Erica Clites, Center for Urban Ecology; Geologic Resources Division
Erika Matteo, Geologic Resources Division
Heather Rogers, Yosemite National Park
Hilton Freed, Grand Teton National Park
Jacalyn Gorczynski, Cape Cod National Seashore
Jacob Grosskopf, Dinosaur National Monument
Jennifer Johanson, Glacier National Park
Jesse Robertson, Grand Canyon National Park (North Rim)
Joe Ruffini, Craters of the Moon National Monument and Preserve
John Ghist, Geologic Resources Division



Elizabeth Waite, Florissant Fossil Beds National Monument, Colorado, USA.

John Warden, Center for Urban Ecology
Karyn Patridge, John Day Fossil Beds National Monument
Katilin Maguire, John Day Fossil Beds National Monument
Kelton Russenburger, Bryce Canyon National Park
Lani Manion, Badlands National Park
Leigh Mastin, Oregon Caves National Monument
Lindsey Harriman, Yellowstone National Park
Louie Thunderhawk, Northern Great Plains Network-American Indian Higher Education Consortium (AIHEC) Internship
Lucas Carrington, Geologic Resources Division

Participants continued on p. 28



Bree McClenning, Mount Rainier National Park, Washington, USA.

GeoCorps participants continued from p. 27

Madeline Weigner, Dinosaur National Monument
Matthew Brown, Prince William Forest Park
Matthew Miller, Glen Canyon National Recreation Area
Michael Cook, Geologic Resources Division
Michael Potts, Gulf Islands National Seashore
Michael Unger, Mammoth Cave National Park
Nadine Reitman, Denali National Park and Preserve
Natalie DeMaioribus, Dinosaur National Monument
Nathan Rossman, Lewis and Clark National Historic Trail
Paul Zarella, Northeast Coastal and Barrier Network
Philip Reiker, Geologic Resources Division
Rebecca Port, Geologic Resources Division
Sevon Geil, Big Thicket National Preserve
Sinte Nupa Gilbert, Northern Great Plains Network—
American Indian Higher Education Consortium
(AIHEC) Internship
Sofia Agopian, Yellowstone National Park
Stephen Elmore, Oregon Caves National Monument
Stewart Edie, Craters of the Moon National Monument
and Preserve
Ted Fremd, Geologic Resources Division
Theodore Barnhart, Bryce Canyon National Park
Timothy Freed, Lewis and Clark National Historic Trail
William Armstrong, Congaree National Park

USDA Forest Service

Adam Brown, Medicine Bow–Routt National Forests
Aryn Hoge, Arapaho & Roosevelt National Forests and
Pawnee National Grassland
Brooke Jones, U.S. Forest Service–Northern Region
Colby Tisdale, Shasta-Trinity National Forest
Cullen Jones, Klamath National Forest
Erik Larson, Hiawatha National Forest
Erin Lynch, Tongass National Forest
Joshua Stevenson, Fraser Experimental Forest,
Arapaho-Roosevelt National Forest
Leah Bedoian, Routt National Forest
Mark Hagemann, Tongass National Forest
Nikki Oliver, Sierra National Forest
Patrick Burns, Fraser Experimental Forest,
Arapaho-Roosevelt National Forest
Paul Doss, Huron-Manistee National Forest
Reba Heiden, Shasta-Trinity National Forest
Robert Haselwander, Custer and Shoshone National Forests
Rose Feinstein, Routt National Forest
Ryan Vasquez, Gila National Forest



Jacob Grosskopf, Dinosaur National Monument, Utah/Colorado, USA.

Positions Open

DEPARTMENT OF EARTH SCIENCES ASSISTANT PROFESSOR BRIDGEWATER STATE UNIVERSITY

The Dept. of Earth Sciences at Bridgewater State University invites applications for a tenure-track position in Sedimentary Geology/Invertebrate Paleontology to begin September 2011. The ideal candidate will be committed to excellence in teaching at the undergraduate level, strongly field-oriented, and focused on integrative research in sedimentary geology, stratigraphy and/or invertebrate paleontology. The successful applicant will develop a junior level course in Sedimentary Geology/Stratigraphy, a senior level course in Paleontology and advanced course/s in the applicant's area of expertise. Teaching introductory geology courses is also expected. The candidate is also expected to develop an active program of research and to mentor undergraduate research students. Other responsibilities include academic advising and service on university-wide committees. This position will be filled at the Assistant Professor level and candidates should possess a Ph.D. by June 2011.

Required Minimum Qualifications: A completed Ph.D. in the geological sciences with a specialization in sedimentary geology.

Preferred Qualifications: Ability to develop undergraduate courses in the sedimentary geology and invertebrate paleontology. Research mentoring of undergraduate students. Strong field orientation.

Applicants should be strongly committed to excellence in teaching and advising, and to working in a multicultural environment that fosters diversity. They should also have an ability to use technology effectively in teaching and learning, the ability to work collaboratively, evidence of scholarly activity, and a commitment to public higher education.

Special Instructions to Applicants: Please attach the following documents to your on-line application: Cover Letter, Resume, A Teaching Philosophy statement

Salary: Commensurate with qualifications and experience

TO APPLY: Interested applicants should apply online at <http://jobs.bridgew.edu>.

Position will remain open until filled.

Bridgewater State University is an affirmative action/equal opportunity employer which actively seeks to increase the diversity of its workforce.

TWO POSITIONS AVAILABLE COASTAL GEOLOGY AND SEDIMENTARY GEOLOGY UNIVERSITY OF NORTH CAROLINA-WILMINGTON

The Dept. of Geography and Geology at the University of North Carolina-Wilmington (www.uncw.edu/earsci) invites applications for two tenure-track positions to begin August 2011:

1. **Coastal Geology** at the rank of Assistant or Associate Professor. We seek an individual with demonstrated expertise in coastal geologic processes, and research interests in a related area such as coastal geomorphology, monitoring and modeling of surface processes, coastal evolution, or coastal hazards and engineering.

2. **Sedimentary Geology** at the rank of Assistant Professor. We seek an individual with demonstrated expertise in sedimentary petrology, and research interests in a related area such as sequence stratigraphy, carbonate or clastic sedimentation, geochronology, or basin analysis.

Primary responsibilities for both positions include teaching and advising students at the undergraduate and graduate levels, directing student research, and developing a vigorous research program with the potential to attract external funding. We especially encourage applicants who will actively engage students in field research. A Ph.D. in the geosciences or related discipline is required.

The department offers B.S. and M.S. degrees in geology, B.S. in oceanography, B.A. in geosciences, and B.A. in geography. UNCW maintains a wide range of research laboratories on the main campus and at the Center for Marine Science (www.uncw.edu/cmsr), including facilities for isotope ratio mass spectrometry, X-ray diffraction, scanning electron microscopy, preparation of petrographic samples, sedimentology, and geospatial analysis.

To apply, complete the online application at <http://consensus.uncw.edu>. A letter of application, brief statements of teaching and research interests, a curriculum vitae and contact information, including e-mail addresses, for three professional references should be uploaded as MS Word or PDF files. For questions about the coastal geology position contact search committee chair Dr. Nancy Grindlay, grindlayn@uncw.edu, +1-910-962-2352. For questions about the sedimentary geology position contact search committee chair Dr. Michael Benedetti, benedettim@uncw.edu. For questions about the online application process contact Ms. Cathy Morris, morris@uncw.edu, +1-910-962-3736. Priority consideration will be given to applications received by 15 Dec. 2010, but applications will be accepted until the position is filled.

UNC Wilmington actively fosters a diverse and inclusive working and learning environment and is an equal opportunity employer. Qualified men and women from all racial, ethnic, or other minority groups are strongly encouraged to apply.

TENURE-TRACK POSITION IN GEOLOGY UTAH VALLEY UNIVERSITY (UVU) OREM, UTAH

The Dept. of Earth Science at Utah Valley University (UVU) invites applications for a tenure-track position in Geology, to begin August 2011. The successful candidate will have a Ph.D. in geology or a closely-related field and expertise in at least two of the following areas: paleoclimatology, economic geology, geochemistry, geophysics, geologic education. Responsibilities will include teaching introductory and upper division courses in geology, as well as engaging in some combination of research, supervision of undergraduate research, service learning, professional work, activity in professional organizations, and/or continuing education. This is primarily a teaching job, and the successful candidate will have a demonstrable commitment to innovative and effective teaching.

UVU, located in Orem, Utah, is a comprehensive state institution of higher education with over 30,000 students. Orem is on the western front of the Wasatch Mountains, with superb opportunities for field-based teaching and research. Orem offers access to numerous outdoor activities including snow sports, hiking, mountain biking, and hunting. The Wasatch Front metropolitan area offers cultural opportunities such as the Sundance film festival and world-class music and dance companies. The UVU Earth Science faculty has strong ties with other universities and with the professional earth sciences community in Utah. UVU and the Dept. of Earth Science strongly support undergraduate research and service learning. The department has numerous active regional and international research projects that focus on involvement of undergraduate students. UVU offers very good insurance and retirement benefits to faculty members. Please see www.uvu.edu/csh/earthscience/ or contact Danny Horns at hornsda@uvu.edu for more information about UVU earth sciences. To apply, please visit www.uvu.jobs. Click on "Search Postings", and then choose "Earth Science" from the department dropdown menu. Applications will be reviewed beginning 28 Jan. 2011. Utah Valley University is an Affirmative Action/ Equal Opportunity/ Equal Access Employer.

ASSISTANT PROFESSOR, SEDIMENTOLOGY, ADRIAN COLLEGE

The Dept. of Geology at Adrian College invites applications for a tenure track position to begin in Fall 2011. We seek a colleague who is committed to teaching excellence in the liberal arts tradition, is field-oriented, has broad interests beyond their specialty, and will provide a balance of classroom, field and laboratory experiences for our students. Mentoring senior capstone research projects is required. Specific areas of interest include sedimentary petrology and/or stratigraphy. Demonstrated excellence in teaching at the undergraduate level is preferred. A Ph.D. at the time of appointment is required but advanced ABD's will be considered.

Adrian College is a private liberal arts college strongly committed to, and supportive of, excellence in teaching and active faculty research that involves undergraduate students. See www.adrian.edu/academics/GEOL/index.php for more information. Please contact Dr. Sarah Hanson, +1-517-264-3944, shanson@adrian.edu, for more information about the position.

Please include a letter of application; statements of teaching and research interests for a liberal arts setting, a vita, and contact information for three references. Send to Deb Devore at Adrian College, 110 S. Madison St., Adrian, MI 49221; ddevore@adrian.edu. Application materials should arrive by 1 Dec. 2010 for full consideration, although the search will remain open until the position is filled. Adrian College is an Equal Opportunity Employer. Women and minorities are strongly encouraged to apply.

TENURE TRACK POSITION SEDIMENTARY GEOLOGY TEXAS TECH UNIVERSITY (POS. #20121TLF005)

The Dept. of Geosciences at Texas Tech University invites applications for a tenure track position in sedimentary geology to begin Fall semester 2011.



UNIVERSITY OF TORONTO MISSISSAUGA

ASSISTANT PROFESSOR EARTH SCIENCES DEPARTMENT OF CHEMICAL AND PHYSICAL SCIENCES (CPS)

We are seeking applications for a tenure-track position at the Assistant Professor level from scholars with research interests in applied geophysics with a commitment to field-based research. The successful applicant will join an earth sciences research cluster at UTM with interests 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, 2011 at a salary commensurate with qualification and experience.

We encourage you to submit your application online by visiting us at <http://www.jobs.utoronto.ca/faculty.htm>, and refer to job number 100087L. 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 30, 2010.

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.

For more information about the Department of Chemical and Physical Sciences, University of Toronto Mississauga, please visit our home page at http://www.utm.utoronto.ca/index.php?id=news_cps.

Depending on experience and qualifications, the successful candidate may be appointed at the Assistant or Associate Professor level; a Ph.D. in geological sciences is required at the time of appointment. We seek a candidate with interests in carbonate/clastic sedimentary processes and petrology, depositional systems, basin analysis, sedimentary tectonics, sequence stratigraphy, or sedimentary geochemistry and diagenesis. The candidate will be expected to teach undergraduate and graduate courses in their specialty, establish an innovative, externally funded research program, and direct M.S. and Ph.D. student research.

The Dept. of Geosciences is one of the fastest growing units at Texas Tech University, with nearly 30 faculty members in solid earth geosciences, geography, atmospheric science, and climate change. We work closely with the National Weather Service and the U.S. Geological Survey Texas Water Science Center which has a field office in our department. The department maintains analytical facilities for light stable isotope mass spectrometry, laser ablation and solution ICP mass spectrometry and elemental analysis, low-temperature aqueous geochemistry, and X-ray diffraction, as well as rock- and thin-section preparation and mineral separation facilities. The Imaging Center of Texas Tech houses several TEM and SEM instruments with EDS, EBSD and CL detectors. All instrumentation and facilities are supervised by full time technical support. Geologic and geophysical interpretation/modeling/mapping software packages such as Geographix Discovery, ProMAX, GeoProbe, and PetroMod, as well as the full suite of ESRI GIS software are available. Additional information about the Dept. of Geosciences may be found at www.depts.ttu.edu/gesc/. Opportunities exist for participation in on-going multidisciplinary programs in Petroleum Engineering and Civil Engineering (hydrology).

Review of applicants will begin 1 Jan. 2011 and continue until the position is filled. Applicants must visit the TTU employment website (<http://jobs.ttextech.edu>), search for requisition #82382, and provide the required information. Afterwards, applicants should submit a letter of application, a description of research & teaching objectives, curriculum vitae, and names and contact information, including e-mail addresses, of at least three references. These documents may be uploaded to the employment website or mailed to: Dr. Hua-wei Zhou, Geosciences Search Committee Chair, +1-806-742-1308; h.zhou@ttu.edu, Dept. of Geosciences, MS 1053, Texas Tech University, Lubbock, TX 79409-1053. Representatives of the department will be present at GSA, SEG, and AGU meetings during the fall of 2010.

Texas Tech University is an equal opportunity/affirmative action institution; women, minorities, veterans and persons with disabilities are encouraged to apply.

FLORIDA MUSEUM OF NATURAL HISTORY UNIVERSITY OF FLORIDA, THOMPSON CHAIR OF INVERTEBRATE PALEONTOLOGY

The Florida Museum of Natural History, University of Florida, invites applications for the Thompson Chair of Invertebrate Paleontology to be hired at the level of Associate or Full Curator (equivalent to Associate or Full Professor) with tenure. The successful candidate will be expected to conduct a dynamic research program and develop the museum's extensive collection of primarily Cenozoic invertebrate fossils that includes five million specimens. The collection is assigned two full-time staff responsible for its operations. A substantial endowment is associated with this position.

This position requires a strong commitment to university education, field work, museum-based research, and outreach. Interactions with allied academic departments include affiliate professorship status with responsibility for supervision of graduate students and teaching two formal courses per year. Minimum qualifications: Strong externally funded research, collections experience, and tenure or at least seven years of post-Ph.D. professional experience (i.e., in academic, research, or related position[s]). The start date is open. The salary is competitive and commensurate with experience.

The search committee will begin reviewing applications on 14 Jan. 2011 and will continue to receive applications until the position (requisition # 0806086) is filled. To ensure full consideration please apply on-line at <http://jobs.ufl.edu>. The application should include: (1) cover letter, (2) curriculum vitae, (3) statement of research, collections, teaching, and outreach experience, vision, and goals; (4) reprints of no more than three publications, and (5) the names of three colleagues who might be contacted for letters of recommendation. Any questions regarding this position or nominations may be directed to the search committee chair Dr. Bruce J. MacFadden, Thompson Chair Search Committee, Florida Museum of Natural History, University of Florida,

P.O. Box 117800, Gainesville, FL 32611-7800; bmacfadd@fmnh.ufl.edu.

The University of Florida is an Equal Opportunity/Affirmative Action Employer. If an accommodation due to a disability is needed to apply for this position, please call +1-352-392-2477 or the Florida Relay System at +1-800-955-8771 (TDD). The selection process will be conducted under the provisions of Florida's "Government in the Sunshine" and Public Records laws.

INTERDEPARTMENTAL POSTDOCTORAL FELLOWSHIP IN GEOSCIENCES YALE UNIVERSITY

The Dept. of Geology and Geophysics at Yale University (www.geology.yale.edu) seeks applicants for a post-doctoral fellowship in research that links geosciences (studies of the solid earth, oceans, atmosphere, climate, and the evolution of life) with other sciences, including, but not limited to, astronomy and astrophysics; environmental studies; physics; chemistry; biology; engineering; anthropology; medical science and public health; economics and political science.

This Postdoctoral Associate position is awarded for two years, contingent on satisfactory progress, and provides a stipend (\$50,000/yr) and base research funds (\$5,000/yr), plus health care benefits and limited expenses for relocation.

The Interdepartmental Postdoctoral Fellowship will have at least two faculty collaborators: the primary sponsor will be from Geology and Geophysics, while others are from one or more other Yale departments. Interested candidates should first contact a faculty member in Geology and Geophysics to define a research theme and to identify other appropriate faculty collaborators. Applicants should submit a curriculum vita, a list of publications, an interdisciplinary research proposal (2-3 pages, in which the Yale collaborators are identified), and a brief letter of endorsement from each of the Yale faculty collaborators. Applicants should also arrange for three reference letters to be submitted online. The deadline for receipt of all application materials is 14 Jan. 2011, and decisions will be announced by or shortly after 15 Mar. 2011. Successful candidates are expected to begin their program at Yale between July 1 and 31 Dec. 2011.

Yale values diversity among its students, staff, and faculty and especially encourages applications from women and underrepresented minority scholars. Applications and letters of reference should be sent online at <https://academicjobsonline.org/ajo/yale/G&G>.

HYDROGEOLOGY ASSISTANT PROFESSOR, SUNY CORTLAND

The Geology Dept. at the State University of New York College at Cortland has a tenure-track, assistant professor position available beginning Fall 2011. The department is seeking applicants who have teaching and research interests in the field of hydrogeology. Additional expertise in areas such as low temperature geochemistry, surface water hydrology, environmental geology, or biogeochemistry is welcome and should complement existing strengths in the department. The successful applicant will be expected to (1) teach courses in hydrogeology; oceanography; environmental, physical or historical geology; and/or other courses in his or her specialty as appropriate; (2) maintain an active research program that produces peer-reviewed results and involves undergraduates; (3) contribute to departmental commitments to environmental science, undergraduate and graduate programs in adolescence education - Earth science, and/or field-based courses and programs; (4) advise and mentor undergraduates; and (5) serve on department and college committees. Ph.D. in hydrogeology, geology or related field at time of appointment required. Preference will be given to applicants who have a demonstrated teaching ability and a strong commitment to research at the undergraduate level. Apply online at <https://jobs.cortland.edu/applicants/Central?quickFind=52321>. Review of application materials will begin 1 Dec. 2010, and will continue until the position is filled. SUNY Cortland is an AA/EEO/ADA employer. We have a strong commitment to the affirmation of diversity and have interdisciplinary degree programs in the areas of multicultural studies.

FACULTY POSITION IN 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 or after 1 Jan. 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, tectonic-climate interactions, 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 website: <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 1 Dec. 2010, 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.

SEDIMENTOLOGY/STRATIGRAPHY WESTERN CAROLINA UNIVERSITY

The Geosciences Program at Western Carolina University (WCU) invites applications for a tenure-track position at the Assistant Professor level to begin August 2011. We seek a geologist with expertise in sedimentology or stratigraphy with significant field experience. The applicant should have a strong commitment to excellence in teaching and research at the undergraduate level. The successful candidate is expected to contribute to the department's vibrant undergraduate research program, develop a research program that includes some focus on the Southern Appalachians, and seek external funding to help support our mission. Teaching duties will include a course in sedimentology and stratigraphy, courses in their area of specialty, and introductory courses including those in the university's liberal studies program.

WCU is part of the University of North Carolina system and is located in Cullowhee in the heart of the Blue Ridge Mountains. WCU is committed to the Boyer model of scholarship, stewardship of place, integrated learning, and engagement. A Ph.D. in Geology or related field, from an accredited institution, is required for the position. In exceptional cases, candidates with an ABD will be considered. For complete information and to apply, go to <https://jobs.wcu.edu> (position 162). For more information or questions, go to gnr.wcu.edu or contact Dr. Jerry Miller, jmiller@wcu.edu, +1-828-227-7367. Review of applications will begin 22 Nov. 2010 and continue until the search is complete. WCU is an AA/EEO employer and conducts background checks. Official transcripts and proper documentation of identity and employability are required at the time of employment.

PETROLOGY UNIVERSITY OF WISCONSIN-OSHKOSH

The University of Wisconsin-Oshkosh Dept. of Geology seeks hard rock, field-oriented geologist for full-time, tenure-track assistant or associate professor position starting 1 Sept. 2011. Specialty area should complement existing faculty expertise. Ph.D. required; prior college/university teaching experience preferred. Successful candidate is expected to develop a vigorous research program, which includes publishing peer-reviewed papers. Teaching responsibilities include introductory courses, lithology, economic geology, geochemistry, field trips, and advising majors. Submit letter of application, concise statement of teaching and research interests and experience, curriculum vitae, and undergraduate and graduate transcripts (original or photocopy) by 31 Dec. 2010 to Dr. William Mode, Chair, Dept. of Geology, University of Wisconsin-Oshkosh, Oshkosh, WI 54901. Have three current letters of reference sent directly to department by that date. For additional information see www.uwosh.edu/departments/geology/. Employment requires criminal background check. AA/EEO.

PALEONTOLOGY/STRATIGRAPHY UNIVERSITY OF WISCONSIN-OSHKOSH

The University of Wisconsin-Oshkosh Dept. of Geology seeks a field-oriented geologist for a full-time, tenure-track assistant professor position starting 1 Sept. 2011. Specialty area should complement existing faculty expertise. Ph.D. required; prior college/university teaching experience preferred. Successful candidate is expected to develop a vigorous research program,

which includes publishing peer-reviewed papers. Teaching responsibilities include historical geology, paleontology, stratigraphy, field trips and advising majors. Submit letter of application, concise statement of teaching and research interests and experience, curriculum vitae, and undergraduate and graduate transcripts (original or photocopy) by 31 Dec. 2010 to Dr. William Mode, Chair, Dept. of Geology, University of Wisconsin–Oshkosh, Oshkosh, WI 54901. Have three current letters of reference sent directly to department by that date. For additional information see www.uwosh.edu/departments/geology/. Employment requires criminal background check. AA/EOE.

**TENURE TRACK POSITIONS
INDIANA UNIVERSITY-PURDUE UNIVERSITY
AT INDIANAPOLIS (IUPUI)**

The Dept. of Earth Sciences (ES) at IUPUI invites applicants for two tenured/tenure track positions in geochemistry and hydrology—rank open. Candidates should have a Ph.D., strong research records, an interest in multidisciplinary research and commitment to undergraduate and graduate education. A Ph.D., received prior to August 2011 in geology, hydrology, limnology, geochemistry, or a closely related field, is required. ES is a growing and evolving department that embraces an Earth Systems approach to research and teaching as we adopt a new interdisciplinary Ph.D. degree program in Applied Earth Sciences. This new program is built on the research strengths of two centers that reside in the department: the Center for Earth and Environmental Science, recognized for excellence in water resources research, and the Center for Urban Health with a focus on earth science-based solutions for improving human health. Efforts will be supported by a number of existing interdisciplinary efforts, state-of-the-art laboratories, instrumented field research stations and information technology resources.

Hydrology/Hydrogeology. We seek an individual with experience in either hydrology or hydrogeology as applied to natural systems and/or environmental geosciences, including water quality and human health. Field-based research and teaching programs are important to the program and preference will be given to individuals who can interface with interdisciplinary research teams, including collaboration with other ES faculty and those in chemistry, biology and public health.

Geochemistry. We will consider individuals with experience in the broad field of low temperature geochemistry, and who can effectively apply their techniques and expertise towards natural, (paleo-) environmental and/or societal issues. Disciplines might include, but are not limited to, aqueous geochemistry, hydrogeochemistry, biogeochemistry, water/mineral/microbe interactions and stable isotope geochemistry. Preference will be given to individuals who can interface with interdisciplinary research and teaching programs, including collaboration with faculty in hydrology, sedimentology, petrology, and remote sensing. Opportunities also exist for collaboration with faculty in other departments at IUPUI, Indiana University, and Purdue University.

Applicants should submit a letter of application, curriculum vitae, statement of research interests, statement of teaching interests and philosophy, and the names and contact information (including e-mail) of at least four references. Review of applications will begin 15 Dec. 2010 but the position will remain open until filled. Interested individuals are encouraged to submit their application electronically to departmental chair, Kevin Mandernack, at kevinman@iupui.edu, specifying either the Hydrology or Geochemistry Search Committee. Alternatively, mailed applications can be sent to: Dept. of Earth Sciences, Indiana University-Purdue University at Indianapolis, 723 West Michigan Street, SL118, Indianapolis, Indiana, 46202-5132. Questions regarding the hydrology/hydrogeology position should be directed to Lenore Tedesco (ltedesco@iupui.edu) and those for the geochemistry position to Andrew Barth (ibsz100@iupui.edu). Competitive start-up award and salary are available. Consideration will be given to mid-rank professionals in addition to entry-level candidates.

IUPUI is Indiana's urban research and academic health sciences campus, and the focal point of IU's Life Sciences Initiative. IUPUI is an equal opportunity, affirmative-action employer.

**LOW-TEMPERATURE GEOCHEMIST
SAM HOUSTON STATE UNIVERSITY**

The Geology Program of the Dept. of Geography and Geology at Sam Houston State University wishes to appoint at the Assistant Professor level a Low-Temperature Geochemist with research interests in the broad field of either Aqueous Geochemistry (surface or groundwater) or Petroleum Geochemistry. The candi-

date will already hold the Ph.D. and will be in process of developing a strong research program with the likelihood of external funding. Primary teaching responsibilities will include an upper level course in Geochemistry to be taught each year; an upper level course related to the candidate's research field to be taught alternate years; plus coverage of sections of an introductory level Geological/Environmental Hazards course designed to attract majors. It would be particularly advantageous if the candidate could offer a general survey course in Hydrology (surface and groundwater) that includes modeling.

At the present time, geology and geography form a combined department with separate degree programs. The geology curriculum is deliberately generalist but rigorous and we have success in placing our graduates in entry level positions in both environmental and petroleum-related fields, as well as in good graduate programs. It is probable that in the relatively near future geology will become an independent department and will begin the process of building a focused graduate program of its own. We seek a geologist who would enjoy full participation from the start of this building process. This includes making funds available to the successful candidate to design and equip a research lab that will support the candidate's research agenda.

The start date for this position will be August 2011. A letter of interest, vita, e-mail addresses of referees and a statement of research interests should be e-mailed or mailed to Dr. Chris Baldwin, baldwin@shsu.edu, Dept. of Geography and Geology, Sam Houston State University, Box 2148, Huntsville, TX 77341-2148.

In addition, candidates apply online at <https://shsu.peopleadmin.com/>.

Sam Houston State University is an Equal Employment Opportunity/Affirmative Action Plan Employer and Smoke/Drug-Free Workplace and a Member of The Texas State University System

**ASSISTANT PROFESSOR
GLOBAL CHANGE BIOGEOCHEMISTRY
WASHINGTON UNIVERSITY IN ST. LOUIS**

Washington University in St. Louis invites applications for a tenure-track assistant professor in the area of global change biogeochemistry. We seek outstanding candidates who apply biogeochemical tools to the study of global change. Areas of interest include but are not limited to: elemental cycling and associated climate feedbacks, microbial processes affecting the carbon cycle and carbon sequestration, organic geochemistry of marine, freshwater, and soil environments, and paleoclimatology and records of environmental change. The successful candidate will be responsible for teaching undergraduate and graduate courses in biogeochemistry and other topics in the area of her or his expertise. It is expected that the candidate will have an outstanding teaching record or otherwise show promise of excellence in teaching and mentoring students. This candidate must also develop and sustain a vigorous research effort in biogeochemistry, maintain a strong publication record, and be active in student advising and university service. We are seeking candidates who will strengthen our research programs in low-temperature geochemistry and paleoenvironmental reconstruction as well as foster collaboration with environmental scientists across the Washington University community.

Candidates must have a Ph.D. with a focus in biogeochemistry, or a related field, at the time of appointment, and should send a letter of application, curriculum vitae, statements of teaching and research interests, and names and contact information of at least four references to Jennifer R. Smith and Jeffrey G. Catalano, Search Committee Co-Chairs, Dept. of Earth and Planetary Sciences, Washington University, Campus Box 1169, 1 Brookings Drive, St. Louis, MO 63130, or via e-mail to GCBFacSearch@eps.wustl.edu. Women and minorities are encouraged to apply. Washington University is an equal opportunity/affirmative action employer. Employment eligibility verification required upon employment. Applications will be considered until the position is filled, but priority will be given to those received by 15 Dec. 2010.

**TENURE-TRACK FACULTY POSITION
HYDROGEOLOGY/HYDROLOGY
CALIFORNIA STATE POLYTECHNIC
UNIVERSITY, POMONA**

The Geological Sciences Dept. invites applications for an Assistant Professor level tenure-track appointment beginning September 2011. Applicants must hold a doctorate in hydrogeology or a related field by August 2011. The ideal candidate will have research and teaching interests that emphasize practical applications of field, laboratory and/or computational skills in one or more of the following areas: groundwater exploration and aquifer characterization; quantitative analysis of

surface and groundwater flow in porous and/or fractured media; hydro-geochemical studies related to contaminant transport, groundwater remediation and/or water quality modeling; anthropogenic and climate impacts on surface and groundwater resources. We seek an enthusiastic teacher who will contribute to instruction of existing water-related courses: Groundwater Geology, Watershed Restoration, GIS Applications in Geology, Field Modules, Meteorology, Oceanography and Studies of a Blue Planet. He/she is expected to develop new undergraduate and graduate courses that emphasize practical applications and draw connections between hydrogeology and environmental, geotechnical and energy industries. The successful candidate will engage undergraduate and Master's degree students in research, assist the Geology Dept. with implementation of its new Masters program and participate in ongoing interdisciplinary collaborations with programs in Civil Engineering, Regenerative Studies, Environmental Design and Geography. Additional desirable assets include established ties to industry or government agencies and demonstrated experience with field studies and data collection using modern instrumentation. Applicants must submit a signed application form (available at <http://geology.csupomona.edu/employment.htm>), letter of interest, CV, statement of teaching and research interests, and contact information for five professional references. A campus interview, three formal reference letters and official confirmation of degree transcripts are required of all finalists. Initial screening begins 17 Jan. 2011. Mail application materials to Hydrogeology Search Chair, Geological Sciences Dept., California State Polytechnic University, Pomona, CA 91768. The University is an Equal Employment, Affirmative Action employer. Full Position Description: <http://geology.csupomona.edu/employment.htm>.

**TWO TENURE TRACK POSITIONS
CLIMATE MODELING
ENVIRONMENTAL/MEDICAL MINERALOGY
TEMPLE UNIVERSITY**

The Dept. of Earth and Environmental Science at Temple University invites applications at all academic ranks for two tenure track positions to begin in August 2011. We seek applicants with research interests in models and observations of present and past climates or environmental/medical mineralogy. The successful candidates will have a Ph.D. degree, established records of accomplishment in their disciplines, a strong commitment to teaching and student advising, and a keen interest in collaboration with other faculty at Temple University to build a new Geoscience Ph.D. program. The candidate is expected to complement existing specialties in our department, including low-temperature aqueous geochemistry, hydrology, environmental geophysics, structural geology, mineralogy, coastal geomorphology, soils, sedimentology/stratigraphy, and paleoclimatology. In addition to research, the candidates are expected to teach graduate and upper level undergraduate courses in their specialties as well as introductory-level geology classes. Advanced computational facilities available for study of global and/or regional climate change include the National Center for Supercomputing Applications (NCSA) and Temple Institute for Computational Molecular Science (IMCS). The deadline for applications is 3 Jan. 2011. Applications should include a CV, statement of teaching and research goals, names and addresses of at least three references, and copies of selected reprints. To apply for these positions, go to <http://ees.cst.temple.edu/search> or send materials to **Chair, Search Committee, Dept. of Earth and Environmental Science, Room 326 Beury Hall, Temple University, Philadelphia, PA 19122**. Inquiries should be directed to geology@temple.edu. Temple University is an equal opportunity, equal access, affirmative action employer committed to achieving a diverse community. The department specifically invites and encourages applications from women and minorities. Preliminary interviews at the 2010 Annual GSA Denver, with additional interviews at the AGU meeting in San Francisco.

**EARTH AND ENVIRONMENTAL SCIENCE
PROFESSORSHIP
UNIVERSITY OF PENNSYLVANIA**

The Dept. of Earth and Environmental Science at the University of Pennsylvania invites applications for a tenured professorship in earth and environmental science that is expected to be filled at the Associate or Full Professor level. The research and teaching interests of the successful candidate must broaden and complement the department's current activities in the areas of earth history and surficial processes. The successful candidate is expected to have developed an internationally

recognized, externally funded, multi-disciplinary research program and will be required to actively participate in undergraduate and graduate teaching and in the administration of the department. Individuals who can further increase interactions with other University science departments are strongly encouraged to apply. Further information about the department may be sought at www.sas.upenn.edu/earth/. Applicants apply online at facultysearches.provost.upenn.edu/applicants/Central?quickFind=50821 with a cover letter, CV, statements of research and teaching interests and 5 publications. The Search Committee will begin to evaluate applications on 10 Nov. 2010. The search will remain open until the position is filled. The University of Pennsylvania is an affirmative action/equal opportunity employer. Women and minority candidates are strongly encouraged to apply.

**FACULTY POSITION
STABLE ISOTOPE GEOCHEMISTRY
UNIVERSITY OF TENNESSEE**

The Dept. of Earth and Planetary Sciences (<http://web.eps.utk.edu>) invites applications for a tenure-track faculty position in Isotope Geochemistry starting Fall 2011. The position will be filled at the Assistant Professor level. Successful candidates are expected to develop a strong, externally funded and well-published research program; to maintain and improve current isotope facilities; to actively participate in teaching as well as graduate and undergraduate student supervision. The position is open to highly motivated candidates with a Ph.D. or equivalent degree in Earth Sciences, Geology, Geochemistry, or a related discipline, at the time of appointment. Post-doctoral experience and/or experience in managing laboratory facilities is highly desirable, although not required. We seek an individual interested in using isotopes to explore a variety of geologic and/or environmental systems. Potential areas of expertise include (but are not limited to) global biogeochemical cycling, clumped isotope analysis, water-rock interactions, environmental science, or paleoclimate analysis.

The successful candidate is expected to teach across the university curriculum, including introductory courses, courses for the undergraduate major, and graduate courses in his/her specialty. In developing a research program, we encourage the successful candidate to take advantage of existing departmental strengths, as well as the department's strong ties with Oak Ridge National Laboratory, the Center for Environmental Biotechnology, and several other University wide research initiatives.

The University of Tennessee-Knoxville is the state's flagship research institution, located in East Tennessee close to Oak Ridge National Laboratory and the Great Smoky Mountains National Park. The Dept. of Earth and Planetary Sciences comprises an energetic group of tenure-track, research, and teaching faculty; post-doctoral researchers; and more than 100 graduate and undergraduate students. Current isotope geochemistry facilities are managed by a research faculty member and include: preparatory laboratories; a Finnigan MAT Delta Plus IRMS with integrated peripheral devices for analysis of C-N-O-S gasses, H-O isotopes in water, and C-O isotopes in carbonate; and a Finnigan MAT Delta Plus GC-IRMS integrated peripheral devices for H-O isotope analysis, C-N characterization, and compound specific C and D/H analysis. Associated facilities include equipment for TIC-TOC analysis, Ion chromatography, UV/Vis spectrophotometry, and a site license for Geochemist's Workbench. ICP-AES facilities are available in UT's Dept. of Chemistry.

Applicants should e-mail their résumé, description of research and teaching interests, and contact information for three references in PDF format to Dr. Linda Kah, Search Committee Chair, Dept. of Earth & Planetary Sciences, University of Tennessee, Knoxville, TN 37996-1410; phone +1865-974-6399; fax +1-865-974-2368; e-mail: lckah@utk.edu. Supplementary materials, such as copies of refereed publications, can be e-mailed or mailed to Dr. Kah. Review of applications will begin on 15 Dec. 2010 and will continue until the position is filled.

The University of Tennessee is an EEO/AA/Title VI/Title IX/Section 504/ADA/ADEA institution in the provision of its education and employment programs and services. All qualified applicants will receive equal consideration for employment without regard to race, color, national origin, religion, sex, pregnancy, marital status, sexual orientation, gender identity, age, physical or mental disability, or covered veteran status.

ASSISTANT PROFESSOR, UINTAH BASIN

The Dept. of Geology at Utah State University Regional and Distance Education Campus is accepting applications for a nine-month, tenure track position located at the USU Uintah Basin Regional Campus in Vernal, Utah.

Responsibilities include teaching (graduate & undergraduate courses), research, and service duties. Ph.D. in geology or a closely associated field is required. See <http://jobs.usu.edu> (req. ID 052291) for more information and to apply online.

**FACULTY POSITION
HYDROGEOLOGY
UNIVERSITY OF WISCONSIN-MADISON**

The Dept. of Geoscience invites applications for a tenure-track assistant professor, beginning August 2011. We seek a broad range of outstanding candidates in hydrogeology with specialties related to physical, chemical and biological processes affecting subsurface flow and transport in porous and fractured geologic media. Research approaches should encompass some combination of field, laboratory, and modeling. Specific areas of interest include (but are not limited to) evaluation, development and sustainable management of water resources; transport, fate and remediation of contaminants; interactions between groundwater and surface water, seawater, snow or ice; groundwater and geologic processes; groundwater and energy resources; groundwater and climate change; and paleohydrogeology.

The evaluation of candidates will focus primarily on their potential for innovative scientific research and teaching. The successful candidate will be expected to mentor and advise graduate students, and maintain an externally funded, internationally visible research program. Potential collaborative interactions exist within the department (see <http://geoscience.wisc.edu/geoscience/>), with other departments and programs on campus (Geological Eng., Civil and Environmental Eng., Geography, Soil Science, Water Resources Management, Environment and Resources, Environmental Chemistry and Technology, Limnology and Marine Science, Center for Climatic Research, Center for Sustainability and the Global Environment, UW Energy Institute), with the Wisconsin Geological and Natural History Survey, and with state and federal agency researchers in the Madison area (USGS, WI Dept. of Natural Resources, USDA). Teaching responsibilities may include introductory geoscience courses for undergraduates as well as upper level undergraduate and graduate level courses related to the candidate's specialty. A Ph.D. in geoscience, hydrologic science or a related field is required by the start of the appointment. Applicants should submit a vita, statements of research and teaching interests, and names and contact information of three or more references by email to hydrosearch@geology.wisc.edu, or by mail to Jean M. Bahr, Hydrogeology Search Committee Chair, Dept. of Geoscience, University of Wisconsin-Madison, 1215 W. Dayton St., Madison WI 53706; +1-608-262-5513.

To ensure full consideration, applications must be received by 15 Nov. 2010. Unless confidentiality is requested in writing, information regarding applicants and nominees must be released upon request. Finalists cannot be guaranteed confidentiality. A criminal background check may be required prior to employment. The University of Wisconsin-Madison is an equal-opportunity/affirmative action employer and encourages applications from women and minorities.

**ASSISTANT PROFESSOR OF GEOSCIENCES
VERTEBRATE PALEONTOLOGY
UNIVERSITY OF NEBRASKA-LINCOLN**

Applications are invited for a tenure track position as Assistant Professor with specialization in vertebrate paleontology in the Dept. of Earth and Atmospheric Sciences at the University of Nebraska-Lincoln. The main duties of the successful candidate will be to develop an active and rigorous research program that is supported by external funding and to teach undergraduate and graduate courses. In addition, the candidate will co-supervise curation of the internationally significant mammal collections within the Vertebrate Paleontology Division of the University of Nebraska State Museum. We seek applicants with research and teaching interests that complement departmental strengths in the related fields of paleontology, sedimentary geology, and paleoclimatology. The candidate should demonstrate strong potential for research and teaching and must hold a Ph.D. in a related field at the time of appointment. Female and ethnic minority candidates are strongly encouraged to apply.

The Sedimentary Geology and Paleontology program is one of the three primary components of the Dept. of Earth and Atmospheric Sciences. The department offers B.S. degrees in Geology and Meteorology/Climatology, as well as M.S. and Ph.D. degrees in Earth & Atmospheric Sciences. Find out more about our department at <http://eas.unl.edu/>.

To apply, go to <http://employment.unl.edu> requisition 100583 and complete the "faculty/administrative form."

Applicants must attach a cover letter, curriculum vitae, statement of research, teaching, and curatorial interests, and names of at least three references via the above website. We will begin to review applications on 15 Nov. 2010, but the position will remain open for applications until it is filled.

The University of Nebraska has an active National Science Foundation ADVANCE gender equity program and is committed to a pluralistic campus community through equal opportunity, work-life balance, and dual careers. More information is available at www.unl.edu/svcaa/faculty/policies/work_life_balance.shtml. Lincoln is a highly livable city with affordable housing and excellent schools (www.unl.edu/ucomm/lincoln/). For further information contact, Dr. Tracy Frank, Search Committee Chair by email, phone, or mail: trfrank2@unl.edu; +1-402-472-9799; Dept. of Earth and Atmospheric Sciences, University of Nebraska-Lincoln, 214 Bessey Hall, Lincoln, NE 68588-0340.

**DEPT. OF EARTH AND ENVIRONMENTAL
SCIENCES, TENURE-TRACK POSITION
ENVIRONMENTAL GEOCHEMISTRY
VANDERBILT UNIVERSITY**

The Dept. of Earth and Environmental Sciences at Vanderbilt University invites applications for a tenure-track faculty position in the general area of Environmental Geochemistry. This position, effective the Fall 2011 semester, is at the Assistant Professor level.

We seek an individual who is aimed at the highest standards of scholarship in both research and teaching at the undergraduate and graduate (M.S., Ph.D.) levels, and who will be attracted by opportunities at Vanderbilt to interact with a diverse, enthusiastic faculty and student body in the Earth and environmental sciences and related fields. The specific research topic is open and may include such topics as ecological and critical zone processes, chemical fate and transport, climate and climate change, and biogeochemical cycling. We welcome applications from candidates applying a variety of analytical, experimental, and/or field-based approaches, and we are especially aimed at individuals with interest in both modern and ancient systems.

Applications should include a vita, a statement of research and teaching interests specific to our program, and names of at least three references (including mail and e-mail addresses and phone numbers). Select applicants will later be asked to provide student evaluations of teaching, if available. Applications should be submitted by e-mail in PDF, MS-Word or Corel-WP format to: EEsposition@vanderbilt.edu. Up to three representative papers may be sent via normal mail to: Search Committee Chair, Dept. of Earth and Environmental Sciences, Vanderbilt University, VU Station B Box 351805, 2301 Vanderbilt Place, Nashville, TN 37235-1805. Review of applications will begin 15 December 2010. Vanderbilt is an equal opportunity/affirmative action employer. Women and minorities are especially encouraged to apply.

**TENURE-TRACK POSITION IN HYDROGEOLOGY
UNIVERSITY OF IOWA**

The Dept. of Geoscience at the University of Iowa (www.uiowa.edu/~geology) invites applications for a tenure-track Assistant Professor with a specialty in hydrogeology. The position is part of a significant university-wide initiative that seeks to build interdisciplinary expertise in water sustainability. We seek an outstanding researcher and teacher with interests in groundwater, and who complements strengths in the department and other campus organizations, such as IIHR-Hydroscience and Engineering (www.iihr.uiowa.edu) and the Center for Global and Regional Environmental Research (www.cgrer.uiowa.edu). Research involving field and laboratory studies of groundwater hydrology and water pollution will be considered a desirable quality. He/she is expected to develop an active, externally-funded program of research and to develop ties with other faculty in our department and across campus working in the environmental and hydrologic sciences and sustainability. In addition to attracting and mentoring graduate students, the successful applicant will be expected to teach at the graduate and undergraduate levels.

The appointment will begin August 2011. A Ph.D. in geoscience or a related field is required by the time of appointment. Candidates must submit applications online at <http://jobs.uiowa.edu/> (requisition #58210). Attachments to the application should include a letter of application and curriculum vitae. The letter of application should include: a statement of teaching interests, evidence of teaching ability, and a statement that describes current and future research activities. Three letters of recommendation should be mailed to Dr. Art Bettis, Search Committee Chair, Dept. of Geoscience, University of Iowa, Iowa City, IA 52242; +1-319-335-1831; art-bettis@uiowa.edu.

Screening of applications begins 30 Nov. 2010 and will continue until the position is filled. Questions regarding this position can be directed to Dr. Bettis or Dr. Mark Reagan (Geoscience Dept. Chair; +1-319-335-1820; mark-reagan@uiowa.edu). The department and the College of Liberal Arts and Sciences are strongly committed to gender and ethnic diversity; the strategic plans of the University and College reflect this commitment. The University of Iowa is an equal opportunity/affirmative action institution. Women and minorities are encouraged to apply.

ASSISTANT/ASSOCIATE PROFESSOR SEISMIC EXPLORATION, UNIVERSITY OF UTAH

The Dept. of Geology and Geophysics at the University of Utah seeks applicants for a tenure track position at the Associate or Assistant Professor level in Seismic Exploration.

Priority will be given to candidates whose research has a focus on seismic imaging including but not limited to processing and interpretation of seismic array data, reflection seismology, inversion, and integrated interpretation with other geophysical data. Preference will be given to a candidate with a strong background in quantitative sciences and with experience in solving practical geological/geophysical problems. The successful candidate should have a proven ability or potential to attract external funds and to build a vibrant research program involving graduate students and post docs. Applicants must hold a Ph.D. in geophysics, or a closely related discipline.

Applicants should e-mail an application letter describing research, teaching, and career interests, a curriculum vitae, and the names and contact information for three referees, all in PDF format to: searchcommittee-seism-expl@lists.utah.edu. Review of applicants will begin 1 Jan. 2011 and continue until the position is filled.

The University of Utah is fully committed to affirmative action and to its policies of nondiscrimination and equal opportunity in all programs, activities, and employment. Employment decisions are made without regard to race, color, national origin, sex, age, status as a person with a disability, religion, sexual orientation, gender identity or expression, and status as a protected veteran. The University seeks to provide equal access for people with disabilities. Reasonable prior notice is needed to arrange accommodations. Evidence of practices not consistent with these policies should be reported to: Director, Office of Equal Opportunity and Affirmative Action, +1-801-581-8365 (V/TDD).

The University of Utah values candidates who have experience working in settings with students from diverse backgrounds, and possess a [strong or demonstrated] commitment to improving access to higher education for historically underrepresented students.

TENURE-TRACK FACULTY POSITION(S) SEDIMENTOLOGY/STRATIGRAPHY, VIRGINIA TECH

The Dept. of Geosciences at Virginia Tech invites applicants for a tenure-track faculty position in sedimentology/stratigraphy starting in the Fall of 2011. Particular subareas of interest include, but are not limited to, physical sedimentology, sedimentary basin analysis with emphasis on marine seismic stratigraphy, high-resolution sequence stratigraphy, sedimentary (bio) geochemistry, chemostratigraphy, and Earth systems history. The position is at the assistant professor level, but outstanding senior candidates will also be considered. The successful candidate is expected to develop an internationally recognized, externally funded, multidisciplinary research program; and to actively participate in the undergraduate and graduate teaching mission of the university. This position is one of several hires in the departments of Geosciences and Biological Sciences to support the Virginia Tech College of Science research clusters in Integrated Studies of Earth Systems and Energy/Environment. To receive full consideration, the applicant must have a Ph.D. degree in Geosciences or a related discipline at the time of appointment and a demonstrated capability/promise to develop an active research program. Preference will be given to candidates whose research areas complement existing strengths in the department.

Consideration of applications will begin as early as 8 Nov. 2010 and will continue until the positions are filled. Salary will be commensurate with rank and experience. Please visit www.hr.vt.edu/employment/ (posting # 0100596) to apply on-line for this position. Applicants should provide a cover letter, resume, research statement, teaching statement, and a list of at least four referees who are familiar with their work. For further information, visit the Dept. of Geosciences website at

www.geos.vt.edu or contact Search Committee chair Dr. Shuhai Xiao by e-mail (xiao@vt.edu). Virginia Tech is an Equal Opportunity/Affirmative Action Institution and the recipient of a National Science Foundation ADVANCE Institutional Transformation Award to increase the participation of women in academic science and engineering careers.

TENURE-TRACK FACULTY POSITION PETROLOGIC PROCESSES, VIRGINIA TECH

The Dept. of Geosciences at Virginia Tech is seeking to fill a tenure-track faculty position to start in the Fall of 2011 in Petrologic Processes. This position is part of the Integrated Studies of Earth Systems cluster hiring initiative of the College of Science. Potential focus areas include magmatism, metamorphism, evolution of the crust and upper mantle, high temperature geochemistry, isotope geochemistry, and geochronology, with an emphasis on plate tectonics and how the material properties of rocks, minerals, and geofluids influence dynamics of the whole Earth system.

The position will likely be at the Assistant Professor level, but outstanding senior candidates are encouraged to inquire and apply. Rank will be determined by the qualifications of the successful applicant and salary will be commensurate with rank and experience. To receive full consideration, applicants must have a Ph.D. in Geosciences or related discipline at the time of appointment and a proven record of successful research. The successful candidate will be responsible for developing and maintaining a vigorous, internationally recognized, externally funded research program that emphasizes multi-disciplinary collaborations, as well as active participation in the undergraduate and graduate teaching mission of the university. Preference will be given to candidates whose research areas complement existing strengths in the department.

Review of applications will begin as early as 8 Nov. 2010 and will continue until the position is filled. Please visit www.hr.vt.edu/employment/ (posting # 0100587) to apply on-line for this position. Applicants should provide a cover letter, CV, research and teaching statements, and a list of at least four references who are familiar with their work. For further information, visit the Dept. of Geosciences website (www.geos.vt.edu) or contact search committee chair Dr. James Spotila by e-mail (spotila@vt.edu).

Virginia Tech is an Equal Opportunity/Affirmative Action Institution and recipient of a National Science Foundation ADVANCE Institutional Transformation Award to increase the participation of women in academic science and engineering careers.

ASSISTANT PROFESSOR TENURE-TRACK POSITION, BOWDOIN COLLEGE

Bowdoin College Dept. of Earth and Oceanographic Science invites applications for a tenure-track position. Assistant professor rank. Ph.D. required (advanced ABDs considered). We seek candidates whose research is within the solid-earth field including such specializations as volcanology, structural geology, tectonics or mineralogy.

Bowdoin College accepts only electronic submissions. Please visit <https://careers.bowdoin.edu> to apply. Application review date: **10 December 2010**.

Bowdoin College is committed to equality through Affirmative Action, and is an equal opportunity employer. For a full position description and further information about Bowdoin, please visit <https://www.bowdoin.edu>.

FACULTY OPENING, ECONOMIC GEOLOGY AND GEOTHERMAL SYSTEMS, RESEARCH ASSISTANT PROFESSOR, UNIVERSITY OF NEVADA-RENO

The Nevada Bureau of Mines and Geology (NBMG), University of Nevada-Reno (UNR), seeks applicants for a tenure-track, Research Assistant Professor faculty position beginning on or after 1 July 2011, with interests in research on both mineral deposits and geothermal systems. Doctoral research must include one or more of the following disciplines: economic geology, structural geology, igneous petrology, geochemistry, exploration geophysics, and hydrogeology. Nevada is one of the most exciting regions in the world to do research in the geosciences and the best in the U.S. for the study of metallic mineral deposits and geothermal energy. For a complete position description and requirements, view the position announcement at www.nbm.unr.edu and <http://jobs.unr.edu/> or contact Geoscience Search, NBMG, Mail Stop 0178, UNR, Reno, NV 89557-0178. Applications received through <http://jobs.unr.edu/> by 23 Dec. 2010 will receive full consideration. EEO/AA. Women and underrepresented groups are encouraged to apply.

Opportunities for Students

Graduate Assistantship, New Mexico Highlands University. Graduate assistantships are available for students wishing to pursue an MS in Geology beginning Fall 2011 term. The NMHU Environmental Geology Program offers a field-intensive curriculum emphasizing the geologic history of Northern New Mexico and the processes responsible for natural resources development and landscape evolution. Program strengths are in mineralogy, petrology, geochemistry, rock-paleomagnetism, structural geology, volcanology, and collaborative endeavors with the Forestry and the New Mexico Forest and Watershed Restoration Institute. The new NSF-Funded Paleomagnetism-Rock Magnetism, Powder X-Ray Diffraction, and Water Chemistry laboratories support wide-ranging analytical research. The NMHU campus in Las Vegas, NM, is situated at the boundary of the Great Plains and the Sangre de Cristo Mountains and is located within a one to two hours driving distance from Cenozoic volcanic fields, Precambrian rock exposures, glaciated valleys, desert terrains, and several world-renowned geologic features - the Valles Caldera, the Rio Grande Rift, and the Harding Pegmatite. A low student:faculty ratio, state-of-the-art laboratory facilities, and committed faculty provide students with a superior learning experience. The graduate assistantship includes a nine-month stipend and tuition waiver per academic year. Application review begins 01/15/10. For more information, contact Dr. Michael Petronis, Environmental Geology, Natural Resource Management Dept., New Mexico Highlands University, Box 9000, Las Vegas, New Mexico 87701, mmpetro@nmhu.edu. For disabled access or services call +1-505-454-3513 or TDD# +1-505-454-3003. AA/EEO Employer.

NSF IGERT Fellowship in watershed resilience and governance, Dept. of Earth and Atmospheric Sciences, University of Nebraska-Lincoln. We invite applications for the Integrative Graduate Education and Research Traineeship (IGERT) program. The NSF grant was awarded to the UNL in 2009. Nebraska occupies the top place in groundwater use for irrigation nationally, ahead of California and Texas. With intricate surface water-groundwater interactions, the governance of watersheds requires controls of new groundwater developments, adaptation of agricultural practices, and social change. We are seeking for subsurface or surface hydrologists that are interested in understanding feedbacks between water management and societal actions in Nebraska. The interdisciplinary program intends to meet challenge of educating U.S. Ph.D. scientists, engineers, and educators to become the leaders and creative agents for change.

Traineeship offers stipend \$30,000 annually for two to three years, paid tuition and fees, funds for travel and research, experience in Europe and externships in state-affiliated organizations. Must be U.S. citizen or permanent resident. Complete information can be found at <http://snr.unl.edu/igert> and from Vitaly Zlotnik, vzlotnik1@unl.edu, +1-402-472-2495, <http://eas.unl.edu/~vzlotnik/Index.htm>.

We have several openings for new graduate students to pursue NASA-related research in structural geology, rock mechanics and planetary tectonics at the University of Nevada, Reno. This work would lead to your M.S. or (preferably) Ph.D. degree in Geological Sciences or Geo-Engineering.

Beginning in July of 2011 (subject to admission to the university and acceptance into the Geomechanics-Rock Fracture Group), the successful applicants will use the principles and techniques of field structural geology and geologic fracture mechanics to examine the growth of normal faults in stratified sedimentary sequences, with Canyonlands National Park as the field area. Opportunities to explore deformation and compaction bands in porous sandstones also exist.

Applicants possessing a M.S. degree in geology, geophysics, rock mechanics, or planetary science are desired, although exceptional students having a B.S. degree in any of these fields without an advanced degree are also encouraged to apply. An appetite for field work and computer applications, including GIS, is required. Prior research experience is required.

For information on the Dept. of Geological Sciences and Engineering, contact Marie Russell at marierussell@unr.edu. For information on the University of Nevada, Reno, including graduate admissions, see our web site at www.unr.edu. For information on this research program, contact Dr. Richard A. Schultz, schultz@mines.unr.edu, www.mines.unr.edu/geo-eng/geomech.



A contribution to our dialogue on energy choices

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INTRODUCTION

The United States and much of the rest of the world must imminently achieve dramatic changes in energy production and consumption. This is driven primarily by the need to limit greenhouse gas production, principally CO₂ (U.S. Senate Committee on Environment and Public Works, 2009; Intergovernmental Panel on Climate Change [IPCC], 2007), and by constraints on oil supplies. A near-complete transition to new and renewable sources is clearly necessary; however, this may take several decades to achieve. We must also use our current energy sources wisely, with regard to both effective utilization and environmental constraints. Our decisions must be considered carefully, because they will be far reaching.

The largest source of U.S. energy is petroleum, 58% of which is imported. Natural gas and coal contribute approximately equal proportions (23.8% and 22.5%, respectively) but with largely different end uses (U.S. Energy Information Admin. [EIA], 2008). Proponents advocate increased use of natural gas for electricity, with the goal of supplanting a large portion of our current coal use. Because CO₂ emissions from natural gas are generally ~56% of those emitted by an energy-equivalent amount of coal (U.S. EIA, 1998), this would substantially limit greenhouse gases. However, increasing gas production on the required scale would create pronounced attendant environmental impacts. Natural gas is important as a clean fuel, but replacing coal might not be reasonably achievable or environmentally sound.

An incomplete understanding of coal's contribution to our energy supply (i.e., electricity, which is how most non-transportation energy is delivered) and the current level of gas development may lead to misconceptions concerning our use of these resources. Our electricity needs are expected to grow. Greenhouse gas-reducing innovations, such as plug-in hybrid vehicles and electric-powered mass transit, are likely to intensify this growth. It is difficult to visualize meeting these needs over the short-term without coal.

CURRENT UTILIZATION AND TRENDS

Natural gas currently makes up ~24% of our domestic energy supply (renewable energy included), and 30% of U.S. natural gas production is used to generate electricity, comprising ~17% of the total. Coal, on the other hand, provides 51% of our

electricity (U.S. EIA, 2008). It would be necessary to triple gas generation to replace current coal usage, excluding any concurrent increases in other gas uses. Renewable energy sources provide ~7% of our total domestic supply, with ~50% used for electricity. Dramatic increases in renewable energy would be needed in order to replace coal. Nuclear power may provide a potential solution, but this warrants a separate discussion on its own relative merits.

The United States has substantial gas resources. Domestic natural gas production in 2008 was 26 trillion cubic feet. Production has increased annually for decades, except for several brief periods following the mid-1970s (U.S. EIA, 2009a). Most remaining (on-shore) supplies are now believed to occur in nonconventional and emerging resources (e.g., coalbed methane, discontinuous stratigraphic traps, shale gas). Development typically requires more concentrated, closely spaced drilling than for past conventional resources.

There are presently ~450,000 gas wells onshore in the United States (U.S. EIA, 2009b; American Gas Association, 2007). In recent years, drilling has occurred at an unprecedented rate, just to meet current demand. Development scenarios can include hundreds or thousands of wells (U.S. Bureau of Land Management [BLM], 2008a, 2008b).

ILLUSTRATIVE COAL AND GAS DEVELOPMENT AREAS

A substantial portion of U.S. coal is produced from a series of mines in Wyoming's Powder River Basin, from the Antelope and North Antelope/Rochelle mine complex in the south to the Buckskin and Rawhide mines in the north (USGS, 2001; Wyoming State Geological Survey, 2002). In 2008, these mines produced ~446 million tons of coal (~34% of U.S. production, as of 2007), which was used almost entirely to generate electricity (BLM, 2009). Not all coal mining is equal, but the relatively subdued topography and generally arid conditions at this locality limit environmental damage. However, burned in conventional power plants, this coal would produce ~3600 lbs of CO₂ per ton, with an average Btu content of ~8500 Btu/lb and 212.7 lbs of CO₂ per million Btu (U.S. EIA, 1994).

Clearly, we can no longer sustain emissions of this scale if we are to achieve the needed reductions in greenhouse gases. Yet the coal mined in this region alone contributes substantially (~18.9%) to the U.S. electricity supply—slightly more, in fact, than the total contributed by natural gas.

Coalbed methane is widely produced from subsurface coal seams to the west of the Powder River Basin coal mining areas. The wells are shallow, requiring less surface disturbance and

more limited production facilities than necessary for “conventional” gas wells. By November 2008, ~27,000 wells had been drilled in the Wyoming portion of the basin, most of these since 2000 (Wyoming Oil and Gas Conservation Commission, 2010a). Complete development may require more than 50,000 wells, and recoverable reserve estimates are as high as 28 TCF, a volume approximately equal to one year’s U.S. gas supply (BLM, 2001). Similar, but less extensive, coalbed methane development is occurring elsewhere in Wyoming, Colorado, Utah, and other states. Data regarding coalbed methane in these regions are available from federal and state agencies (USGS, 2001, 2010; BLM, 2008; Wyoming Oil and Gas Conservation Commission, 2010b).

Concentrated development, by deep wells and using “conventional” surface facilities, is occurring in the prolific Jonah and Pinedale Anticline oil and gas fields in western Wyoming. As many as 9,000 additional wells are anticipated within the surrounding area over the next 10–20 years (BLM, 2008a, table 13 therein).

Colorado’s Piceance Basin, the Uintah Basin/Book Cliffs area of Utah, and other parts of Wyoming have also experienced accelerated oil and gas development. Thousands more wells are expected in these areas (BLM, 2007, 2008c). Similar natural gas resources exist at other localities throughout the western U.S. and on other parts of the country, where comparable levels of development are likely.

RECONSIDERING NATURAL GAS vs. COAL

Natural gas production should be balanced against impacts on other resources and land uses. Even if sufficient resources exist, it is not certain that accelerating production to triple its current rate, or more, is achievable within a short time. When environmental constraints and consequences and historically increasing consumption are considered, the goal of supplanting coal production becomes even more daunting.

Impacts associated with drilling can be managed, but the level of activity in recent years, driven by existing demand, is taxing our ability to mitigate them. Some resources (e.g., water, air quality, sensitive wildlife species) have been adversely affected or placed at risk. The U.S. Government Accountability Office (2005) has documented that federal offices responsible for managing resources on western U.S. public lands, where most future energy extraction is expected, were increasingly unable to cope with rising levels of development several years ago. Production at the projected levels is likely to overwhelm efforts to mitigate environmental effects, resulting in legal challenges, environmental degradation, and other unacceptable consequences.

If the true cost of using natural gas as a replacement for coal is considered, it might be wiser to limit coal’s emissions than to dismiss its use entirely. Several cooperative carbon-capture/sequestration research efforts are underway (National Energy Technology Laboratory, 2009). Given the urgency of the climate situation and the magnitude of coal’s contribution to our energy supply, accelerated research and development is warranted. Certainly, the coal and electric utility industries must step up as principal participants in sequestration research, development, and practice.

The geologic community can play a key role in the national dialogue regarding our energy supply. Pertinent data are readily available and accessible using the following references. Development areas can be examined easily using Google Earth.

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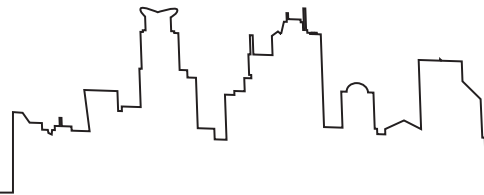
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