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## Open-source archive of active faults for northwest South America

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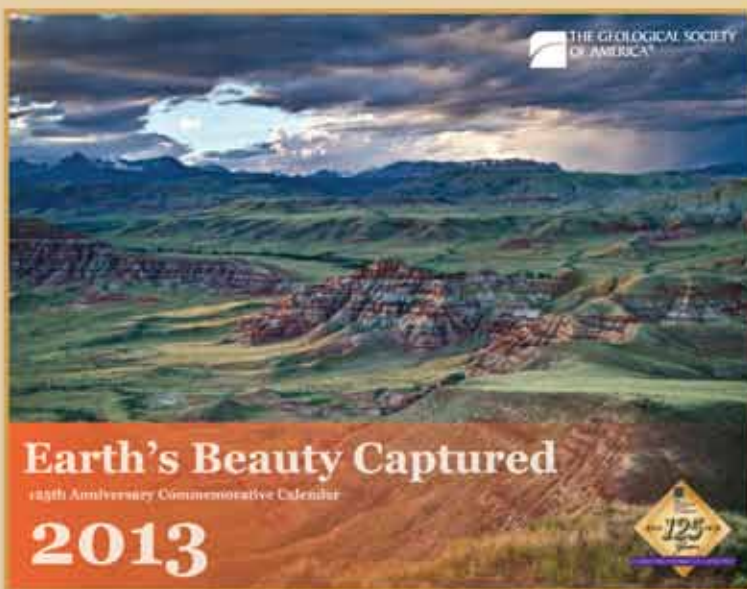
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#### 4 Open-source archive of active faults for northwest South America

Gabriel Veloza, Richard Styron, Michael Taylor, and Andrés Mora

**Cover:** Active faulting modifies the landscape, especially in the eastern foothills of the Colombian Andes. This photo looks E-SE at uplifted fluvial terraces and risers in the hanging wall of the active east-directed Yopal-Cusiana thrust system bounding the Llanos basin of Colombia. Studies document active faulting located in the interior of South America, far from the subduction boundary. Understanding the distribution and kinematics of active faulting is an important step in mitigating seismic hazards. Photo by Michael Taylor. See related article, p. 4–10.



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**Erratum:** In the July 2012 *GSA Today* (v. 22, no. 7, p. 16) the affiliation for newly elected GSA Fellow Fu-Yuan Wu was listed incorrectly as *Institute of Geology and Geophysics*. It should be the *Chinese Academy of Sciences*. GSA regrets this error.

# Open-source archive of active faults for northwest South America

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## ABSTRACT

We present a publicly available database of active structures for the northern Andes based on the literature, our own field mapping, interpretation of digital elevation models, earthquakes, and the regional velocity field obtained from Global Positioning System (GPS) studies. The “Active Tectonics of the Andes” database (ATA v.1.0) is a digital archive of more than 400 active faults available in a variety of digital formats for use by the scientific and teaching communities. ATA v.1.0 is an open-source archive that is updateable based on new results obtained by the scientific community, and it should prove useful to scientists, teachers, policy makers, and the general population. We use ATA v.1.0 in combination with surface velocities from GPS to evaluate the regional kinematics of faulting in northwest South America. In particular, we find that the development of active strike-slip systems is controlled, in part, by the degree of convergence obliquity between subducting oceanic plates and South America.

## INTRODUCTION

Active deformation of northwest South America is characterized by interaction between the Caribbean and Nazca plates with the South American margin, in sharp contrast to the classic Andean convergent margin south of 5°S. This change in plate configuration is reflected in the distribution and kinematics of active structures in the upper plate, where strain is distributed over hundreds of active structures capable of generating damaging earthquakes. In the south, Peru is dominated by thrust faulting along the forearc and sub-Andean zones, largely in response to subduction, whereas left-lateral strike-slip and normal faulting are characteristic of higher elevations and the retroarc region to the east (Dalmayrac and Molnar, 1981; Dewey and Lamb, 1992; McNulty et al., 1998) (Fig. 1). Ecuador’s recent deformation is similarly partitioned between well-developed thrust systems and the Guayaquil-Algeciras right-lateral fault system (Fig. 1). Colombia exhibits a more complex tectonic framework, with subduction of the Caribbean and Nazca slabs beneath northwest South America, and the arc collision of the Chocó–Panamá indenter (Farris et al., 2011). The northern margin of South America is also partitioned between south-directed thrusting along the southern Merida Andes, which contrasts with high rates of dextral shear across the central and northern portions of the range (Fig. 1),

accommodating transpression across the Caribbean–South American plate boundary (Pindell et al., 2005).

The Andes have dense population centers, concentrated mostly in elevated regions of the Venezuelan and Colombian Andes and along the Pacific coasts of Ecuador and Peru. A shared characteristic of these urban centers is their proximity to seismically active faults. For example, the cities of Bucaramanga and Santiago de Guayaquil lie adjacent to the Bucaramanga and Guayaquil-Algeciras faults, and major cities such as Lima are above an active subduction zone. Earthquake hazards are not limited to the well-described subduction zone settings—devastating earthquakes occur in continental settings where active structures are often smaller but shallower and close to population centers (e.g., England and Jackson, 2011); the 2008 and 2010 earthquakes in New Zealand and China, respectively (e.g., Robinson et al., 2011), provide recent examples. To achieve the goal of understanding the distribution and kinematics of active faults, digital archives of active structures are being compiled worldwide. Attention has been paid to the Andes (e.g., Paris et al., 2000; Costa et al., 2006), and similar databases have been made for other orogens (e.g., Styron et al., 2010) and the western United States (USGS, 2006). These databases are useful for understanding seismic hazard and the dynamic mechanisms driving deformation.

We present a publicly available database, “Active Tectonics of the Andes” (ATA v.1.0), comprising over 400 active faults from northeast Venezuela to southern Peru. These structures were mapped from our own field observations, interpretation of geologic maps, topography, remote sensing data, and earthquake seismicity from national databases of the geological surveys of Venezuela, Colombia, Ecuador, and Peru (FUNVISIS, INGEOMINAS, EPN, and IGP, respectively [see references]). Fault names and kinematics are compiled from academic journals and regional compilations. Faults were mapped at scales ranging from ~1:1,000,000 to 1:100,000, depending on the scale of the structure, the quality of remote sensing imagery, and accounting for uncertainties in fault kinematics. ATA v.1.0 is suitable for displaying with most GIS packages (e.g., ArcGIS), the Generic Mapping Tools (Wessel and Smith, 1998), and Google Earth. Where available, millennial and longer-term slip rates and references are included as metadata in .shp and .kml formats. User input is encouraged to contribute to or refine the database.

## TECTONIC SETTING

Slip partitioning in the northern Andes is highly dependent on the plate boundary configuration relative to the surface velocity field. Where convergence is orthogonal, we generally expect to observe pure shear deformation (in map view), whereas in regions

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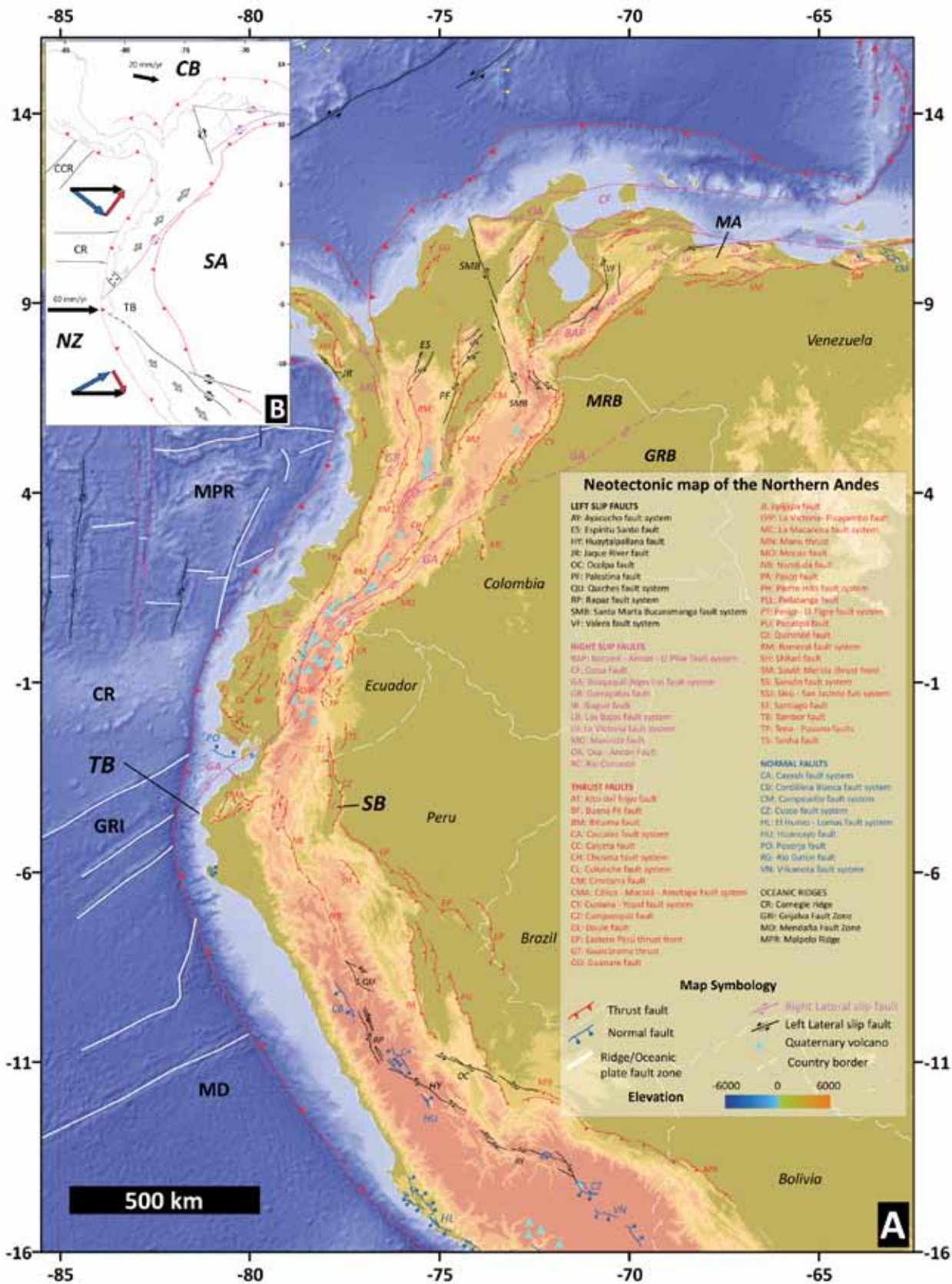


Figure 1. (A) Active faults of northwest South America. Thrust faults and normal faults have bars and balls on the hanging wall. Arrows indicate horizontal motion for strike slip faults. GRB—Guaviare River basin; MA—Mérída Andes; MRB—Meta River basin; SB—Santiago basin; TB—Talara bend. (B) Schematic model for slip partitioning of northwest South America. Eastward motion of Nazca Plate is partitioned into trench-parallel (red arrows) and trench-normal (blue arrows) components. Velocities for Nazca and Caribbean plates from Trenkamp et al. (2002). Trench-parallel components of the velocity field increase away from the Talara Bend, with the maximum velocity gradient located in that area. Note the position of the Carnegie Ridge relative to the Talara Bend, where strike-slip faults initiate. CB—Caribbean plate; CCR—Cocos Ridge; CR—Carnegie Ridge; NZ—Nazca plate; SA—South American plate; TB—Talara bend.

of oblique convergence, an element of simple shear deformation is expected. Orthogonal convergence between the Nazca and South American plates is restricted to the region near 5°S latitude, whereas the Caribbean plate is underthrusting obliquely below northern South America (Fig. 1). To the north and south, rapid increases in convergence obliquity lead to the development of significant trench-parallel strike-slip faults (Dewey and Lamb, 1992) (Fig. 1). Thrust faults bound the forearc and sub-Andean zones, though their shortening rates and histories are largely unknown. The northern tectonic domain is characterized by the presence of abundant volcanism and low magnitude earthquakes, whereas volcanism is virtually absent south of the Carnegie Ridge; seismic events are larger, but less frequent (Fig. DR1, GSA supplemental data repository<sup>1</sup>).

### Northern Andean Domain (~5°S–12°N)

North of the Talara bend, slip partitioning occurs along active thrust and dextral faults. The longest dextral fault in this area is the Guayaquil-Algeciras fault system (Fig. 1A), extending ~2000 km from central Ecuador to southern Colombia. The Guayaquil-Algeciras fault is segmented based on changes in fault strike, forming contractional structures along restraining bends. The southernmost segment is the Guayaquil-Pallatanga fault, which is dominantly right-slip, but close to the trench it is associated with normal faulting in the Gulf of Guayaquil. Estimated extension rates for the Gulf of Guayaquil range from 2.5 to 9 mm/yr (Lavenue, 2006), with a right-lateral component estimated to be  $3.8 \pm 0.9$  mm/yr over the past 1.4 Myr (Lavenue et al., 1995). The La Victoria–Pisayambo segment is thrust dominated and occurs along the central fault segment located in the Ecuadorian hinterland (Fig. 1). Here, the Guayaquil-Algeciras fault has a slip rate of  $1.4 \pm 0.3$  mm/yr (Lavenue et al., 1995). The northern strand of the Guayaquil-Algeciras fault system is defined by the Chingual–La Sofia right-slip fault, also known as the Cayambe-Afiladores–Sibundoy fault, with slip rates between  $7 \pm 3$  mm/yr over the past 37 kyr (Ego et al., 1996) and a Quaternary average of  $11.9 \pm 7$  mm/yr (Tibaldi et al., 2007). The fault system continues to the northeast, where east-directed range-bounding thrust faults occur along the easternmost Colombian Andes (Fig. 1). In Colombia, the Guayaquil-Algeciras fault system is described in detail by Velandia et al. (2005), where recently active structures include synthetic and antithetic Riedel faults, pull apart basins, and releasing bends. Based on the maximum age of Quaternary offset geomorphic features, the minimum slip rate for the Guayaquil-Algeciras fault system in Colombia is ~1.5 mm/yr (Chorowicz et al., 1996). Potentially, the fault system merges with the easternmost frontal thrust system of Colombia (i.e., the Cusiana–Yopal fault system), although a direct kinematic linkage is not documented (Costa et al., 2006; Velandia et al., 2005). However, the kinematic compatibility between the Guayaquil-Algeciras fault system and the Cusiana–Yopal fault system suggests the two are interacting. Furthermore, observations from seismic reflection profiles also suggest that active deformation is transferred into the active foreland basin (Mora et al., 2010).

Other first-order fault systems of the Colombian Andes include the northwest-striking Santa Marta–Bucaramanga fault system, which is a left-slip fault system, ~500 km in length (Fig. 1). Its southeastern tip is located near the central portion of the eastern Cordillera and sits above the Bucaramanga seismic nest. The Santa Marta–Bucaramanga fault system is thought to be the surface response to slab collision (Taboada et al., 2000). Here, it splays in map pattern into an imbricate fan and links with northeast-striking thrust faults (Fig. 1). To the northwest, the Santa Marta–Bucaramanga fault system terminates at the northwestern corner of the Sierra Nevada de Santa Marta. Slip rate estimates for this fault system range from 0.2 mm/yr, based on maximum ages of Quaternary offset features (Paris et al., 2000), to 5 and 15 mm/yr, based on paleoseismological studies close to its northern end (Diederix et al., 2009; Idárraga–García and Romero, 2010). This fault system has a  $6 \pm 2$  mm/yr interseismic rate based on elastic dislocation modeling of GPS data (Trenkamp et al., 2002).

In the region of the Maracaibo block, the Merida Andes do not represent a typical Andean-type convergent margin—there is no active volcanism or deep earthquake seismicity, and the location and extent of the subducting slab remains uncertain (Fig. 1A; Fig. DR1 [see footnote 1]) (van der Hilst and Mann, 1994; Bezada et al., 2010). Active slip appears to be partitioned mainly between east-striking right-slip faults across Venezuela and onto south-directed thrust systems associated with the South Merida thrust system. A significant structure of this kinematic domain is the right-slip Boconó–Ancon–El Pilar fault system, which is ~1,600 km in length. The Boconó–Ancon–El Pilar fault system is east-striking and transfers slip from the subduction zone associated with the eastern Caribbean plate boundary. This fault system continues west and curves to the south where it terminates in eastern Colombia, feeding slip into a southeast-directed imbricate thrust system (Fig. 1A). Slip rate estimates for different segments of the fault yield a Quaternary average of 10 mm/yr (Audemard et al., 2000). Shortening rates along the south-verging thrusts of the Merida Andes remain unknown, as are rates of normal faulting in eastern Venezuela. Northwest of the Boconó–Ancon–El Pilar fault system is the Oca–Ancon fault system, a right lateral fault extending more than 400 km from Venezuela to northern Colombia, where it bounds the northern margin of the Santa Marta massif, forming a v-shaped conjugate fault system with the Santa Marta–Bucaramanga fault (Trenkamp et al., 2002; Acosta et al., 2007; Costa et al., 2006). Based on paleoseismological analysis, the Oca–Ancon fault system has a slip rate of ~2 mm/yr (Audemard, 1996).

### Central Andean Domain (~5°S–15°S)

The convergent margin of the Peruvian Andes is characterized by oblique subduction of the Nazca plate (McNulty et al., 1998), as well as the subduction of the Carnegie Ridge, Mendaña Fault Zone, and Nazca Ridge at the northern, central, and southern segments, with an inferred flat-slab geometry for the Nazca plate (Gutscher et al., 2000). The absence of seismicity above the subducted Carnegie ridge and Mendaña Fault zone, combined

<sup>1</sup>GSA Data Repository item 2012274, Figure DR1, is online at [www.geosociety.org/pubs/ft2012.htm](http://www.geosociety.org/pubs/ft2012.htm). You can also request a copy from GSA Today, P.O. Box 9140, Boulder, CO 80301-9140, USA; [gsatoday@geosociety.org](mailto:gsatoday@geosociety.org).

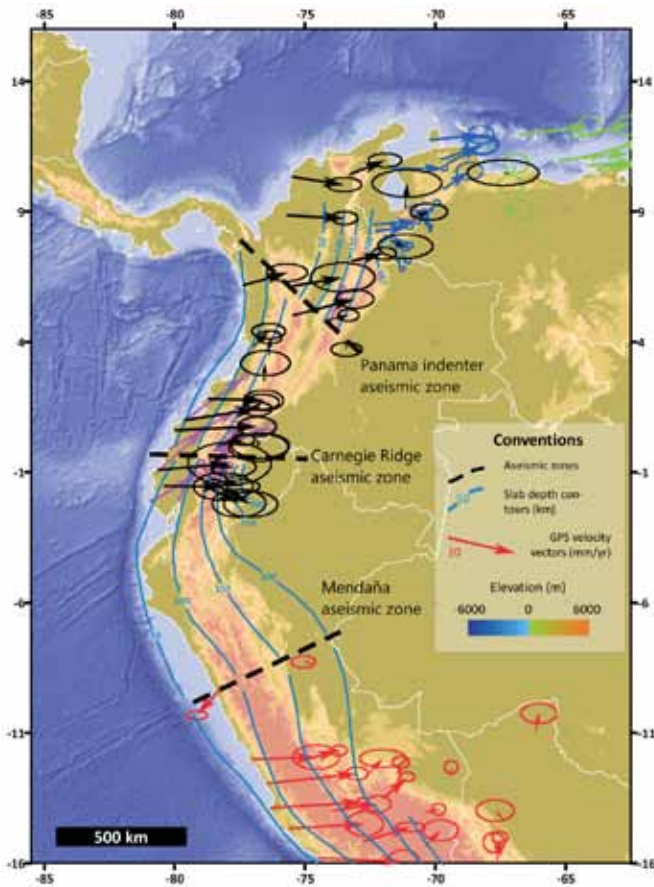


Figure 2. GPS velocity vectors for the northern Andes from Kendrick et al., 2001 (red); Pérez et al., 2001 (green); Trenkamp et al., 2002 (black); Pérez et al., 2011 (blue); and the USGS, 2012 (purple). Structural contours for the Nazca slab determined from earthquake hypocenters and modified after Gutscher et al., 2000.

with the absence of volcanism (Figs. 1A and 2), is distinctive for this segment of the Peruvian Andes. Deformation in the Sub-Andean zone is accommodated by east-northeast-directed thrusting in the eastern foothills and interacting left-lateral and normal faults within the Andean highlands (Fig. 1A).

Active thrust faults and folds are common along the sub-Andean zone of Peru. Plio-Pleistocene sediments are deformed by the west directed Campanquiz thrust on the eastern margin of the Santiago Basin (Fig. 1A). Thrust faults are dominantly north-striking with lengths between 100 and 600 km, striking perpendicular to the main geodetic shortening direction. South of 5°S, the Andes change to a northwest trend. Here, left-lateral faults cut obliquely across the Andes from the retroarc foreland basin toward the Cordillera Blanca to the west. Estimated rates of strike-slip faulting range between 2–3 mm/yr over the past 2 Myr (Sévrier et al., 1985). The Cordillera Blanca is a west-southwest-dipping detachment (normal) fault located in the Peru highlands. It is thought to represent either orogenic collapse (McNulty et al., 1998; Giovanni et al., 2010) or subduction of buoyant aseismic ridge-related extension (McNulty and Farber, 2002). Normal faults are also located along the Peru coast, where offset marine terraces indicate slip rates of ~0.1 mm/yr. Here, normal faulting

accommodates coseismic subsidence in the landward part of the thrust wedge during strain release associated with subduction zone thrust events (Saillard et al., 2011).

### Tectonic Model for Active Deformation

The ATA database is useful for synthesizing the regional tectonic framework by comparing the distribution and kinematics of active faulting to the GPS velocity field (Fig. 2). We compiled GPS velocities from a variety of sources (Kendrick et al., 2001; Pérez et al., 2001, 2011; Trenkamp et al., 2002; USGS, 2011), referenced to stable South America in the ITRF2000 reference frame. The velocities decrease eastward across the entire width of the orogen, consistent with previous studies using elastic dislocation modeling (e.g., Trenkamp et al., 2002), showing that convergence is primarily accommodated across the locked subduction megathrust with minor deformation accommodated on upper plate faults.

As previously described, oblique convergence leads to slip partitioning into trench-normal thrusting along the trench and sub-Andean and trench-parallel strike-slip faulting in the orogen interior. The GPS velocities are decomposed into their trench-normal and trench-parallel components (Fig. 3); these surface velocities reflect end-member components of pure dip-slip faulting on thrust faults and horizontal motion along the strike-slip faults. The true degree of partitioning is not recoverable directly from the interseismic strain field, but earthquake focal mechanisms are consistent with active slip partitioning. Unlike previous studies, we consider the entire Andean margin north of southern Peru. In this view, the variation in convergence obliquity due to the changing trend of the margin causes a large increase in the trench-parallel component of the velocity field, with the highest gradient of the velocity in southern Ecuador and northern Peru (Fig. 1B). The large trench-parallel velocity gradient at the Talara bend suggests that trench-parallel extension is localized here, as indicated by northwest-striking normal faults at the Gulf of Guayaquil, where Pliocene sediments in the extensional basins exceed 5 km in thickness (Lavenu et al., 1995). We suggest the trench-parallel component of basal shear stresses acting on the North Andean block causes it to move in an arc-parallel direction due to oblique subduction (Fig. 1B), analogous to the Sumatran arc (Fitch, 1972).

Although the northern Andes display a gross north-south symmetry at 5°S, differences between the Ecuadorian-Colombian and Peruvian Andes exist, observed both in the GPS velocity field and in the distribution of active faults (Figs. 1 and 3). North of 5°S, the across-strike gradient in trench-parallel velocity is large, at 1–2 cm/yr of dextral shear. In the south, the trench-parallel velocity gradient is consistent with sinistral shear at <1 cm/yr (Fig. 3). Similarly, trench-parallel strike-slip faulting in Ecuador and Colombia is well-developed, with faults extending for hundreds of kilometers and Holocene slip rates near 1 cm/yr (e.g., Guayaquil-Algeciras fault system; Lavenu et al., 1995; Tibaldi et al., 2007). Peruvian trench-parallel strike-slip faults, only observed in central and southern Peru, are shorter along-strike, suggesting less displacement magnitude (e.g., Cowie and Scholz, 1992) and possibly lower slip rates, but the rates are currently unknown. The differences may result in part from the different boundary conditions on the far end of mobile blocks. The north

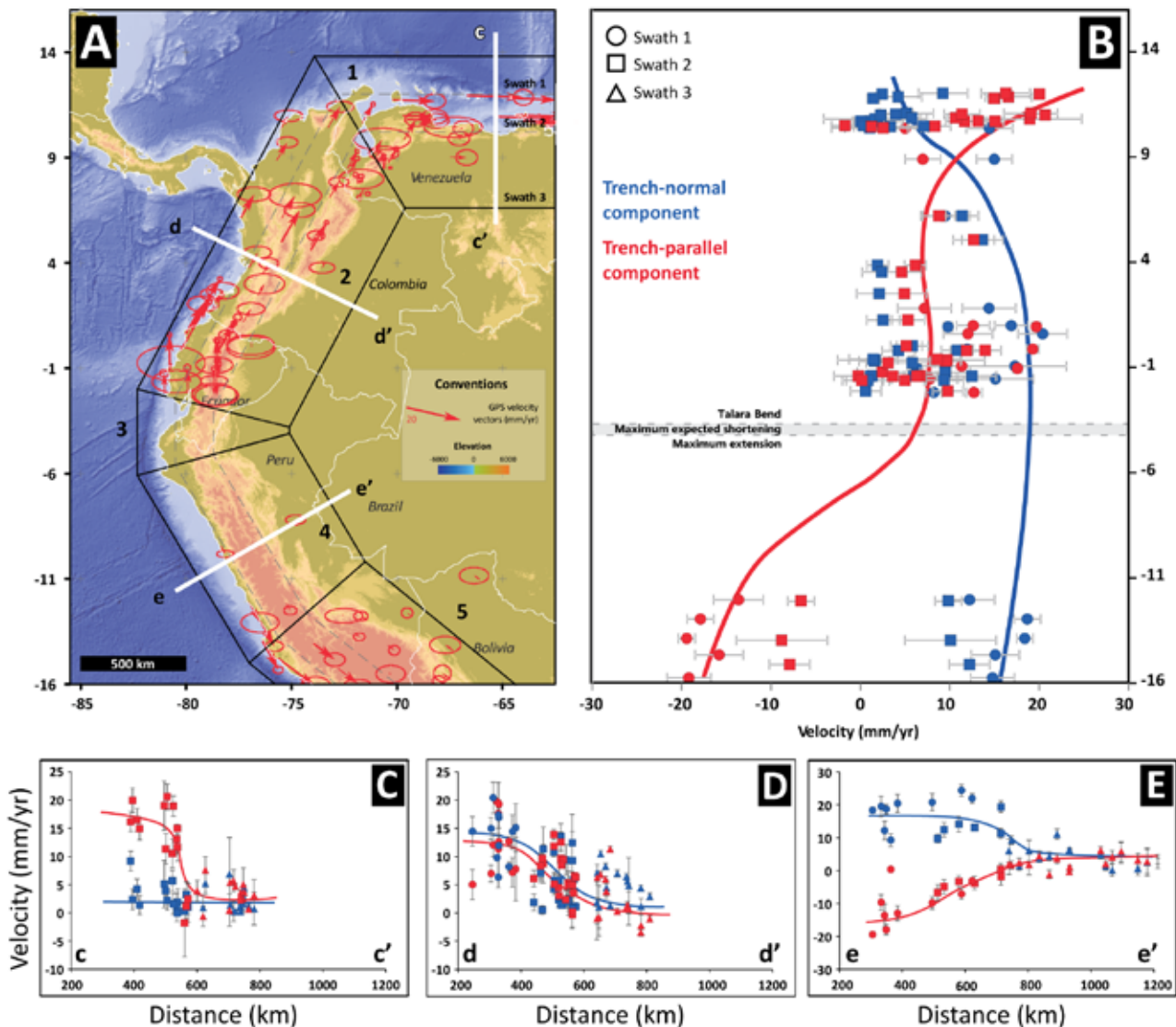


Figure 3. (A) Trench-parallel component of GPS velocities. Swath profiles span the trench and 200 km inboard (Swath 1), from 200 to 400 km (Swath 2), and from 400 to 800 km (Swath 3) inboard. Numbers denote the different domains defined for the GPS analysis: 1—Venezuela; 2—Colombia; 3—Ecuador; 4 and 5—Peru. (B) Trench-parallel and normal components plotted as a function of latitude. Positive trench-parallel velocities are defined as counterclockwise. Note the opposing sense of motion in trench-parallel velocities around 5°S at the Talara Bend. Red and blue lines are the approximate trends of trench parallel and normal components in the different domains. Components from Swath 3 are not shown for clarity. (C), (D), and (E) are the trench normal and parallel projections of the velocity components for each domain. See (A) for profile locations. CASM station from Kendrick et al., 2001, was excluded from the analysis.

Andes override the Caribbean plate, resembling a subduction boundary in some respects, while motion of the southern coastal block is constrained by the Altiplano and northward-moving slivers south of the bend (Wang et al., 2007). Slip partitioning in Venezuela is largely reflected by right-slip faulting with slip rates between 3–17 mm/yr (Fig. 3), which is in agreement with slip rates derived from seismological analysis of 8–10 mm/yr for the Boconó Fault (Audemard et al., 2000). In comparison, north-south shortening plays a more minor role but is still significant, with shortening rates of ~2 mm/yr (Fig. 3).

#### Active Tectonics of the Andes Database

The ATA v.1.0 database may be downloaded at the following link: <https://documents.ku.edu/ORGs/Academics/>

College of Liberal Arts and Sciences/Geology/ActiveAndesMap/ATA-1.0. For additions or modifications to the database, please contact the authors.

#### CONCLUSIONS

The Ecuadoran-Colombian and Peruvian Andes display similar deformation styles, mirrored across latitude ~5°S. Although a wide variety of factors, such as rheology and mantle dynamics, exert control on deformation (e.g., Isacks, 1988), which were not taken into account in this analysis, the observed slip partitioning is largely controlled by the local convergence velocity and degree of convergence obliquity. In the north, convergence is highly oblique, and slip partitioning is expressed as trench-normal thrusting and rapid and well-developed trench-parallel right-slip



faulting, as shown in the upper part of Figure 3B. This region is also characterized by abundant, but low-magnitude, earthquakes (Fig. DR1 [see footnote 1]) and active volcanism between 5°S and 7°N, where the subducting slab is inferred to dip ~30° (Gutscher et al., 2000) (Fig. 2). The subduction geometry is thought to change near the active arc collision with the Chocó-Panamá block, where flat-slab subduction shifts volcanism to eastern Colombia (Figs. 1 and 2).

Large gradients in trench-parallel motion may cause extension in the Gulf of Guayaquil. To the south, in northern Peru, convergence obliquity is relatively low, and trench-parallel left-slip faulting is not observed. However, the trench-parallel component of the surface velocity field increases to the south, commensurate with increasing convergence obliquity. Pure shear deformation of the central Andes is expressed as active east-directed shortening and crustal thickening, while strike-slip faulting and eastward transport occurs to the north. Right-slip faulting is characteristic of the Merida Andes, accommodating the eastward motion of the Caribbean plate and the limited coupling across the plate boundary between South America and the Caribbean (Fig. 1B).

## ACKNOWLEDGMENTS

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## Check out GSA's 2013 GeoVentures™!

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These 2013 GeoVentures are beginning to fill up! Register now to secure your spot on one of these amazing trips. For more information, visit [www.geoventures.org](http://www.geoventures.org) or e-mail Gary Lewis at [glewis@geosociety.org](mailto:glewis@geosociety.org).

### Trips for Everyone

**Death Valley National Park:** Geology in a Land of Contrasts and Extremes. Furnace Creek, California, USA; 11–17 March.

### Trips for K–12 Educators

- **Ecuador and the Galápagos Islands:** Quito, Ecuador, 4–14 June.
- **Rocky Mountain Field Camp:** Boulder, Colorado, USA, 21–26 June.
- **Explore Hawaiian Volcanoes:** Hilo, Hawaii, USA, 11–19 July (this trip is open to all K–12 educators and their families).
- **Iceland—Land of Fire and Ice:** Reykjavik, Iceland, 30 July–5 August.

[www.geoventures.org](http://www.geoventures.org)

Educators on a recent GSA GeoVenture to Iceland examined the Almannagjá fault at Þingvellir National Park, the site of one of the best surface expressions of mid-ocean rifting anywhere on Earth. Þingvellir is considered the most important cultural heritage site in Iceland and has been classified as a UNESCO World Heritage site.



## CALL FOR NOMINATIONS

# 2013 GSA Medals & Awards



### PENROSE MEDAL

The Penrose Medal was established in 1927 by R.A.F. Penrose Jr. to be awarded in recognition of eminent research in pure geology, for outstanding original contributions, or for achievements that mark a major advance in the science of geology. This award is made only at the discretion of the GSA Council, and nominees need not be members of the Society. *Penrose's sole objective was to encourage original work in purely scientific geology, which is interpreted as applying to all scientific disciplines represented by GSA. Scientific achievements should be considered rather than contributions in teaching, administration, or service. Mid-career scientists who have already made exceptional contributions should be given full consideration for the award.*

### DAY MEDAL

The Day Medal was established in 1948 by Arthur L. Day to be awarded annually, or less frequently, at the discretion of GSA Council, for outstanding distinction in contributing to geologic knowledge through the application of physics and chemistry to the solution of geologic problems. *Day's intent was to recognize outstanding achievement and inspire further effort rather than reward a distinguished career.* Scientific achievements should be considered rather than contributions in teaching, administration, or service.

### YOUNG SCIENTIST AWARD (DONATH MEDAL)

The Young Scientist Award was established in 1988 to be awarded to a young scientist (35 years or younger throughout the year in which the award is to be presented—for 2013, only those candidates born on or after 1 January 1978 are eligible) for outstanding achievement in contributing to geologic knowledge through original research that marks a major advance in the earth sciences. The award consists of a gold medal (the Donath Medal) and an honorarium.

### How to Nominate

To ensure thorough consideration by the respective committees, please follow these nomination instructions carefully; additional information supplied will not enhance the nomination. Paper submissions will still be accepted; however, we encourage electronic submission. For each candidate please submit the following:

1. **Nomination form:** Please go to <https://rock.geosociety.org/forms/Awardform.asp> to submit the form online or for hardcopy download to submit via post.
2. **Supporting documents,** to be submitted as e-mail attachments or via post; for Penrose, Day, and Young Scientist, the following supporting documents are required:

- **curriculum vitae;**
- a summary (300 words or fewer) of the scientific contributions to geology that qualify the candidate for the award;
- a selected bibliography of no more than 20 titles—for the Donath medal only 10 titles are required;
- letters from each of five GSA Fellows or Members **in addition** to the person making the nomination. **For the Day Medal only:** letters from five scientists with at least three of those being from GSA Fellows or Members and up to two from fellows or members of the Mineralogical Society of America, Geochemical Society, or American Geophysical Union.



The deadline for receipt of all medal, award, and recognition nominations is 1 February 2013.



## CALL FOR NOMINATIONS

# 2013 GSA Medals & Awards



### GSA PUBLIC SERVICE AWARD

GSA Council established the GSA Public Service Award in 1998 in honor of Eugene and Carolyn Shoemaker. This annual award recognizes contributions that have materially enhanced the public's understanding of the earth sciences or have significantly served decision makers in the application of scientific and technical information to public affairs and earth science-related public policy. This may be accomplished by individual achievement in

- authorship of education materials of high scientific quality that have enjoyed widespread use and acclaim among educators or the general public;
- acclaimed presentations (books and other publications, mass and electronic media, or public presentations, including lectures) that have expanded public awareness of the earth sciences;
- authorship of technical publications that have significantly advanced scientific concepts or techniques applicable to the resolution of earth-resource or environmental issues of public concern; or
- other individual accomplishments that have advanced the earth sciences in the public interest.

The award will normally go to a GSA member, with exceptions approved by Council, and may be presented posthumously to a descendant of the awardee.

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#### How to Nominate

Paper submissions will still be accepted; however, we encourage electronic submission.

1. **Nomination form:** Please go to <https://rock.geosociety.org/forms/Awardform.asp> to submit the form online or for hardcopy download to submit via post.
2. **Supporting documents**, to be submitted as e-mail attachments or via post.
  - **curriculum vitae;**
  - a letter of nomination (300 words or fewer);
  - a brief biographical sketch that clearly demonstrates the applicability of the selection criteria;
  - a selected bibliography of no more than 10 titles.

### THE BROMERY AWARD FOR THE MINORITIES

The Bromery Award for the Minorities should be given to a member of any minority group, preferably African Americans, who qualifies under at least one of these two categories:

1. Nominee has made significant contributions to research in the geological sciences, as exemplified by one or more of the following:
  - Publications which have had a measurable impact on the geosciences;
  - Outstanding original contributions or achievements that mark a major advance in the geosciences;
  - Outstanding lifetime career which demonstrates leadership in geoscience research.
2. Nominee has been instrumental in opening the geoscience field to other minorities, as exemplified by one or more of the following:
  - Demonstrable contributions in teaching or mentoring which have enhanced the professional growth of minority geoscientists;
  - Outstanding lifetime career service in a role which has highlighted the contributions of minorities in advancing the geosciences;
  - Authorship of educational materials of high scientific quality that have enjoyed widespread use and acclaim among educators or the general public.

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#### How to Nominate

Paper submissions will still be accepted; however, we encourage electronic submission.

1. **Nomination form:** Please go to [www.geosociety.org/awards/nominations-Bromery.htm](http://www.geosociety.org/awards/nominations-Bromery.htm) to submit the form online or for hardcopy download to submit via post.
2. **Supporting documents**, to be submitted as e-mail attachments or via post.
  - **curriculum vitae;**
  - a letter of nomination (300 words or fewer);
  - letters from three scientists with at least two from GSA Fellows or Members and one from a member of another professional geoscience organization;
  - an optional selected bibliography of no more than 10 titles.

The deadline for receipt of all medal, award, and recognition nominations is 1 February 2013.



## CALL FOR NOMINATIONS

# 2013 GSA Medals & Awards



### GSA DISTINGUISHED SERVICE AWARD

GSA Council established the GSA Distinguished Service Award in 1988 to recognize individuals for their exceptional service to the Society. GSA members, Fellows, associates, and employees may be nominated for consideration, and any GSA member or employee may submit a nomination for the award. GSA's Executive Committee will select awardees, and GSA Council must ratify all selections. Awards may be made annually, or less frequently, at the discretion of Council.

#### How to Nominate

Paper submissions will still be accepted; however, we encourage electronic submission.

- Nomination form:** Please go to <https://rock.geosociety.org/forms/Awardform.asp> to submit the form online or for hardcopy download to submit via post.
- Supporting documents**, to be submitted as e-mail attachments or via post.
  - **curriculum vitae;**
  - a letter of nomination (300 words or fewer);
  - a brief biographical sketch that clearly demonstrates the applicability of the selection criteria;
  - an optional selected bibliography of no more than 10 titles.

### SUBARU OUTSTANDING WOMAN IN SCIENCE AWARD

*Sponsored by Subaru of America Inc.*



The Subaru Outstanding Woman in Science Award recognizes a woman who has had a major impact on the field of the geosciences based on her Ph.D. research. The generous support of Subaru of America, Inc., in conjunction with the Doris M. Curtis Fund, makes this award possible. GSA's 103rd president, Doris Curtis pioneered many new directions for geology, not the least of which was her tenure as GSA president after an unbroken chain of 102 men. Causes dear to her were women, public awareness, minorities, and education. Women are eligible for this award the first three years following their Ph.D. degree.

#### How to Nominate

Paper submissions will still be accepted; however, we encourage electronic submission.

- Nomination form:** Please go to <https://rock.geosociety.org/forms/Awardform.asp> to submit the form online or for hardcopy download to submit via post.
- Supporting documents**, to be submitted as e-mail attachments or via post.
  - **curriculum vitae including** dissertation title and abstract;
  - a letter of nomination that clearly states how the Ph.D. research has impacted the geosciences in a major way;
  - a selected bibliography of no more than 10 titles; and
  - three letters of support.

#### AWARD NOTES

Candidates whose names are submitted by the respective award committees to GSA Council but who do not receive an award will remain under consideration by those committees for three years. For those still under consideration, it is recommended that an updated nomination letter be sent to GSA.

All nomination forms and submission instructions are online at [www.geosociety.org/awards/](http://www.geosociety.org/awards/). Nomination forms and instructions may also be obtained from GSA Grants, Awards, and Recognition, P.O. Box 9140, 3300 Penrose Place, Boulder, CO 80301-9140, USA, +1-303-357-1028, [awards@geosociety.org](mailto:awards@geosociety.org).

The deadline for receipt of all medal, award, and recognition nominations is 1 February 2013.



## CALL FOR NOMINATIONS

# 2013 GSA Medals & Awards



### GSA FELLOWSHIP

Fellowship is an honor that is bestowed on the best of our profession once per year at the GSA Spring Council meeting and is recognized at our yearly Annual Meeting. GSA members are elected to Fellowship in recognition of distinguished contributions to the geosciences. A **GSA Fellow** may support *only two* nominees per election cycle and only **one** as a primary nominator. A **GSA member** who is not a Fellow may not be a *primary* nominator, but may be a secondary nominator for no more than **two** nominees per election cycle.

The primary nominator is responsible for collecting the entire nomination packet (including letters of support) and must submit the nomination as one e-mail (with supporting documents as attachments) or as one package by via post. Letters of support sent separately will not be accepted.

### How to Nominate

Paper submissions will still be accepted; however, we encourage electronic submission.

1. **Nomination form:** Please go to [www.geosociety.org/members/fellow.htm](http://www.geosociety.org/members/fellow.htm) to submit the form online or for hardcopy download to submit via post.

2. **Supporting documents**, to be collected by the primary nominator and submitted as one package as e-mail attachments or via post:

- a letter of nomination, including a summary of the nominee's significant contributions supporting the selected criteria for election (up to one page);
- the nominee's curriculum vitae;
- a paragraph stating the nominee's total number of publications and a selected bibliography (up to four pages); and
- a supporting letter of nomination from each of the secondary nominators.

### AGI MEDAL IN MEMORY OF IAN CAMPBELL

The AGI Medal in Memory of Ian Campbell recognizes singular performance in and contribution to the profession of geology. Candidates are measured against the distinguished career of Ian Campbell, whose service to the profession touched virtually every facet of the geosciences. Campbell was a most uncommon man of remarkable accomplishment and widespread influence, and in his career as a geologist, educator, administrator, and public servant, he was noted for his candor and integrity. To submit a nomination, go to [www.agiweb.org/direct/awards.html](http://www.agiweb.org/direct/awards.html).

## GEOINFORMATICS DIVISION AWARD

GSA's Geoinformatics Division is pleased to announce the first recipient of its new award for

*Outstanding Contributions in Geoinformatics:*

**Linda C. Gundersen** (U.S. Geological Survey–Reston).

Please join the Division during its joint reception with the Geoscience Information Society (GSIS) at the GSA Annual Meeting & Exposition on Tues., 6 Nov. (6–9 p.m.), to honor Gundersen.

This award is presented to an individual who has made distinguished contributions to the geosciences through the application and promotion of geoinformatics.

To make nominations for 2013, please contact Kerstin Lehnert, [lehnert@ldeo.columbia.edu](mailto:lehnert@ldeo.columbia.edu), by 1 Feb. 2013.

### AGI MARCUS MILLING LEGENDARY GEOSCIENTIST MEDAL

The Marcus Milling Legendary Geoscientist Medal is given to a recipient with consistent contributions of high-quality scientific achievements and service to the Earth sciences having lasting, historic value; who has been recognized for accomplishments in field(s) of expertise by professional societies, universities, or other organizations; and is a senior scientist nearing completion or has completed full-time regular employment. Prior to 2007 it was called the AGI Legendary Geoscientist Award. To submit a nomination, go to [www.agiweb.org/direct/awards.html](http://www.agiweb.org/direct/awards.html).

The deadline for receipt of all medal, award, and recognition nominations is 1 February 2013.



## CALL FOR NOMINATIONS

# 2013 GSA Medals & Awards



### JOHN C. FRYE ENVIRONMENTAL GEOLOGY AWARD

**Deadline:** 31 March 2013

In cooperation with the Association of American State Geologists (AASG), GSA makes an annual award for the best paper on environmental geology published either by GSA or by one of the state geological surveys.

Anyone can nominate a paper as long as it is selected from a GSA or state geological survey publication and published during the preceding three full calendar years. The nomination must include a paragraph stating the pertinence of the paper.

Each nominated paper will be judged on its uniqueness or significance as a model of its type of work and its overall worthiness for the award. The paper must (1) establish an environmental problem or need; (2) provide substantive information on the basic geology or geologic process pertinent to the problem; (3) relate the geology to the problem or need; (4) suggest solutions or provide appropriate land-use recommendations based on the geology; (5) present the information in a manner that is understandable and directly usable by geologists; and (6) address the environmental need or resolve the problem. It is preferred that the paper be directly applicable to informed laypersons (e.g., planners, engineers).

**Please send your nominations to** Program Officer, Grants, Awards & Recognition, GSA, P.O. Box 9140, Boulder, CO 80301-9140, USA.

#### 2012 AWARD RECIPIENTS NAMED

The 2012 award will be presented at the GSA Annual Meeting in Charlotte, North Carolina, USA, to **John T. Neubert, Jeffrey P. Kurtz, Dana J. Bove, and Matthew A. Sares**, for *Natural Acid Rock Drainage Associated with Hydrothermally Altered Terrane in Colorado*; Bulletin 54, Colorado Geological Survey, 2011.

### 2013 NATIONAL AWARDS

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


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

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

The **Vannevar Bush Award** is presented periodically to a senior statesperson of science and technology who, through public service in science and technology, has made an outstanding contribution toward the welfare of humankind and to the United States. Nominations should be accompanied by a complete biography and a brief citation summarizing the nominee’s scientific or technological contributions to our national welfare in promotion of the progress of science. Learn more at [www.nsf.gov/nsb/awards/bush.jsp](http://www.nsf.gov/nsb/awards/bush.jsp).

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

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



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# GSA Position Statement

## Promoting Earth Science Literacy for Public Decision Making

**GSA members** are invited to submit comments and suggestions regarding the following Position Statement draft by **15 November 2012** via link at [www.geosociety.org/positions/](http://www.geosociety.org/positions/).

The Geological Society of America (GSA) recognizes the critical need for citizens and policy makers to understand important aspects of the Earth system as they face issues related to natural resources, energy, natural hazards, and human impacts on the environment. GSA supports the active involvement of geoscientists and geoscience educators in helping to improve the knowledge and understanding of the geosciences among members of the general public in order to support informed decision making by Earth's citizens and communities. GSA and GSA members should contribute to education and outreach about fundamental concepts of Earth science, issues related to long-term human sustainability on Earth (such as the use and availability of water, minerals, and energy resources), and socially prominent topics (such as climate change and natural hazards preparedness).

### Rationale

For most people, formal education in the geosciences is often minimal. Once an individual has his or her last experience in formal Earth science education, perhaps in middle school, updating their knowledge with new information becomes difficult. People may not understand the relevance of the geosciences to their lives, either in the short or long term. Most citizens are not aware that they access and use geoscience information when they attend to news about the weather and natural hazards or use computer-based visualization tools that display Earth data sets.

The U.S. National Research Council has recommended, and the National Science Foundation has mandated, that scientists effectively disseminate the outcomes of their research. This obligation comes not only from the fiscal responsibility of the scientists to the public who paid for the research, but also from the public's need for information and knowledge with which to make informed decisions. Communications must go beyond the scholarly dissemination of scientific research results and place the scientific insights into the context of locally relevant and societally important issues that individuals and communities need to address.

### Public Policy Aspects of Promoting Earth Science Literacy

A healthy democracy, or any representative or direct-election form of government, relies upon an informed and educated citizenry to guide the country. This need becomes greater or intensifies as populations increase, resources become more scarce, the social and economic impacts from natural hazards increase, and human impacts on the environment increase. However, making informed choices about energy and natural resources, preparing for natural hazards, and mitigating and adapting to climate change requires an understanding of geoscience processes and timescales. An informed and educated citizenry can guide decision makers as they develop regulations and put in place infrastructures that can protect citizens

and communities, safeguard the environment, ensure access to energy, and preserve natural resources.

### Recommendations

#### *Geoscientists are encouraged to*

- Consider their work in the context of its relevance for addressing societal problems, and, if appropriate, identify key elements of their work for public and educational outlets;
- Seek to improve the perceived relevance of the geosciences by the public and the public's understanding of Earth and the environment across all aspects of geosciences, but with particular attention to natural resources, energy, natural hazards, and impact on the environment by individuals and communities; and
- Use various avenues to achieve these ends, including formal and informal education, communication with the public through mainstream media, web pages, blogs and wikis, social media, and other types of professional outreach, including interviews, museum displays, and workshops with teachers, schools, and governmental, organizational, and social programs.

#### *Employers of geoscientists and geoscience educators are encouraged to*

- Support geoscience education and outreach by providing employees with the tools and training for public engagement and fostering partnerships with professional outreach organizations; and
- Provide formal recognition of their employees' efforts to increase public understanding of Earth and the environment by rewarding these activities with favorable salary and promotion decisions and with company/organization staff awards.

#### *Educators of future geoscientists are encouraged to*

- Weave opportunities for actual or simulated public engagement into the formal curriculum for future geoscientists; and
- Provide knowledge, skills, mentoring, contacts, and internships for undergraduate and graduate students relevant to careers in which they will use their geoscience expertise to address societal issues.

### Opportunities for GSA and GSA Members to Help Implement Recommendations

#### *GSA members can*

- Lead or participate in geoscience workshops and other geoscience educational activities for non-science experts, including citizens, community groups, professionals, and policy makers, whose efforts affect and are affected by the geosciences;
- Participate in discussions that address societal issues or problems to help inform the discussion from a geoscience perspective and contribute to solutions;



- Communicate with their elected officials about issues for which geoscience can provide support—either through informing decisions or by providing solutions;
- Identify legislation that can be informed by the geosciences and alert GSA’s Geology and Public Policy Committee, GSA’s Geology and Society Division, and the GSA Associated Societies if action by GSA and its membership might positively contribute to that legislation; and
- Participate in Congressional Visits Day with GSA to help educate members of Congress and their staff.

*The Geological Society of America can*

- Support geoscience education and outreach by providing GSA members with tools and training for public engagement and fostering partnerships with professional outreach organizations;
- Provide avenues to enable collective or individual actions through GSA Committees and Divisions and through organizations with which GSA is affiliated;
- Publish and publicize successful examples of initiatives that have increased public understanding of Earth and the environment and of societal decisions that have benefited from geoscience input;
- Encourage academic institutions to value and reward in a concrete way faculty and staff activities that improve understanding of the geosciences;
- Identify experts to speak and engage with the media, legislators, and other stakeholders on geoscience topics that have ramifications for societal issues;
- Identify legislation that can be informed by the geosciences and pursue avenues to effectively and positively affect that legislation;
- Support changes to pre-college curricula to include a year of Earth-science education at both the middle school and high school levels, as advocated by the National Research Council’s *Framework for K–12 Science Education* and the *Next Generation Science Standards*; and
- Support this effort by addressing the recommendations from the GSA position statements, including *The Importance of Teaching Earth Science*, *Expanding and Improving Geoscience in Higher Education*, and *Rewarding Professional Contributions*.

Inquiries about GSA or this position statement should be directed to GSA’s Director for Geoscience Policy, Kasey S. White, at +1-202-669-0466, [kwhite@geosociety.org](mailto:kwhite@geosociety.org).

The Geological Society of America is a diverse Society with more than 25,000 members around the world, representing a wide array of professional disciplines. Our members hold diverse opinions, and no individual, except for the GSA President or Executive Director, should be construed to be speaking on behalf of the Society. GSA position papers can be viewed at <http://www.geosociety.org/positions/>.

## New Position Statements Approved

At its April 2012 meeting, GSA Council approved new Position Statements on Geoheritage and Supporting Planetary Exploration along with revised versions of Water Resources, The Value of Geologic Mapping, and Geoscience and Natural Hazards Policy. These are summarized below; the full versions, along with other statements, are online at [www.geosociety.org/positions/](http://www.geosociety.org/positions/). In addition, GSA endorsed the Association of American Universities document on “Visa Problems Harming America’s Scientific, Economic and Security Interests.”

**Geoheritage:** GSA supports the conservation of geoheritage sites to meet present and future educational, scientific, aesthetic, cultural, and economic needs.

**Supporting Planetary Exploration:** GSA supports planetary exploration to advance research concerning the evolution of Earth; to deepen and expand human understanding of our place in the universe; to reinforce science, technology, engineering, and math (STEM) education and the effective training of the next generation of scientists; to increase U.S. competitiveness in science and technology development; and to enhance the quality of life through technological innovation.

**Water Resources:** To ensure the availability of safe and reliable fresh water resources, GSA encourages partnerships that improve the fundamental scientific understanding and analyses of water resources; enhance collection, management, and accessibility of water resource information; increase stakeholder involvement in all aspects of water resource education, assessment, and decision making; and broaden education and outreach to foster collaboration among government agencies, educational institutions, industrial and agricultural users, and the public.

**The Value of Geologic Mapping:** To improve the scientific basis for public and private natural resource, environmental, and land-use decisions, GSA supports comprehensive geologic mapping on local, state, and national scales and advocates increased public investments for current state and national geologic mapping programs.

**Geoscience and Natural Hazards Policy:** GSA urges scientists, policy makers, and the public to work together to reduce our vulnerability to natural hazards. GSA strongly supports government investment in research, monitoring, and outreach programs to better characterize the nature and distribution of natural hazards and their impacts on modern society, to increase hazards awareness, and to enlist the resources of the private sector. Geoscientists must effectively communicate and integrate their research and monitoring results into functional public policy, reach out to the private sector for mutual benefit, and work to integrate geoscience into scientifically sound educational programs at all levels.

# 2013 GSA Section Meeting Calendar

## **Northeastern 18–20 March 2013**

Bretton Woods, New Hampshire, USA  
Local Committee Chair: Brian Fowler

**Abstracts deadline:** 11 December 2012

## **Southeastern 20–21 March 2013**

San Juan, Puerto Rico  
Local Committee Co-Chairs: Lizzette A. Rodríguez  
and Dave Bush

**Abstracts deadline:** 11 December 2012

## **South-Central 4–5 April 2013**

Austin, Texas, USA  
Local Committee Chair: Elizabeth Catlos

**Abstracts deadline:** 15 January 2013

## **North-Central 2–3 May 2013**

Kalamazoo, Michigan, USA  
Local Committee Chair: Alan Kehew

**Abstracts deadline:** 5 February 2013

## **Rocky Mountain 15–17 May 2013**

Gunnison, Colorado, USA  
Local Committee Co-Chairs: Tim Wawrzyniec  
and Amy Ellwein

**Abstracts deadline:** 12 February 2013

## **Cordilleran 20–22 May 2013**

Fresno, California, USA  
Local Committee Chair: John Wakabayashi

**Abstracts deadline:** 19 February 2013



[www.geosociety.org/  
Sections/meetings.htm](http://www.geosociety.org/Sections/meetings.htm)

## *Call for Applications*

**2013–2014 GSA-USGS**

### **Congressional Science Fellowship**

**Deadline for application:** 1 February 2013

Bring your science and technology expertise to Capitol Hill to work directly with national leaders at the interface between geoscience and public policy.

The GSA-USGS Congressional Science Fellowship provides a rare opportunity for a geoscientist to work in a House or Senate personal or committee office for one year. Prospective candidates are GSA members with a broad geoscience background and excellent written and oral communication skills. The fellowship is open only to U.S. citizens or permanent U.S. residents, with a minimum requirement of a master's degree with at least five years professional experience or a Ph.D. at the time of appointment.

Learn more at [www.geosociety.org/csf/](http://www.geosociety.org/csf/) or by contacting Ginger Williams, +1-303-357-1040, [gwilliams@geosociety.org](mailto:gwilliams@geosociety.org).

Put your professional and academic background, experience applying scientific knowledge to societal challenges, and passion for shaping the future of the geosciences, to work in this coveted arena.

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Brazil: landslides



Thailand: geological hazards



Greece



South Africa: groundwater



Australia: potable groundwater



Romania: pollution



Sweden



West Africa: water



Jamaica: earthquakes

Honduras: sustainable water systems



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For more information on GWB, please visit [www.seg.org/gwb](http://www.seg.org/gwb).*



# SOUTH-CENTRAL

47th Annual Meeting  
Austin, Texas, USA  
4–5 April 2013

[www.geosociety.org/Sections/sc/2013mtg/](http://www.geosociety.org/Sections/sc/2013mtg/)



Loop 360 Bridge at Sunset, Austin, Texas USA. Photo by Dan Herron, HerronStock.com. Used with permission of the Austin CVB.

*Celebrating Advances in Geoscience: Our Science, Our Societal Impact, and Our Unique Thought Processes*

## LOCATION

The Jackson School of Geosciences at The University of Texas at Austin (UT-Austin) welcomes you to celebrate the 125th Anniversary of the Geological Society of America in the capital city of Texas. Austin is the gateway to the Texas Hill Country, with rolling hills, sparkling waterways, and fascinating geology. This historic city commonly ranks on top-10 lists of best places to live and visit and is known for being the Live Music Capital of the World® with nearly 200 live music venues. The meeting, situated on campus, will take a look at how far we have come as a result of scientific and technological advances in the last 50 years as well as predictions for future advances.

## CALL FOR PAPERS

**Abstract deadline:** 15 January 2013

## Technical Sessions

Please submit your abstract online; an abstract submission fee of US\$10 for students and US\$15 for all others will be charged. If you cannot submit online, please contact Nancy Wright, +1-303-357-1061, [nwright@geosociety.org](mailto:nwright@geosociety.org).

## Theme Sessions

- Tectonic Evolution of South-Central Laurentia: Megacontinents and Exotic Terranes, Orogenic Belts and Rifts: Celebrating the Career of Wm. R. Muehlberger.** Ian W.D. Dalziel, UT-Austin, [ian@utig.ig.utexas.edu](mailto:ian@utig.ig.utexas.edu); Staci Loewy Mickler, UT-Austin, [sloewy@jsg.utexas.edu](mailto:sloewy@jsg.utexas.edu); Patricia Wood Dickerson, American Geosciences Institute and UT-Austin, [patdickerson@earthlink.net](mailto:patdickerson@earthlink.net).
- Origins of Granites: A Tribute to Chappell and White.** David London, Univ. of Oklahoma, [dllondon@ou.edu](mailto:dllondon@ou.edu); Calvin G. Barnes, Texas Tech Univ., [cal.barnes@ttu.edu](mailto:cal.barnes@ttu.edu).
- Teaching Central Texas Geology: Honoring the Career of Leon Long.** Hilary Olson, UT-Austin, [hilaryclementolson@gmail.com](mailto:hilaryclementolson@gmail.com); Laurie Schuur Duncan, UT-Austin, [laurieduncan@jsg.utexas.edu](mailto:laurieduncan@jsg.utexas.edu).
- The Paleontology of Texas: A Session in Honor of Wann Langston Jr.** Michelle R. Stocker, UT-Austin, [mstocker@utexas.edu](mailto:mstocker@utexas.edu).
- The Ouachita Orogenic Belt: Structure, Foreland Basins, Tectonics, and Geophysics.** Ibrahim Çemen, Univ. of Alabama, [icemen@as.ua.edu](mailto:icemen@as.ua.edu); Gregory Dumond, Univ. of Arkansas, [gdumond@uark.edu](mailto:gdumond@uark.edu); Randy Keller, Univ. of Oklahoma, [grkeller@ou.edu](mailto:grkeller@ou.edu).
- Delving Deeper into Petrogenesis: Advances in Petrology and Geochronology with Applications to Tectonics.** Jeff Marsh, UT-Austin, [jhmarsh@jsg.utexas.edu](mailto:jhmarsh@jsg.utexas.edu); David Young, The Univ. of Texas at San Antonio, [david.young@utsa.edu](mailto:david.young@utsa.edu); Eric Kelly, UT-Austin, [eric.kelly@utexas.edu](mailto:eric.kelly@utexas.edu); Spencer Seman, UT-Austin, [spencer.seman@gmail.com](mailto:spencer.seman@gmail.com).
- New Ideas about the Geologic Evolution and Petroleum Potential of the Gulf of Mexico.** Robert J. Stern, The Univ. of Texas at Dallas, [rjstern@utdallas.edu](mailto:rjstern@utdallas.edu); Peter D. Clift, Louisiana State Univ., [pclift@lsu.edu](mailto:pclift@lsu.edu).
- Novel Geochemical and Isotopic Approaches to Reconstructing Sedimentary Provenance, Sediment Dispersal, and Paleogeography of the Gulf of Mexico.** Daniel Stockli, UT-Austin, [stockli@jsg.utexas.edu](mailto:stockli@jsg.utexas.edu); John Snedden, UT-Austin, [jsnedden@utig.ig.utexas.edu](mailto:jsnedden@utig.ig.utexas.edu).
- Temporal and Kinematic Linkage between Rifting in the Gulf of Mexico and U.S. Atlantic Margins and the Influence of CAMP.** Harm Van Avendonk, UT-Austin, [harm@ig.utexas.edu](mailto:harm@ig.utexas.edu); Daniel Stockli, UT-Austin, [stockli@jsg.utexas.edu](mailto:stockli@jsg.utexas.edu).
- Results from EarthScope and Related Studies in the South-Central United States.** Jay Pulliam, Baylor Univ. and UT-Austin, [jay@ig.utexas.edu](mailto:jay@ig.utexas.edu); Harold Gurrola, Texas Tech Univ., [harold.gurrola@ttu.edu](mailto:harold.gurrola@ttu.edu).
- Magmatic and Metamorphic Petrology in the South-Central United States.** Callum J. Hetherington, Texas Tech Univ., [callum.hetherington@ttu.edu](mailto:callum.hetherington@ttu.edu); Kenneth Johnson, Univ. of Houston Downtown, [johnsonk@uhd.edu](mailto:johnsonk@uhd.edu).
- Desired Future Conditions and Modeled Available Groundwater: The New Groundwater Management Paradigm in Texas.** W.F. (Kirk) Holland, Barton Springs/Edwards Aquifer Conservation District, [kholland@bseacd.org](mailto:kholland@bseacd.org)

- .org; John Dupnik, Barton Springs/Edwards Aquifer Conservation District, jdupnik@bseacd.org.
13. **The Role of the Geosciences in Water Sustainability: Examples, Challenges, and Societal Impacts.** David M. Borrok, Univ. of Louisiana at Lafayette, dborrok@gmail.com; Durga D. Poudel, Univ. of Louisiana at Lafayette, ddpoudel@louisiana.edu; Johnathan R. Bumgarner, USGS, jbumgarner@usgs.gov.
  14. **Proxy Records of Abrupt Holocene Climate and Environmental Change.** Mark R. Besonen, Texas A&M–Corpus Christi, mark.besonen@tamucc.edu; Peter D. Clift, Louisiana State Univ., pclift@lsu.edu; Rong Fu, UT-Austin, rongfu@jsg.utexas.edu.
  15. **Climate Change, Earth Process and Human Impacts in Determining Earth's Landscapes.** Rong Fu, UT-Austin, rongfu@jsg.utexas.edu; Suzanne A. Pierce, UT-Austin, suzperce@jsg.utexas.edu.
  16. **Scientific Ocean Drilling and the Reconstruction of Past Environments.** Debbie Thomas, Texas A&M–College Station, dthomas@ocean.tamu.edu; Peter D. Clift, Louisiana State Univ., pclift@lsu.edu.
  17. **Coastal and Estuarine Sedimentary Processes in Modern and Holocene Systems.** Tim Dellapenna, Texas A&M, dellapet@tamug.edu; Elizabeth Heise, The Univ. of Texas at Brownsville, elizabeth.heise@utb.edu.
  18. **Reefs and Reef-Like Structures of SW USA: Their Current Economic Value and Deep Time Biological Implications.** Ann Molineux, Texas Natural Science Center, UT-Austin, annm@austin.utexas.edu; Robert W. Scott, Univ. of Tulsa, rWSCOTT@cimtel.net.
  19. **From Micro to Nano: Applications of Electron Microbeam Techniques in the Geosciences.** Donggao Zhao, UT-Austin, dzhao@jsg.utexas.edu; George Morgan, Univ. of Oklahoma, gmorgan@ou.edu; Terry Colberg, Oklahoma State Univ., terry.colberg@okstate.edu.
  20. **Frontiers in 3-D Imaging for Geoscience.** Rich Ketcham, UT-Austin, ketcham@jsg.utexas.edu.
  21. **Fractures, Faults, and Fluids: From Observations to Numerical Models.** Estibalitz Ukar, UT-Austin, esti.ukar@gmail.com; John M. Sharp, UT-Austin, jmsharp@jsg.utexas.edu.
  22. **Nano-Petrophysics and Fluid Flow in Porous Media.** Qinhong Hu, The Univ. of Texas at Arlington, maxhu@uta.edu.
  23. **Soil as a Mediator of Geological Processes.** M.H. Young, UT-Austin, michael.young@beg.utexas.edu; T.G. Caldwell, UT-Austin, todd.caldwell@beg.utexas.edu.
  24. **Building Comprehensive Models of Epicratonic Paleoenvironments from Integrated, Basin-Scale, Lithostratigraphic and Chemostratigraphic Datasets.** Harry Rowe, UT-Austin, hrowe@uta.edu; Stephen Ruppel, UT-Austin, stephen.ruppel@beg.utexas.edu.
  25. **New Directions on Basin Analysis; Linking Structure with Stratigraphy using Geochemical and Isotopic Techniques.** Edgardo Pujols, UT-Austin, edgardopujols@utexas.edu; Josh Burrus, UT-Austin, josh.burrus@utexas.edu; Michael Gordon Prior, UT-Austin, mprior@utexas.edu.
  26. **Engaging the Next Generation of Geoscientists.** Kathy Ellins, UT-Austin, kellins@ig.utexas.edu; Laurie Serpa, The Univ. of Texas El Paso, lfserpa@utep.edu.



Cattle in Wildflowers. Photo by Dan Herron, HerronStock.com. Used with permission of the Austin CVB.

27. **Confronting the Challenges of Climate Literacy.** Alison Mote, The Ann Richards School for Young Women Leaders, alison.mote@austinisd.org; Leslie Salter, Vancleave High School, lsalter@jcsd.k12.ms.us.
28. **Undergraduate Research (Posters).** Elizabeth Heise, The Univ. of Texas at Brownsville, elizabeth.heise@utb.edu.

## FIELD TRIPS

We are planning to publish a field guide for trips associated with this meeting, to be available for sale at the meeting. The deadline for manuscript submissions is **29 October** if editors handle peer review or **30 November** if the paper is submitted with two reviews.

1. **Urban Hydrogeology of Austin, Texas.** C.M. Woodruff, Jr., UT-Austin, chockw@swbell.net; Edward W. Collins, UT-Austin; Raymond M. Slade, Jr., UT-Austin.
2. **The Llano Uplift, Central Texas: Field Trip for Teachers and Geologists at Any Level.** Leon Long, UT-Austin, leonlong@jsg.utexas.edu; Laurie Schuur Duncan, UT-Austin, laurieduncan@jsg.utexas.edu; Hilary Olson, UT-Austin, hilaryclementolson@gmail.com; Rich Ketcham, UT-Austin, ketcham@jsg.utexas.edu.
3. **Late Cretaceous Strata and Vertebrate Fossils of North Texas.** Louis L. Jacobs, Southern Methodist Univ. (SMU), jacobs@smu.edu; Michael J. Polcyn, SMU, mpolcyn@smu.edu; John Wagner, SMU, jwagner@smu.edu; Dale Winkler, SMU, dwinkler@smu.edu.
4. **Friesenhahn Cave: Late Pleistocene Paleoecology and the Predator-Prey Relationships of Mammoths with the Extinct Scimitar Cat.** Russell W. Graham, The Pennsylvania State Univ., rgraham@ems.psu.edu; Ernest L. Lundelius, Jr., UT-Austin, erniel@geo.utexas.edu; Laurence Meissner, Concordia Univ., laurence.meissner@concordia.edu.
5. **Orogenic Belts, Voluminous Magmatism, and Continental Rifting: Tectonic Evolution of the Big Bend Region, West Texas.** Patricia Wood Dickerson, AGI and UT-Austin, patdickerson@earthlink.net.
6. **Sedimentary Deposits of the K/Pg Boundary and Basal Paleocene Recovery Interval, Brazos River, Texas.** Thomas E. Yancey, Texas A&M, tyancey@geos.tamu.edu.
7. **The Search for Devil's Eye: Retrace the Historic Dumble Survey with Modern Mobile Technology.** Ann Molineux, UT-Austin, annm@austin.utexas.edu; Louis Zachos, Univ. of Mississippi, lgzachos@olemiss.edu; Unmil Karadker, UT-Austin, unmil@ischool.utexas.edu.
8. **Traversing the Trinity and Edwards Karst Aquifers along the Blanco River Basin.** Marcus Gary, Edwards Aquifer Authority, mgary@edwardsaquifer.org.
9. **Late Cretaceous (Campanian) Submarine Volcanism and Associated Carbonate Deposition, Austin Area, Central Texas.** S. Christopher Caran, Texas Water Development Board, chris.caran@twdb.texas.gov; Alan J. Cherepon, Texas

Commission on Environmental Quality, alan.cherepon@tceq.texas.gov.

10. **Basal Eocene Sabinetown Transgression in the Upper Wilcox Group of Central Texas, Bastrop County, Texas.** Thomas E. Yancey, Texas A&M, tyancey@geos.tamu.edu.
11. **Geology and Geomorphology of the Enchanted Rock State Natural Area, Central Texas.** Rob Reed, UT-Austin, rob.reed@beg.utexas.edu.
12. **Traverse of Tertiary Sedimentary Rocks (Paleocene-Miocene), Central Texas Gulf Coastal Plain.** Earle F. McBride, UT-Austin, efmcbride@jsg.utexas.edu; Charles M. Woodruff, UT-Austin, chockw@swbell.net.

## OPPORTUNITIES FOR STUDENTS

See the meeting website for information about travel grants, volunteering, and other opportunities.

### Mentor Programs

At the free **Roy J. Shlemon Mentor Program in Applied Geoscience** luncheon on Thurs., 4 Apr., you'll be able to discuss career goals, prospects, and challenges with professional geoscientists from multiple disciplines.

Thinking about applied hydrogeology or hydrology as a career? At the free **John Mann Mentors in Applied Hydrogeology Program** luncheon on Fri., 5 Apr., you'll be able to network and discuss career prospects with hydrogeology professionals.

## REGISTRATION

**Early registration deadline: 4 March**  
**Cancellation deadline: 11 March**

Online registration will begin in January 2013. For further information, or if you have special requirements, please contact Elizabeth Catlos or Peter Clift. Anyone interested in proposing additional theme sessions or field trips should contact Peter Clift or Brian Hunt.

### 2013 South-Central GSA Committee

**General Chair:** Elizabeth Catlos, ejcatlos@gmail.com

**Technical Program Chair:** Peter Clift, pclift@lsu.edu

**Field Trip Chair:** Brian Hunt, brianh@bseacd.org

**Media Relations Chair:** J.B. Bird, jbird@utexas.edu (assisted by Marc Airhart, mairhart@jsg.utexas.edu)

**K-12 Teacher Program Co-Chairs:** Kathy Ellins, kellins@utig.ig.utexas.edu; Hilary Olson, hilaryclementolson@gmail.com

**Community College Liaison:** Robert Blodgett, rblodget@austincc.edu (assisted by Maurine Reiss, mriess@jsg.utexas.edu)

**Event Coordinator:** Erin Negron, erin.negron@jsg.utexas.edu

**Student Volunteers Chair:** Jessica Smith, jsmith@jsg.utexas.edu

# 2013 Section Meeting Mentor Programs

## STUDENTS:

### *Interested in Working in Applied Geology?*

Meet Your Career Mentors at Your Next GSA Section Meeting!

*Sponsored by the GSA Foundation*

**GSA Contact:** Jennifer Nocerino, [jnocerino@geosociety.org](mailto:jnocerino@geosociety.org)

When you attend one or both of the mentor luncheons at your 2013 Section Meeting, you'll have the opportunity to chat one-on-one with working geoscientists who want to help

YOU succeed. These mentors will answer your questions and share insights on how to get a job after graduation.

At the free **Roy J. Shlemon Mentor Program in Applied Geoscience** luncheon, you'll be able to discuss career goals, prospects, and challenges with professional geoscientists from multiple disciplines.

Thinking about applied hydrogeology or hydrology as a career? At the free **John Mann Mentors in Applied Hydrogeology Program** luncheon, you'll be able to network and discuss career prospects with hydrogeology professionals.



### **Northeastern Section Meeting**

Bretton Woods, New Hampshire, USA

**Shlemon Program in Applied Geoscience:** Monday, 18 March  
**Mann Mentors in Applied Hydrogeology:** Tuesday, 19 March



### **Southeastern Section Meeting**

San Juan, Puerto Rico

**Shlemon Program in Applied Geoscience:**  
Wednesday, 20 March  
**Mann Mentors in Applied Hydrogeology:** Thursday, 21 March  
Palominito Islet, Puerto Rico. Image courtesy seepuertorico.com.

### **South-Central Section Meeting**

Austin, Texas, USA

**Shlemon Program in Applied Geoscience:** Thursday, 4 April  
**Mann Mentors in Applied Hydrogeology:** Friday, 5 April  
Loop 360 Bridge at Sunset, Austin, Texas, USA. Photo by Dan Herron, HerronStock.com.  
Used with permission of the Austin CVB.



### **North-Central Section Meeting**

Kalamazoo, Michigan, USA

**Shlemon Program in Applied Geoscience:** Thursday, 2 May  
**Mann Mentors in Applied Hydrogeology:** Friday, 3 May  
Looking southwest from N. Edwards Street in downtown Kalamazoo, Michigan.  
Round-topped towers are the Radisson Plaza hotel.



### **Rocky Mountain Section Meeting**

Gunnison, Colorado, USA

**Shlemon Program in Applied Geoscience:** Wednesday, 15 May  
**Mann Mentors in Applied Hydrogeology:** Thursday, 16 May  
Curecanti National Recreation Area west of Gunnison, which includes Blue Mesa Lake, Colorado's largest body of water. Photo courtesy U.S. National Park Service.



### **Cordilleran Section Meeting**

Fresno, California, USA

**Shlemon Program in Applied Geoscience:** Monday, 20 May  
**Mann Mentors in Applied Hydrogeology:** Tuesday, 21 May  
Death Valley, California, USA. Image courtesy NASA.

# Renew Your MEM

## The GSA Membership Advantage

- **Premier Journals**  
*Geology, GSA Bulletin, Lithosphere, and Geosphere*
- **Scientific Exchange—GSA Meetings and 17 Geoscience Divisions**
- **Publish and Present Research**
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## Join GSA Divisions

- Archaeological Geology
- Coal Geology
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Toroweap Point, Grand Canyon, Arizona Coordinates. Photo by Bret Webster.



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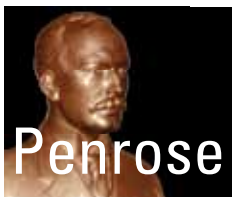
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# Penrose Conference Report

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

Il Ciocco, Castelvecchio Pascoli, Lucca, Italy  
25–31 March 2012.

### CONVENERS

**Donald Fisher**, Dept. of Geosciences, Penn State University, University Park, Pennsylvania, USA, [dmf6@psu.edu](mailto:dmf6@psu.edu)

**César Ranero**, Barcelona Center for Subsurface Imaging, Barcelona, Spain, [cranero@cmima.csic.es](mailto:cranero@cmima.csic.es)

**Paola Vannucchi**, Dipartimento di Scienze della Terra, Università degli Studi di Firenze, Firenze, Italia, [paola.vannucchi@unifi.it](mailto:paola.vannucchi@unifi.it)

### ORGANIZING COMMITTEE

*Eli Silver, Univ. of California at Santa Cruz; Demian Saffer, Penn State Univ.; Greg Moore, Univ. of Hawaii; Kelin Wang, Univ. of Victoria; Onno Onken, GFZ Potsdam; Timothy Dixon, Univ. of Miami; Carlo Doglioni, Univ. di Roma "La Sapienza"; Claudio Faccenna, Univ. di Roma 3; Jean-Yves Collot, Geoazur Nice; Francesca Remitti, Univ. di Modena e Reggio Emilia; Giancarlo Molli, Univ. di Pisa; Roland von Huene, Univ. of California at Davis; Serge Lallemand, Geosciences Montpellier; Sean Willett, ETH Zurich.*

### INTRODUCTION

This conference was held 25–31 March at Il Ciocco, a venue in the hills overlooking the town of Barga, Italy, at the foot of the Apuane Alps. The meeting location was ideally suited for field trips, including a two-day pre-meeting field trip that focused on the sub-Ligurian thrusts and associated underthrust sediment section, and a one-day post-meeting trip in the Apuane Alps that related to the exhumed metamorphic rocks of the underthrust continental margin. The conference brought together 64 scientists from 15 different countries.

The purpose of this Penrose Conference was to explore recent developments related to deformation, fluid flow, and mass transfer in the forearc of convergent plate boundaries and their potential relationships to earthquake phenomena and seismogenesis. The meeting included onshore studies, marine observations, and insights from geodynamic modeling. A number of time scales were considered, from the short-term secular variations of the seismic cycle to the long-term evolution of

structure and topography. Talks and posters were grouped into four themes: (1) Short and Long Time Scales of Deformation, (2) Structure of Margins and Relationship to Seismicity, (3) Deformation Processes and Seismicity in the Forearc, and (4) Fluids and Forearc Properties.

### Short and Long Time Scales of Observation

This session addressed deformation and deformation rates in forearcs at a range of time scales. It began with a keynote presentation by K. Wang that explored the variations in stress and deformation that accompany the earthquake cycle, with systematic variations in the nature of upper plate seismicity and the GPS velocity field (relative to the upper plate) over the duration of the interseismic period. Other related issues that generated discussion were the significance of normal faults in forearcs and the potential for dynamic weakening at high velocities where rate-state friction behavior may not apply. Talks in this session addressed the evolution of splay faults and the conditions for splay fault reactivation, the interpretation of the regional velocity field in Central America, and the rupture characteristics of tsunamigenic earthquakes that lead to rapid slip in the shallow updip region of the forearc. Overall, this session emphasized that the shallow segment of plate boundary faults has complex behavior and can both store elastic strain and slip coseismically during large earthquakes.

### Structure of Margins and Relationship to Seismicity

This session highlighted examples from convergent margins around the world, including the Sumatra, Nankai, Middle America, Makran, Aleutian, Mediterranean, Colombia, Ecuador, Hispaniola, and Apennine margins. The keynote talk by J.-Y. Collot focused on structures within the underthrust sediment sequence observed in a high-resolution seismic reflection profile of the Ecuador margin. Extensional structures are observed at shallow depths that give way to shortening features further down dip. It was noted that extensional structures are typical of the early history of underthrust rocks. Such structures were also observed, for example, on the pre-meeting field trip in blocks contained within the strata that were incorporated in the plate boundary shear zone beneath the Ligurian units.

Discussion followed about when the term “subduction channel” is appropriate when referring to the material that is underthrust beneath the forearc. Introduced into the literature by Shreve and Cloos in 1988, the term originally referred to a deforming channel along the plate boundary where combinations of shear flow and pressure-driven flow could lead to a variety of behaviors, including two-way flow regimes where material is exhumed by return flow beneath the forearc wedge. This led to a debate—that ended inconclusively—about how narrowly the term “subduction channel” should be defined and whether it is a useful term when referring to the subducting sediments at relatively shallow depths where much of the slip may be restricted to a narrow shear zone. The discussion made apparent the need for higher geophysical resolution at depth to resolve these issues.



Participants. See page 28 for a list of names.

F. Tilmann presented a second keynote talk that emphasized the segmentation of the subduction interface both along-strike and downdip as illustrated by seismicity along many convergent margins. He also showed the difficulty of using past performance as an indicator of future behavior. There were numerous examples of the impact that lateral variations in the incoming plate have on the deformation and fluid flow in the upper plate. New studies of the Mediterranean basin described the feedbacks between sedimentation, accretion, backarc basin formation, slab rollback, and the seismic hazard potential of the segmented arcs that make up this plate boundary. N. Bangs presented preliminary results of a recent 3-D seismic survey of the forearc wedge offshore Costa Rica that showed depth-related variations in structural style with extension at shallow levels and contraction at deeper levels.

### Deformation Processes and Seismicity in the Forearc (and Deeper)

This session began with a keynote presentation by S. Lallemand on how the deformation of the downgoing oceanic plate, the state of stress of the upper plate as an indicator of elastic strain accumulation, and/or the “subduction channel” play(s) a role in the seismogenesis of subduction zones, with a global assessment of the upper and lower bounds of the seismogenic zone in terms of slab dip plate velocity and age of plate at the trench. The role of seamounts in seismogenesis and deformation of the upper plate was emphasized by several speakers and poster presenters because seamounts appear to show a complex behavior as nucleation points to earthquakes or barriers to rupture propagation. One topic of discussion that generated great interest was the relationship between permanent deformation, such as normal or thrust faults with a long, complicated slip history, and the stress variations associated with the earthquake cycle. S. Willett presented a keynote talk in which he used thermomechanical numerical models of forearc basin evolution to show that strata infill geometry could be used to evaluate the competition between sedimentation, which stabilizes the forearc, and the deformation that occurs outboard of the stable region. There was some consideration of the impact of tectonic erosion and accretion on seismicity in subduction zones, as well as new estimates of erosion rates based on forearc subsidence from the recent CRISP-IODP drilling offshore Costa Rica that are significantly faster than

previous estimates. This session included contributions on deformation processes from Nankai, Tohoku, Costa Rica, and New Zealand.

### Fluids and Forearc Properties

One of the highlights of this session was new high-resolution bathymetry data from the Costa Rica Margin (E. Silver, J. Kluesner) that was used to identify scarps and seeps that indicate focused fluid flow. Posters presented results of consolidation experiments on fluid flow parameters, coupled models of fluid flow and transport, analysis of velocity porosity relationships in different parts of the forearc system, and field studies of fluid alteration.

### Pre-Meeting Field Trip in the Ligurides

The two-day pre-conference field trip, led by F. Remitti and P. Vannucchi, focused on the east side of the Apennine chain, which corresponds to the shallowest part of the complex built by west-directed subduction. In this region, the Late Cretaceous–middle Eocene intraoceanic accretionary prism, built at the front of the European plate and represented by the External Ligurian Units, sits on top of Oligo-Miocene foredeep turbidites of the subducting Adria plate. Sandwiched between the two are more-or-less chaotic units of early Cretaceous–middle Miocene rocks forming the Sestola-Vidiciatico Tectonic Unit interpreted as the early-middle Miocene interplate shear zone—the object of the trip. During the first day, the field trip was organized around providing examples of the offscraped and frontally accreted oceanic and trench sediments forming the Ligurian prism, as well as the slope sediments unconformably deposited on top. On the second day, the field trip examined the units forming the plate boundary shear zone underthrust beneath the Ligurian units and overthrust above the Adriatic foredeep turbidites. Participants concentrated on the deformation of these units as well as on the evidence for incorporation of blocks from the upper plate dissected by faults that record layer parallel extension.

### Post-Meeting Field Trip in the Apuane Alps

The post-meeting field trip, led by G. Molli, provided the opportunity to examine structures and strain indicators from Apuane metamorphic rocks of the continental margin that were

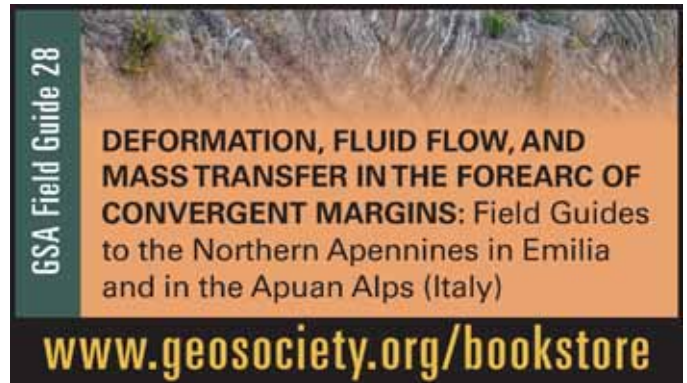
deforming at the same time as the Sestola-Vidiciatico Tectonic Unit. These units were underthrust and underplated in the early-middle Miocene and finally exhumed during the development of extensional structures starting from the late Miocene. Special emphasis was given to the deformed breccias from spectacular quarries of the Carrara marble. The role of fluids and fluid-rock interaction during underplating and exhumation was discussed in the context of extensional deformation.

## ACKNOWLEDGMENTS

We would like to thank the Tectonics Program of the National Science Foundation for support of graduate students and early career faculty. We would also like to thank the European Geosciences Union (EGU) for the support to P. Vannucchi and R. von Huene as EGU ambassadors. This meeting was cosponsored by the European Geosciences Union, the Italian Geological Society, the Spanish Ministry of Science and Innovation, and the U.S. National Science Foundation.

**Participants:** Tiago M. Alves, Nathan L. Bangs, Anne Bécel, Rocío Bernal-Olaya, Mirko Carlini, Wu-Cheng Chi, Irina Chursina, Mark Cloos, Jean-Yves Collot, Darrel S. Cowan, Stuart Crampin, Carlos Doglioni, Ake Fagereng, Donald M. Fisher, Marina Frederick, Thomas W. Gardner, Dibakar Ghosal, Sean S. Gulick, Kellen L. Gunderson, Peter J. Haeussler, Shuoshuo Han, Pierre Henry, Justin W. Herbert, Gaku Kimura, Joe D. Kington, IV, Jared Kluesner, Peter C. LaFemina, Serge Lallemand, Rachel Laver,

Maureen A. LeVoi, Pilar Llanes, Yossi Mart, Kylara M. Martin, Lisa C. McNeill, Kathryn Metcalf, Raphaelae Moeremans, Gregory F. Moore, Kristin Morell, Jason Phipps Morgan, Julia K. Morgan, Andrew Newman, Devon Anne Orme, Alina Polonia, César R. Ranero, Robert Reece, Francesca Remitti, Holly Rotman, Valenti Sallares, Julia Schneider, David W. Scholl, Eli A. Silver, Satish Singh, Gemma Smith, Telemaco Tesei, Frederik Tilmann, Harold J. Tobin, Joanne Tudge, Michael B. Underwood, Paola Vannucchi, Roland von Huene, Kelin Wang, Susanna I. Webb, Sean D. Willett, Lindsay Lowe Worthington, Asuka Yamaguchi, and Yuzuro Yamamoto.



United Nations  
Educational, Scientific and  
Cultural Organization

## Two New UNESCO World Heritage Sites Selected for Globally Outstanding Geologic Values

During the 24 June–6 July 2012 United Nations Educational, Scientific, and Cultural Organization (UNESCO) World Heritage Committee meeting in Saint Petersburg, Russia, two new UNESCO World Heritage Sites were selected for their globally outstanding geologic values: **Chengjiang Fossil Site, China**, and **Lena Pillars, Russian Federation**. The two sites were “inscribed” World Heritage under the World Heritage Convention criterion (viii): outstanding examples representing major stages of Earth’s history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features. Twenty-six new sites total were added to the World Heritage List during the 2012 meeting in Saint Petersburg.

GSA plays a role in this process through its International Program. GSA International Liaison, Wesley Hill, assists UNESCO, the International Union of Geological Sciences (IUGS), and the International Union for Conservation of Nature (IUCN) by finding global geologic desk-top evaluators to write a review of the sites during the selection review process.

Hill is currently working with the 2013 nominated sites and the review reporting process. Four sites have been nominated under criterion viii for the 2013 World Heritage selection process: Mount Etna, Italy; El Pinacate and Gran Desierto de Altar Biosphere Reserve, Mexico; Namib Sand Sea, Namibia; and Tajik National Park (Mountains of the Pamirs), Tajikistan. The 2013 World Heritage Site selections will be announced in June.

For more information on the newly inscribed 2012 UNESCO World Heritage Sites go to <http://whc.unesco.org/en/newproperties/>.



# In Memoriam



GSA notes with regret the deaths of the following Society members. Notifications were received between 1 May and 31 July 2012.

**Louis F. Blanchard**

El Paso, Texas, USA  
20 May 2009  
(notified 21 May 2012)

**Art D. Ettlinger**

Vancouver, B.C., Canada  
Notified 15 May 2012

**Robert H. Nanz Jr.**

Houston, Texas, USA  
20 May 2012

**Edgar E. St. James Jr.**

Katy, Texas, USA  
26 December 2011  
(notified 21 May 2012)

**William F. Brace**

Concord, Massachusetts, USA  
2 May 2012

**Ron Fray**

Platina, California, USA  
Notified 25 May 2012

**Stephen A. Norwick**

Rohnert Park, California, USA  
20 June 2012

**Iris M. Totten**

Manhattan, Kansas, USA  
26 May 2012

**Bruce W. Chappell**

Wollongong, NSW, Australia  
22 April 2012

**Claudia J. Lewis**

Santa Fe, New Mexico, USA  
Notified 9 May 2012

**Pierre Saint-Amand**

Ridgecrest, California, USA  
Notified 15 December 2011

**Bradford Babbitt Van Diver**

Black Mountain, North Carolina, USA  
26 April 2012

**Norma Westman Del Giudice**

Seattle, Washington, USA  
Notified 11 May 2012

**Arthur Mirsky**

Indianapolis, Indiana, USA  
23 June 2012

**Lowell R. Satin**

Anchorage, Alaska, USA  
26 April 2009  
(notified 24 July 2012)

To honor a friend or colleague with a GSA Memorial, please go to [www.geosociety.org/pubs/memorials/mmlGuid.htm](http://www.geosociety.org/pubs/memorials/mmlGuid.htm) to learn how. Contact the GSA Foundation, [www.gsafweb.org](http://www.gsafweb.org), if you would like to contribute to the Memorial Fund.



## About People

GSA Fellow **Kirk Johnson**, chief curator and vice president of research and collections at the Denver Museum of Nature & Science, has been named Director of the Smithsonian's National Museum of Natural History.

GSA Fellow **Peter Buseck** of Arizona State University has had the considerable honor of having a mineral named after him. The mineral, buseckite, was discovered in a meteorite found near the village of Zakłodzie, Poland. The discovery is detailed in a 2012 *American Mineralogist* article (v. 97, p. 1226–1233).

Learn more and catch up on other member news at [www.geosociety.org/news/memberNews.htm](http://www.geosociety.org/news/memberNews.htm).

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## Call for Proposals

2013 ANNUAL MEETING & EXPOSITION

# Celebrating Advances in Geoscience

Denver, Colorado, USA, 27–30 October

Annual meeting session proposals are now being accepted.  
Help shape the 2013 Annual Meeting and be a part of the 125th Anniversary!

### 2013 Field Trips

Proposals due **3 Dec. 2012**

Any GSA member can propose a field trip; use this opportunity to teach your colleagues and peers about the breathtaking geology of the Denver, Colorado, USA, region. Trips can be anywhere from a half day to 5 days long. Questions? Contact Beth Engle, +1-303-357-1006, [bengle@geosociety.org](mailto:bengle@geosociety.org).

### 2013 Technical Sessions

Proposals due **8 Jan. 2013**

Share your knowledge, experience, and research, and draw from a myriad of geoscience experts by submitting a technical session proposal. Help mold what is sure to be a dynamic technical program at next year's 125th Anniversary Meeting in Denver.

### 2013 Short Courses

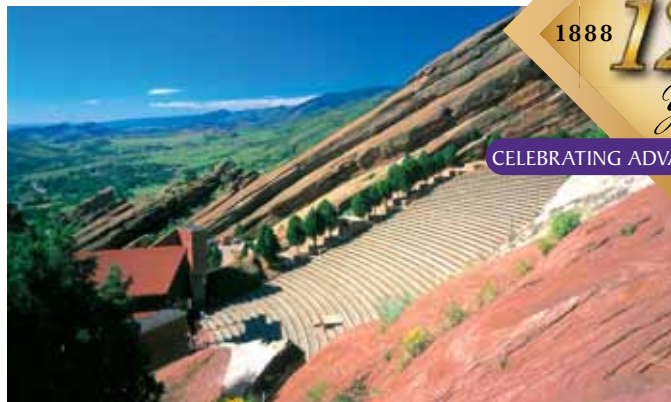
Proposals due **1 Feb. 2013**

Short courses make a great start to the annual meeting. Offer a short course to help your colleagues, peers, students, and K–12 teachers develop professional, teaching, and research skills at all levels, and be a part of the action. Questions? Contact Jennifer Nocerino, [jnocerino@geosociety.org](mailto:jnocerino@geosociety.org).



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Red Rocks Amphitheatre. Photo by Ron Ruhoff. Photo courtesy Denver Metro Convention & Visitors Bureau.



Echo Lake with Mount Evans in the background. Photo by Richard Grant, courtesy Denver Metro Convention & Visitors Bureau.

[www.geosociety.org/meetings/2013/](http://www.geosociety.org/meetings/2013/)



# GSA ANNUAL MEETING & EXPOSITION

4–7 NOVEMBER 2012 • CHARLOTTE, NORTH CAROLINA, USA

In just a few weeks, thousands of geoscience professionals and their guests will travel to Charlotte for several days of learning, networking, camaraderie, and just plain fun! Over the past several months, we have highlighted some of the fantastic opportunities that await you in Charlotte. If you missed any of the articles, you can still read about it online.

GSA is a professional society with a global and growing membership of more than 25,000 individuals at the forefront of geoscience research. In today's

world, it is imperative that you, our members, have a platform to present your cutting-edge research. This is the first time in more than 25 years that GSA's Annual Meeting has been held in the Southeast, so we hope that you have chosen to take advantage of this opportunity. If you haven't registered yet, there's still time. You can even register online throughout the meeting or at the onsite registration desk.

We look forward to welcoming you to Charlotte, North Carolina, USA!



**REMINDER:** ELECTION DAY is 6 November (during the meeting): GSA recommends that U.S. citizens coming to the meeting vote early or sign up for an absentee ballot in order to ensure that all geoscience voices are heard!

[www.geosociety.org/meetings/2012/](http://www.geosociety.org/meetings/2012/)

# Lunchtime Lectures



## LUNCHTIME LECTURES

Please join us during the lunch hour (12:15 to 1:15) each day during the meeting for these extraordinary opportunities to hear from some of GSA's best and brightest and to discuss topics important to geoscience and society. Learn more about these lecturers on the meeting website.

### LUNCHTIME LECTURE 1

#### GSA Presidential Address and Presentation of the President's Medal

Sunday, 4 Nov., 12:15–1:15 p.m.

Charlotte Convention Center, Ballroom A

Please join us for this special lunchtime lecture—the Presidential Address of GSA President George H. Davis, “Where Our Deepest Passions Intersect the World’s Compelling Needs.” Following this address, GSA Past President John W. Geissman will present the President’s Medal to Bill McKibben, author, educator, environmentalist, and Scholar in Residence in Environmental Studies at Middlebury College. *All are welcome*; no reservations, tickets, or meeting registration are required to attend.

### LUNCHTIME LECTURE 2

#### GSA Awards Ceremony

Monday, 5 Nov., 12:15–1:15 p.m.

Charlotte Convention Center, Ballroom A

Please join GSA's President George H. Davis and GSA's Vice President Suzanne Mahlborg Kay to honor and greet the GSA medal and award recipients for 2012. Citations and responses for the 2012 recipients of the Penrose Medal, the Arthur L. Day Medal, the Young Scientist Award (Donath Medal), the GSA Public Service Award Medal, the GSA Distinguished Service Award, The Subaru Outstanding Woman in Science Awardee, The Bromery Award for the Minorities, and the American Geological Institute (AGI) Medal in Memory of Ian Campbell will be presented. The John C. Frye Environmental Geology Awardee, the ExxonMobil Field Camp Awardee, the GSA Division awardees, the International Section's Honorary Fellow, and the newly elected GSA Fellows will also be recognized. *All are welcome*; no reservations, tickets, or meeting registration are required to attend.

### LUNCHTIME LECTURE 3

#### SWITCH: The Global Energy Transition

Scott W. Tinker, 2012 Michel T. Halbouty Lecturer

Tuesday, 6 Nov., 12:15–1:15 p.m.

Charlotte Convention Center, Ballroom A

GSA Fellow Scott Tinker is the state geologist of Texas, director of the Bureau of Economic Geology, director of the Advanced Energy Consortium, and the Allday Endowed Chair and acting Associate Dean of Research at The University of Texas (UT) at Austin's Jackson School of Geosciences. Tinker spent 17 years in the oil and gas industry prior to joining UT in 2000.

Tinker's passion is building bridges between academia, industry, and government. Toward that end, he has given nearly 500 invited and keynote lectures, visited over 45 countries, and most recently produced and is featured in the acclaimed documentary film on global energy, *SWITCH*.

You will have two opportunities to view *SWITCH* before hearing Tinker's lecture: Sunday and Monday, 4–5 Nov., 9–11 a.m., in Ballroom A at the Charlotte Convention Center.

### LUNCHTIME LECTURE 4

#### What Do the Election Results Mean for Science?

David Conover and Albert Teich

Wednesday, 7 Nov., 12:15–1:15 p.m.

Charlotte Convention Center, Ballroom A

The long election season will finally be over on 7 Nov. What do the results of the presidential and congressional races mean for science? This distinguished panel, moderated by GSA Director for Geoscience Policy Kasey White, will examine how election results will shape environmental and energy policy, federal funding for geoscience research and minerals development, and more.

**David Conover** has more than 20 years of experience in public policy, having served in the executive and legislative branches of the U.S. government, as well as in the private sector at a major corporation. Conover is currently senior vice president at Dutko Grayling. He holds a J.D. *cum laude* from the Georgetown University Law Center and a B.A. with highest honors from the University of Virginia and is licensed to practice law in Virginia.

**Albert Teich** is Research Professor of Science, Technology & International Affairs at the Center for International Science & Technology Policy in the Elliott School at George Washington University. From Feb. 1990 through Dec. 2010, he served as director of Science & Policy Programs at the American Association for the Advancement of Science (AAAS). He earned a B.S. in physics (1964) and a Ph.D. in political science (1969), both from MIT.



**PARDEE KEYNOTE SYMPOSIA HIGHLIGHTS**

Symposia are special sessions consisting of invited abstracts on innovative topics presented in a creative way. See the July and August issues of *GSA Today* for descriptions of the other four symposia, or go online, [www.geosociety.org/meetings/2012](http://www.geosociety.org/meetings/2012).

- 4. **Shale Gas Development and Hydraulic Fracturing Impacts on Water Resources in the United States.** Avner Vengosh, Brian W. Stewart, Jennifer C. McIntosh, Susan L. Brantley. Cosponsored by *GSA Hydrogeology Division*.

Advances in drilling technologies and production strategies such as horizontal drilling and hydraulic fracturing have significantly improved the production of natural gas by stimulating the flow of gas and liquids to and from wells. New research is highlighting the need to make shale-gas extraction as sustainable as possible. This Pardee Symposium addresses the key issues related to the possible impacts of shale gas development on water resources in the U.S. and includes key professionals from academia and industry who will present their often-debated perspective on the possible effects on the quantity and quality of water resources.

- 5. **Supercontinent Cycles through Earth History.** A. Krishna Sinha, Kent Condie, Robert D. Hatcher. Cosponsored by *GSA Structural Geology and Tectonics Division; GSA Geophysics Division; GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division*.

This symposium will discuss the geologic framework of supercontinent cycles through Earth's history, including the implications of tectonic, petrologic, geochronologic and biologic processes.

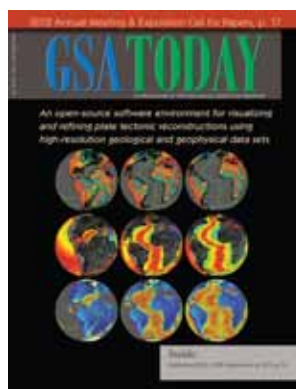


Plate tectonic reconstructions using GPlates. April/May 2012 *GSA Today* cover image courtesy Sabin Zahirovic, Earthbyte Group.

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# Staying and Playing



Glory Road at the NASCAR Hall of Fame. Image ©Sean Busher and NASCAR Hall of Fame.

# CHARLOTTE

## ➔ MORE THINGS TO DO & SEE IN CHARLOTTE

Now that the technical program is set, it's time to think about what you want to experience in the Queen City! These four museums are located within a block or two of the Charlotte Convention Center. All but the NASCAR Hall of Fame (which is adjacent to the convention center) are part of the Levine Center for the Arts.

If you are looking for shopping in Charlotte Center City, look no further than the museum gift shops! Information on the various museums located in the area will be available onsite in the Guest Hospitality Suite and at the City Information Booth, both in the Charlotte Convention Center.

### NASCAR HALL OF FAME

If you are looking for a **high-tech, interactive museum tour with your friends**, this is the one for you! The NASCAR Hall of Fame is a great place to go for a little friendly competition. The not-to-be-missed activities include the **Pit Challenge**, in which teams of three compete for the fastest pit stop. This includes jacking up the car, changing the tire, and adding fuel. Can you beat the GSA Meetings Dept. team time of 18 seconds? Watch the video at [www.geosociety.org/meetings/2012/nascar.htm](http://www.geosociety.org/meetings/2012/nascar.htm). You can also race against your friends in the qualifying and racing simulators. Designed by iRacing, they provide the most authentic virtual driving experience around. Challenge Dick Berg, the reigning GSA Race Champion and current Technical Program Chair, to a race! Even non-NASCAR fans will have fun with the hands-on activities. If you are a gamer, there are 50-plus hands-on digital kiosks that will keep you occupied. Your entry card has RFID technology, so you can continue your visit on your home computer. Discounted tickets can be purchased in advance or onsite through GSA Annual Meeting Registration.

### GANTT CENTER FOR AFRICAN-AMERICAN ARTS + CULTURE

The Harvey B. Gantt Center for African-American Arts + Culture is named in honor of Harvey Bernard Gantt, a well-respected community leader and businessman who was the first

African-American student admitted to Clemson University and Charlotte's first African-American mayor. The Hewitt Collection of African-American Art is a permanent display that celebrates the expression and passion of twenty artists, including Romare Bearden, Margaret Burroughs, Jonathan Green, Jacob Lawrence, Elizabeth Catlett, and Henry Ossawa Tanner. The current touring exhibit is "America I AM: The African American imprint," which celebrates nearly 500 years of African-American contributions to the United States.

### BECHTLER MUSEUM OF MODERN ART

The Bechtler Museum displays works by some of the most important and influential artists of the mid-20th century, including Miró, Giacometti, Picasso, Calder, Hepworth, Nicholson, Warhol, Tinguely, Ernst, Le Corbusier, and Chillida. The museum itself is a work of art—it is only the second in this country to be designed by Swiss architect Mario Motta. The building's dominant feature is the expansive fourth-floor gallery. It includes floor-to-ceiling windows that surround an atrium, offering frame-like views of the art from one side of the floor to the other. Until recently, the collection was privately held by the Bechtler family of Switzerland, and only a handful of these wonderful pieces had been on public view in the United States.

### MINT MUSEUM UPTOWN

This museum features the internationally renowned Craft + Design collection, as well as outstanding collections of American, contemporary, and European art. You'll also find work by Childe Hassam, Robert Henri, and Ansel Adams. The Craft + Design collection is made up of crafts in glass, fiber art, metal, studio jewelry, design, studio furniture, wood art, and clay. The Charlotte area was built on crafts and textiles, and this museum, known as one of the top craft museums in the nation, celebrates that history.



## Upcoming GSA Foundation Events in Charlotte

As the 2012 GSA Annual Meeting approaches, the GSA Foundation Board and staff are ramping up for a number of events that inform members of the programs we are able to support at GSA and that celebrate the remarkable generosity of GSA members and corporate supporters.

For longtime meeting attendees and Foundation supporters, these will be familiar. If this is your first GSA Annual Meeting in a while, or if you have only recently begun to contribute to GSA programs through the Foundation, here is a synopsis of planned activities.

**The GSA Foundation Booth** will be on the exhibit floor in the Charlotte Convention Center, GSA Headquarters area. Foundation staff will be able to answer any questions you may have about the GSA programs we support, about your past or current giving to the Foundation, and about any future plans or ideas you might have concerning the Foundation's efforts on behalf of the Society. We will also be happy to talk to you about including GSA in your estate plans. The ever-popular **Silent Auction**, featuring rock and mineral specimens, books and geological reports (some as old as GSA), field gear, wine, and more will also be in this area of the exhibit hall.

**Students** who have made a gift to the Foundation should stop by the booth to receive a token of our appreciation and a ribbon identifying you as a Foundation donor to attach to your badge.

The Foundation will host several social events to honor both donors and recipients. Most of these are by invitation; if you would like information about attending, please ask our staff.

- The **GSA Foundation Board** will hold its semi-annual business meeting on Saturday, 3 Nov. GSA members who have an interest in being involved in the work of the Foundation on behalf of GSA may wish to attend;
- The **Pardee Coterie Breakfast** on Sunday, 4 Nov., for those who have included the Foundation in their estate plans;
- The **Student Research Award Ceremony** on Monday, 5 Nov.;
- The **Senior Fellows Reception** on Tuesday, 6 Nov.;
- The **Penrose Circle Lounge** will be open in the Convention Center roughly coincident with the hours of the technical sessions to provide all Penrose Circle donors a quiet place to meet colleagues, leave luggage or umbrellas, get online, print boarding passes, and simply relax away from the hubbub of the meeting.

If you are a student interested in the many research and travel grants or GeoCorps™ America internships that the Foundation supports, a faculty member who would like to learn more so you can advise your students about these opportunities, or a present or future donor to the Foundation who would like to understand the impact of member support on GSA programs, please drop by the Foundation booth to chat.

[www.gsafweb.org](http://www.gsafweb.org)

If you would like to make a contribution to the Foundation, please go to [www.gsafweb.org/makeadonation.html](http://www.gsafweb.org/makeadonation.html) or contact Anna Christensen, Chief Development Officer, GSA Foundation, +1-303-357-1007, [achristensen@geosociety.org](mailto:achristensen@geosociety.org).

## Classified Rates—2012

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

| Classification             | Per Line for 1st month | Per line each add'l month (same ad) |
|----------------------------|------------------------|-------------------------------------|
| Positions Open             | \$8.95                 | \$8.70                              |
| Fellowship Opportunities   | \$8.95                 | \$8.70                              |
| Opportunities for Students |                        |                                     |
| First 25 lines             | \$0.00                 | \$4.75                              |
| Additional lines           | \$4.75                 | \$4.75                              |

## Positions Open

### GEOLOGY AND GEOPHYSICS POSITIONS TEXAS A&M UNIVERSITY

**Assistant Professor in Geology and Geophysics—Hydrogeology:** We seek a field-based hydrogeologist whose interests complement existing departmental strengths, including laboratory and theoretical studies, fluvial geomorphology, fractured reservoirs, rock physics, and isotope and environmental geochemistry. The successful candidate will be expected to develop and maintain a vigorous, externally-funded research program, and teach introductory geology and graduate-level courses in specialized topics.

**Assistant Professor in Geology and Geophysics—Reflection Seismology:** The successful candidate will establish an active, innovative externally funded research program that emphasizes the use of geophysical techniques interpreting subsurface geology. Preference will be given to applicants whose interests complement current departmental strengths in petroleum geology and geophysics, sedimentology, stratigraphy, and structural geology. The successful candidate will be expected to teach effectively at the undergraduate and graduate levels in their specialty, including classes in the Petroleum Certificate curriculum and to supervise undergraduate, M.S. and Ph.D. research, including students who are interested in pursuing careers in the petroleum industry.

**Assistant Professor in Geology and Geophysics—Rock Mechanics/Rheology/Structure:** The successful applicant will establish an active research program in the Department Geology and Geophysics and the Center for Tectonophysics. We are particularly interested in individuals who creatively combine experimental rock mechanics with observational or theoretical approaches in conducting research that is important and timely. Preference will be given to applicants whose interests complement and broaden our existing strengths in poromechanics, fracture and earthquake physics, rheology of the crust and uppermost mantle, and multidisciplinary studies of natural and engineered subsurface systems.

**Assistant Professor in Geology and Geophysics—Sedimentology/Stratigraphy:** The successful can-

didate will be expected to initiate and maintain a vigorous, externally-funded research program that could include sequence stratigraphy, the sedimentary record of long-term climate change, depositional processes, diagenesis, or any related area of study. In addition, the candidate will be expected to teach effectively at the undergraduate and graduate levels in his or her specialty and to supervise undergraduate, M.S., and Ph.D. research.

**All positions require a Ph.D.** in a related field. Post-doctoral research and teaching experience is preferred. Applicants should demonstrate a strong record of scholarship and the potential for developing an internationally recognized research and teaching program. Review of applications will begin 30 Oct. 2012 and will continue until a suitable candidate is found. Applicants should submit a PDF file containing a letter of application, curriculum vitae with details of published work, a statement of research and teaching interests, and contact information (including e-mail) for at least four references to [michelebeal@tamu.edu](mailto:michelebeal@tamu.edu).

The successful candidates will be encouraged to participate in interdisciplinary research and teaching programs of the College of Geosciences, including the Berg-Hughes Center for Petroleum and Sedimentary Systems, the Center for Tectonophysics, the Integrated Ocean Drilling Program (IODP), and the Water Management & Hydrologic Science Program, and in programs of other Colleges of the University. Texas A&M University, a land-, sea-, and space-grant university, is located in a metropolitan area with a dynamic and international community of 172,000 people. Texas A&M University is an affirmative action/equal opportunity employer committed to excellence through the recruitment and retention of a diverse faculty and student body and compliance with the Americans with Disabilities Act. We encourage applications from minorities, women, veterans, and persons with disabilities. Texas A&M University also has a policy of being responsive to the needs of dual-career partners ([employees.tamu.edu/Jobs/careers/dcsDetails.aspx](http://employees.tamu.edu/Jobs/careers/dcsDetails.aspx)).

### ASSOCIATE ISOTOPE GEOCHEMIST OR ISOTOPE GEOCHEMIST (DEPENDING ON QUALIFICATIONS) ILLINOIS STATE GEOLOGICAL SURVEY PRAIRIE RESEARCH INSTITUTE UNIV. OF ILLINOIS AT URBANA—CHAMPAIGN

We are seeking an individual to fill one position. The successful individual's qualifications will determine the level to which he/she is appointed.

Responsibilities include: Design, initiate, and complete investigations of light stable isotopes plus radiocarbon and tritium to help solve environmental, energy, and geological problems through basic and applied research. Conduct and assist research on existing projects and programs (e.g., carbon sequestration, enhanced oil recovery). Communicate results of those investigations in a variety of formats and venues. Minimum qualifications: Master's degree in geology, chemistry, or related discipline. Ph.D. preferred. Seven years (for Associate Isotope Geochemist level) or twelve years (for Isotope Geochemist level) related industry and/or research experience post bachelor's degree. Demonstrated

ability to conduct research in light stable isotope geochemistry. Demonstrated scientific leadership qualities. Ability or demonstrated ability to acquire external funds. Established publications record. For a complete description of the position and qualifications please visit [www.isgs.uiuc.edu/about-isgs/employment/iso-geochemist.shtml](http://www.isgs.uiuc.edu/about-isgs/employment/iso-geochemist.shtml).

To apply all candidates must submit an online profile through [jobs.illinois.edu](http://jobs.illinois.edu) by the close of the posting period. Qualified candidates must upload a letter of application which details qualifications noted above, résumé, and the names, addresses, phone numbers, and e-mail addresses of three professional references. All requested information must be submitted for your application to be considered. Incomplete information will not be reviewed. Applications must be received by 31 Oct. 2012.

For further information please contact Lori Walston-Vonderharr, Human Resources, Illinois State Geological Survey, at [lwalston@illinois.edu](mailto:lwalston@illinois.edu) or +1-217-244-2401.

The University of Illinois is an Affirmative Action, Equal Opportunity Employer, [www.inclusiveillinois.illinois.edu](http://www.inclusiveillinois.illinois.edu).

### ASSISTANT PROFESSOR, SEDIMENTARY PROCESSES, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

The Department of Earth, Atmospheric and Planetary Sciences at the Massachusetts Institute of Technology invites applications for a junior faculty position in Sedimentary Processes. We seek an individual with broad interests, a research program that includes field observations, and a commitment to interdisciplinary studies. **Applicants should submit a curriculum vitae; one-page descriptions of research and teaching plans; and the names, e-mail addresses, and phone numbers of three professional referees by 14 Dec. 2012.** Please do not ask your referees to upload letters at the time of application; letters will be requested directly by MIT. Questions may be addressed to Prof. Leigh Royden, Search Committee Chair, at [lroyden@mit.edu](mailto:lroyden@mit.edu). Applications are being accepted at Academic Jobs Online (<https://academicjobsonline.org/ajo>). To receive consideration, a complete application must be received. Search Contact: Mr. Michael Richard, HR Administrator, EAPS, 54-912 Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139-4307; e-mail: [mjr@mit.edu](mailto:mjr@mit.edu); phone: +1-617-253-5184; fax: +1-617-253-8298. MIT is an Equal Opportunity/Affirmative Action employer. Applications from women and underrepresented minority candidates are encouraged. MIT is a non-smoking environment.

### ASSOCIATE, FULL PROFESSOR PETROLEUM GEOLOGY MIDWESTERN STATE UNIVERSITY

The Department of Chemistry, Physics, and Geosciences invites applications for the Robert L. Bolin Distinguished Professor of Petroleum Geology (a tenure-track position) to begin Spring 2013. We seek candidates with **expertise in petroleum geology, source/reservoir characterization, or exploration geophysics**. The successful candidate will **teach introductory courses, Petroleum Geology, and other**

**appropriate upper-level courses.** Experience in developing a successful undergraduate research program will be given special consideration. Requirements include a Ph.D. in geosciences, strong interpersonal skills, and publications in refereed journals commensurate with experience. MSU is a comprehensive public university serving over 6000 students. The Geosciences Program has strong ties with regional petroleum exploration and environmental science communities and is poised for continued growth in the next five years. Send an application letter, CV, statements of teaching and research interests, and the names and contact information of three references to Dr. R.L. Dodge, Geosciences, Midwestern State University, 3410 Taft Blvd., Wichita Falls, TX 76308; email: [rebecca.dodge@mwsu.edu](mailto:rebecca.dodge@mwsu.edu). Review of applications will begin immediately, and this position will remain open until filled. This position is designated as security sensitive and requires the finalist to complete a criminal background check. EEO/ADAAA compliance employer.

**TENURE-TRACK POSITION  
ENVIRONMENTAL (LOW TEMPERATURE)  
GEOCHEMIST DEPARTMENT OF  
GEOLOGICAL SCIENCES, CALIFORNIA STATE  
UNIVERSITY LONG BEACH**

Assistant or Associate Professor: Rank and salary depend upon qualifications and experiences. Start date: 19 August 2013.

**Qualifications:** Ph.D. in the Geological Sciences or closely related field and record of successful, grant-supported research in environmental geochemistry with focus on low-temperature fluid-solid earth material interaction. Candidate must be able to communicate effectively with an ethnically and culturally diverse campus community and demonstrate potential for excellence in teaching and for developing and sustaining an independent, externally funded research program involving students. Demonstrated excellence in teaching and a record of published research in environmental geochemistry are desired. The successful candidate will utilize the broad range of analytic instrumentation in the Signal Hill Environmental Geochemistry laboratory and the CSULB Institute for Integrated Research in Materials, Environment, and Society.

For further information, see [www.csulb.edu/divisions/aa/personnel/jobs/cnsm/](http://www.csulb.edu/divisions/aa/personnel/jobs/cnsm/).

**Application:** Review of applications begins 14 Jan. 2013; position open until filled. Send letter of application, CV, statement of teaching/research goals, and three letters of recommendation directly from referees to Geological Sciences Search Committee, Dept. of Geological Sciences, California State University, Long Beach, 1250 Bellflower Blvd. Long Beach, CA 90840-3902; telephone: +1-562-985-4809; e-mail: [envgeochem@csulb.edu](mailto:envgeochem@csulb.edu). CSULB is an Equal Opportunity Employer.

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

The Department of Geography, Geology and Planning invites applications for a tenure-track Assistant

Professor with an emphasis in Structural Geology and Mineralogy to begin in **August 2013**. Ph.D. (or ABD) in Geology or closely related field required at time of appointment. Expertise in Mineralogy and Structural Geology at a level adequate to supervise master's level graduate students, an aggressive research agenda documented by a detailed research plan, and a commitment to both undergraduate and master's-level teaching and service are required. Be able to facilitate a work environment that encourages knowledge of, respect for, and development of skills to engage with those of other cultures or backgrounds. Demonstrated knowledge and understanding of multicultural and diversity issues. Post-doctoral research experience and evidence of teaching effectiveness would be advantageous.

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

Apply online at [www.missouristate.edu/academicopenings](http://www.missouristate.edu/academicopenings). Attach a letter of application, curriculum vitae, detailed research plan, and contact information for 3–5 professional references to the electronic employment application. The evaluation of applications will begin **31 Oct. 2012** and will continue until a successful candidate is found. Further information can be obtained at +1-417-836-5800; fax +1-417-836-6006; e-mail: [GP@missouristate.edu](mailto:GP@missouristate.edu), or visit our website at [geosciences.missouristate.edu](http://geosciences.missouristate.edu). Missouri State University is an affirmative action/equal opportunity institution. The University is dedicated to the goal of building a culturally diverse and inclusive faculty and staff committed to teaching and working in a multicultural environment and strongly encourages applications from women, persons for underrepresented ethnic and racial groups, individuals with disabilities and covered veterans. Employment will require a criminal background check at University expense.

**ASSISTANT PROFESSOR  
QUANTITATIVE STRUCTURAL GEOLOGY  
OR GEOMECHANICS  
WEST VIRGINIA UNIVERSITY**

The Dept. of Geology and Geography at West Virginia University seeks to hire an Assistant Professor specializing in quantitative structural geology with interest in the study of fractured reservoirs and geomechanics. The successful candidate will have the opportunity to develop a vigorous externally-funded research program which contributes to the area of energy resources and to the WVU Advanced Energy Initiative ([energyresearch.wvu.edu](http://energyresearch.wvu.edu)). The new hire will also teach courses in geology at the undergraduate and graduate levels to help meet the department's growing enrolment. Applicants should have a Ph.D. in geology, earth science or related field by the start date. Evidence of ability to establish a strong externally-funded research program and of commitment to teaching excellence at the undergraduate and graduate levels in geology is required. We are open to candidates with diverse academic and professional backgrounds. The department values intellectual

diversity and demonstrated ability to work with diverse students and colleagues.

Candidates should apply by sending a .pdf file with all their application materials as an e-mail attachment to [jtoro@wvu.edu](mailto:jtoro@wvu.edu). Questions may be addressed to Dr. Jaime Toro at the same address or via telephone at +1-304-293-9817. The submitted .pdf file should include (1) a letter of application detailing research and teaching interests and how these relate to departmental research activities; (2) resume/curriculum vitae; (3) names and complete contact information for three references. Review of applications will begin 15 Oct. 2012 and continue until the position is filled. The anticipated start date is 16 Aug. 2013.

Please see [www.geo.wvu.edu/files/geomechanics.pdf](http://www.geo.wvu.edu/files/geomechanics.pdf) for additional information.

West Virginia University is an affirmative action, equal opportunity employer. Applications from women, minorities, individuals with disabilities and covered veterans are encouraged.

**TENURE-TRACK, ASSISTANT PROFESSOR  
STRUCTURAL GEOLOGY  
MARSHALL UNIVERSITY**

The Geology Dept. at Marshall University invites applications for a tenure-track position in Structural Geology at the Assistant Professor level beginning Fall Semester 2013. A Ph.D. is preferred at the time of appointment, but outstanding ABDs will be considered. We seek first and foremost an outstanding teacher or the demonstrated potential to become one. Primary upper level teaching responsibilities will be courses in Structural Geology, Geologic Field Mapping, and Computer Methods. Introductory teaching responsibilities will include Physical Geology. In addition, the ability to develop and teach Geophysics is desirable. The Geology Dept. also seeks candidates who will contribute to the University's general education curriculum with its emphasis on a common First Year Seminar and core curriculum courses that enhance student's critical thinking, and the College's support of Interdisciplinary programs of study. The normal teaching load includes one upper level and one introductory course per semester. Release time will be given to the successful candidate during the first three years to facilitate the development of a high quality, externally supported research program. The Geology Dept. places a high priority on a field-oriented approach to teaching and research, and commitment to undergraduate research. Interest and/or experience with Appalachian geology are also desirable. For more information, please visit [www.marshall.edu/geology](http://www.marshall.edu/geology). **If you are attending the Geological Society of America Annual Meeting, 4–7 Nov. 2012, in Charlotte, North Carolina, please stop by our booth to talk with a representative of the Marshall Geology Dept.**

Applicants must send a cover letter, current curriculum vitae, statements of research plans and teaching philosophy, and selected reprints, as a single PDF file referencing Search 12911 to [recruiting@marshall.edu](mailto:recruiting@marshall.edu). Applicants must also request that three letters of reference be sent to the same address. All applications and supporting material must include your name and the position number in the subject line of the email. Candidates who are

invited to campus for interviews must have official undergraduate and graduate transcripts sent by their degree granting institutions prior to the interview date. Review of applications will begin on 15 Nov. 2012, and continue until the position is filled. Marshall University is the recipient of the U.S. Labor Department's EVE Award for its Affirmative Action Employment Opportunity Programs. Additional information about Marshall University and Huntington may be found at [www.marshall.edu/mu-advance/candidates.asp](http://www.marshall.edu/mu-advance/candidates.asp).

#### HYDROGEOLOGIST

##### (ASSISTANT PROFESSOR, TENURE-ELIGIBLE) WICHITA STATE UNIVERSITY

The Dept. of Geology at Wichita State University invites applications for a faculty position in hydrogeology beginning August 2013. We are seeking to hire a tenure-eligible assistant professor. In particular, we seek a candidate with research expertise in environmental and ground water issues, complemented with a knowledge of computer modeling and an interest in sustainability. In addition to developing an externally funded research program, successful candidates will be expected to teach introductory, major, and graduate level classes. The candidate must have a Ph.D. in the Geosciences, an established record of publication commensurate with the applicant's career stage, and is expected to complement our existing departmental strengths in low-temperature geochemistry, paleontology, petroleum geology, sedimentology, stratigraphy, and structural geology and interact with broader segments of the WSU community.

Candidates must go on line at <http://jobs.wichita.edu> to apply for the position. Interested applicants should submit cover letter, curriculum vitae, statements of research and teaching interests, and contact information for at least three references. Applicants should also send copies of relevant publications to the Search Committee Chair, Dept. of Geology, 1845 Fairmount Ave., Wichita State University, Wichita, KS 67260-0027. We will begin review of applications after 15 Oct. 2012; however, applications will be accepted until the position is filled. Wichita State University is an equal employment opportunity/affirmative action employer. Applicants with an interest in broadening participation in higher education and members of under-represented groups are encouraged to apply. Offers of employment are contingent upon completion of a satisfactory criminal background check as required by Board of Regents policy.

#### STRATIGRAPHY FACULTY POSITION UNIVERSITY OF KENTUCKY

The Dept. of Earth and Environmental Sciences at the University of Kentucky invites applications for the **Pioneer Natural Resources Professor in Stratigraphy** beginning August 2013. We are anticipating a hire at the assistant professor level (tenure-track), but exceptional candidates at a more senior level will be considered. We seek candidates with field-oriented and/or numerical-modeling expertise in particular. In addition to maintaining a productive externally funded research program, the new faculty member will teach and mentor at the introductory, major, and

graduate levels. The successful individual will have a demonstrated publication record and potential for developing a nationally recognized research program; relevant experience beyond the Ph.D. is desirable. Interested applicants should submit a merged .pdf document to Stratigraphy Search Committee, c/o Dr. Ed Woolery ([woolery@uky.edu](mailto:woolery@uky.edu)). The document should include: cover letter, curriculum vitae, brief statements of research and teaching interests, copies of relevant research publications, and contact information for at least three references. We will begin review of applications on Dec. 01, 2012; however, applications will be accepted until the position is filled. The University of Kentucky is an Affirmative Action/Equal Opportunity university that values diversity and is located in an increasingly diverse geographical region. Women, persons with disabilities, and members of other under-represented groups are encouraged to apply. The University also supports family-friendly policies. Additional details of the Dept. of Earth and Environmental Sciences (faculty, research clusters, and facilities) and the University of Kentucky may be viewed at our web pages: [www.as.uky.edu/ees](http://www.as.uky.edu/ees) and [www.uky.edu](http://www.uky.edu).

#### POST-DOCTORAL OPPORTUNITY IN GEOSTATISTICS, THE UNIVERSITY OF DELAWARE

The Dept. of Geological Sciences at the University of Delaware has an opening for a postdoctoral researcher to work on an NSF-sponsored project on continental shelf-scale processes of aquifer-ocean interactions. The project will involve geostatistical modeling of the Hawaiian Islands and the Bengal Basin. Experience in geostatistical modeling is preferred. Interested applicants should apply online at [www.udel.edu/udjobs](http://www.udel.edu/udjobs).

For additional information contact Dr. Holly Michael ([hmmichael@udel.edu](mailto:hmmichael@udel.edu)). Anticipated start date is 1 Sept. 2013.

The UNIVERSITY OF DELAWARE is an Equal Opportunity Employer.

#### ASSISTANT PROFESSOR, GEOLOGY UNIVERSITY OF TORONTO

The Dept. of Earth Sciences, University of Toronto, invites applications from outstanding individuals for a tenure-stream appointment at the rank of Assistant Professor.

The appointment will begin on 1 July 2013 and is in the fields of geology applied to the formation/evolution of the Earth's solid crust, preferably those related to metamorphic processes. This may include, for example, candidates engaged in mineralogy/petrology, structural geology, geochemistry, economic geology and mineral deposits, or cross-disciplinary research in these general areas. Applicants must have a Ph.D. or be near completion.

In addition to establishing an internationally recognized independent research program, the successful candidate must have a strong commitment to teaching. He/she will be expected to teach introductory geoscience courses and graduate and upper level undergraduate courses in fields related to their specialization, and conduct field-based teaching of undergraduate and graduate students. Candidates must display evidence of excellence in teaching and

research. Salary to be commensurate with qualifications and experience.

All application materials should be submitted online, please visit <http://uoft.me/academicopportunities> Job #1201005. Applications should include a cover letter, curriculum vitae, including a list of publications and a brief statement describing the applicant's research program and teaching philosophy. Applicants should also ask three referees to send letters directly to: [geol\\_sec@es.utoronto.ca](mailto:geol_sec@es.utoronto.ca) by the closing date, 1 Nov. 2012. For more information about the Dept. of Earth Sciences, please visit our home page at: [www.es.utoronto.ca](http://www.es.utoronto.ca)

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.

All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority.

#### ASSISTANT PROFESSOR GEOLOGY/PHYSICAL GEOGRAPHY SALISBURY UNIVERSITY

Salisbury University seeks a Tenure-Track Assistant Professor in Geology/Physical Geography.

**Area of Specialization:** Groundwater hydrology, stratigraphy, sedimentology or coastal plain geology preferred.

**Primary Job Duties:** Teach up to 24 credit hours (or equivalent) per year. This will include undergraduate courses and labs to support the Earth Science major and the Physical Geography tracks within the Geography major; may also include teaching field-based courses. The faculty member is expected to conduct undergraduate research in their field of specialization, challenge undergraduate students with integrated instruction and exploration, and utilize an effective teaching style that supports a diverse student body.

**Requirements:** A Ph.D. in Geology, Physical Geography or related discipline is required (ABD may be considered). If ABD; would be hired at the rank of Instructor, with the requirement that candidate complete doctoral degree by June 2014.

Applications will be accepted via Salisbury University's **Online Employment Application System**. Please visit our website at [www.salisbury.edu/HR/Jobs/](http://www.salisbury.edu/HR/Jobs/) to apply online. See the FAQs of the Online Employment Application System for more information and instructions.

To be considered an applicant, you must apply online and submit the following: (1) a letter of interest, (2) curriculum vitae, (3) evidence of teaching excellence and scholarly publication, (4) academic transcripts (can be a copy), and (5) the names and contact information of at least **three** professional references.

Note: All documents that you wish to provide must be attached to your application in the Online Employment Application System. Please do not send any other documents via E-mail. If you have any questions about the position, please contact **Dr. Brent Zaprowski** at [bjzaprowski@salisbury.edu](mailto:bjzaprowski@salisbury.edu).

Applications submitted by 2 Jan. 2013 will receive first consideration. The position will remain open until filled. Salary is competitive and commensurate with qualifications and experience. Appointment will be contingent upon verification of eligibility to work in the U.S. and is expected to begin 13 Aug. 2013.

The Dept. of Geography and Geosciences at Salisbury University consists of 13 faculty members with specializations in GIScience, Atmospheric Science, Physical Geography, Geology, and Environmental/Land-Use Planning. The department offers a B.S. in Earth Science and a B.S. in Geography, as well as a M.S. in GIS Management.

This position is based in Salisbury Maryland. Founded in 1925, Salisbury University is one of 13 institutions that compose the University System of Maryland. Salisbury University is a selective undergraduate institution within the University System of Maryland. The University is close to ocean beaches and the Chesapeake Bay and 2–3 hours from the metropolitan areas of Washington, Baltimore, Philadelphia, and Norfolk. SU has been cited nationally as one of the top ten public regional universities in the North according to the *U.S. News and World Report*, and has also been recognized by the *Princeton Review* and *Kiplinger's* magazine. SU has 388 full-time faculty members serving a student population of approximately 8,600.

Salisbury University has a strong institutional commitment to diversity and is an Equal Opportunity/Affirmative Action employer, providing equal employment and educational opportunities to all those qualified, without regard to race, color, religion, national origin, gender, age, marital status, disability, genetic information, or sexual orientation.

**TENURE TRACK  
LOW TEMPERATURE GEOCHEMISTRY  
DEPARTMENT OF GEOLOGICAL SCIENCES  
COLLEGE OF NATURAL  
SCIENCE & MATHEMATICS  
CALIFORNIA STATE  
UNIVERSITY FULLERTON**

**Position:** The Dept. of Geological Sciences at California State University Fullerton invites applications for a tenure-track, Assistant Professorship that will begin August 2013. The successful candidate is expected to develop an active, field-based, externally-funded research program in low temperature geochemistry involving undergraduate and Master's students. Teaching responsibilities will include introductory-level Earth science courses, environmental geology, aqueous geochemistry, and undergraduate/graduate courses in the candidate's field of expertise. The department places a strong emphasis on field-based instruction in all class offerings.

**Qualifications**

- A Ph.D. in Geological Sciences is required at the time of appointment.
- Must be committed to excellence in teaching our diverse student population and working effectively with faculty, staff and students.
- Must have ability to teach introductory courses as well as academic preparation to teach courses in field of specialization.
- Evidence of field-based or lab-based research in

geochemistry and an interest in teaching field and/or lab methods.

**Appointment Date: 22 August 2013**

**Rank & Salary:** This is a tenure-track position at the rank of Assistant Professor with a competitive salary and an excellent comprehensive benefits package including: health/vision/dental plans, spousal, domestic partner and/or dependent fee-waiver, access to campus child-care, an affordable housing program, defined-benefit retirement through the state system, and optional tax-sheltering opportunities. For a detailed description of benefits, go to [http://hr.fullerton.edu/Benefits/Faculty\\_Unit\\_3.pdf](http://hr.fullerton.edu/Benefits/Faculty_Unit_3.pdf).

**Job Control Number: 23603G-12-015.**

**Department:** The department currently has approximately 100 undergraduate majors, 25 MS students and 11 full-time faculty. California State University, Fullerton, is a large, urban, Hispanic-serving institution that offers unique collaborative opportunities with faculty at CSUF as well as other universities and governmental agencies in the southern California metropolitan region. Fullerton's location offers convenient access to coastal, mountain, and desert environments, providing many opportunities for field-based research and instruction. Abundant collaborative research and teaching opportunities exist within the Departments of Geological Sciences, Biology, Chemistry and Biochemistry and the Environmental Studies Program. Applicants are encouraged to visit <http://geology.fullerton.edu/> for additional information.

**Application Procedure:** To apply, please send (1) a detailed curriculum vita; (2) a letter of application; (3) a teaching statement that includes: a discussion of relevant course work and/or experience in preparation for teaching, a list of courses you would be qualified to teach, and a statement of your teaching philosophy; (4) a statement of your future research plans and goals; and (5) letters of recommendation from at least three references familiar with your teaching and research potential. Applicants and referees should send materials directly to Dr. Adam Woods, Search Committee Chair, Dept. of Geological Sciences, California State University, Fullerton, 800 N. State College Blvd., Fullerton, California 92834-6850, [awoods@fullerton.edu](mailto:awoods@fullerton.edu).

**Application Deadline:** Applications will be accepted until the position is filled. To ensure full consideration, submit all application materials by 16 Nov. 2012.

Cal State Fullerton is an Equal Opportunity/Title IX/503/504/VEVRA/ADA Employer.

*Achieving a Climate of Success Through Diversity & Equity.*

**TENURE-TRACK, APPLIED GEOPHYSICIST  
BAYLOR UNIVERSITY**

Baylor, the world's largest Baptist university, holds a Carnegie classification as a "high-research" institution. Baylor's mission is to educate men and women for worldwide leadership and service by integrating academic excellence and Christian commitment within a caring community. Baylor is actively recruiting new faculty with a strong commitment to the classroom and an equally strong commitment

to discovering new knowledge as Baylor aspires to become a top tier research university while reaffirming and deepening its distinctive Christian mission as described in Pro Futuris ([www.baylor.edu/profuturis/](http://www.baylor.edu/profuturis/)).

The Dept. of Geology at Baylor University invites applications for a tenure-track Assistant Professor in Applied Geophysics beginning August 2013. Applicants must hold a Ph.D. in geophysics, physics, or geology with an emphasis in geophysics at the time of appointment. The Department currently consists of 14 geoscientists ([www.baylor.edu/Geology/](http://www.baylor.edu/Geology/)).

Preference will be given to a candidate with a strong background in quantitative sciences whose research interests complement those of existing geophysical strengths in our department. Current strengths include earthquake seismology, potential field methods, geodynamics, and petroleum geology. Research involving processing and interpretation of seismic reflection data, and integrated interpretation with other geophysical and geological data, is desirable, although other research areas in geophysics would be considered. The successful candidate should have the potential to attract external funds and to build a strong research program involving graduate students. The successful candidate should also have the potential to build a vibrant teaching program including graduate and undergraduate courses in geophysics and/or petroleum geology.

**Application Process:** Send letter of application, including statement of teaching and research interests, curriculum vitae, copies of transcripts, and the names and contact information for three references to: Dr. Jay Pulliam, Chair, Search Committee, Dept. of Geology, Baylor University, One Bear Place #97354, Waco, TX 76798-7354 (Tel: 254-710-2361; e-mail: [Jay\\_Pulliam@baylor.edu](mailto:Jay_Pulliam@baylor.edu)). Applications will be reviewed beginning Sept. 30, 2012 and applications will be accepted until the position is filled. Baylor is a Baptist university affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Opportunity employer, Baylor encourages minorities, women, veterans, and persons with disabilities to apply.

**POST-DOC, DIVISION OF INVERTEBRATE  
PALEONTOLOGY, BIODIVERSITY INSTITUTE  
UNIVERSITY OF KANSAS**

The Division of Invertebrate Paleontology in the University of Kansas Biodiversity Institute seeks a 2-year, full time, post-doctoral associate with experience and interest in invertebrate paleontology and bioinformatics to work on an Advancing the Digitization of Biological Collections grant covering invertebrate fossils. Required qualifications include a Ph.D. in geology, systematics, paleontology or closely related field, working knowledge of the taxonomy and identification of invertebrate fossils, experience databasing natural history collections, experience managing projects, and demonstrated communication skills. For additional information and complete application instructions visit [www.ku.edu/employment/](http://www.ku.edu/employment/), position #00209886 or contact Bruce S. Lieberman, [blieber@ku.edu](mailto:blieber@ku.edu). To apply, complete the online application and attach cover letter, curriculum

vita, and contact information for 3 professional references. Review begins 1 Nov. 2012. Equal Opportunity Employer M/F/D/V.

**SENIOR-LEVEL FACULTY POSITION  
BAYLOR UNIVERSITY**

Baylor, the world's largest Baptist university, holds a Carnegie classification as a "high-research" institution. Baylor's mission is to educate men and women for worldwide leadership and service by integrating academic excellence and Christian commitment within a caring community. Baylor is actively recruiting new faculty with a strong commitment to the classroom and an equally strong commitment to discovering new knowledge as Baylor aspires to become a top tier research university while reaffirming and deepening its distinctive Christian mission as described in Pro Futuris ([www.baylor.edu/profuturis/](http://www.baylor.edu/profuturis/)).

The Dept. of Geology at Baylor University is pleased to announce a search for a new faculty position for hire with an open starting date beginning in August of 2013 in **Paleoclimatology or Paleoclimate Modeling**. The Department currently consists of 14 geoscientists, including geologists, geophysicists and geographers (please see the department website at [www.baylor.edu/Geology/](http://www.baylor.edu/Geology/) for further information).

**PALEOCLIMATOLOGY/PALEOCLIMATE MODELING.** The Dept. of Geology at Baylor University invites applications for a Senior Level hire at the rank of Associate to Full Professor, in the general areas of paleoclimatology or paleoclimate modeling, beginning August of 2013. A Ph.D. in Geology, Geochemistry, Biogeochemistry, or related field is required at the time of appointment. The Geology Department seeks an individual with an established, strong research record and a research area that compliments the existing group of 6 tenured and tenure-track faculty members in terrestrial paleoclimatology. Some examples might include biogeochemistry or paleoclimate modeling applied to field and laboratory studies of terrestrial climate records archived within fluvial (river and floodplain), eolian (loess and sand dune), lacustrine (lake), and coastal systems. The individual must be able to communicate and collaborate with Geology faculty members who are currently engaged in studies in the general area of paleoclimatology, and to carry out a vigorous externally funded research program that involves both undergraduate and graduate students. A strong commitment to excellence in teaching is essential, with both undergraduate and graduate courses that might include paleoclimate modeling or biogeochemistry, as well as other courses in his/her area of specialization. Research space for terrestrial paleoclimatology is available in the 500,000-square-foot "state-of-the-art" Baylor Sciences Building, and startup funds associated with this position are highly competitive.

Send letter of application, including statement of teaching and research interests, curriculum vitae, transcripts, and the names and contact information for three references to: Dr. Steven G. Driese, Paleoclimatology Search Committee Chair, Dept. of Geology, Baylor University, One Bear

Place #97354, Waco, TX 76798-7354 (Tel: 254-710-2361; applications sent by e-mail to: [Steven\\_Driese@baylor.edu](mailto:Steven_Driese@baylor.edu)). The review of applications will begin 1 Dec. 2012 and applications will be accepted until the position is filled. Baylor is a Baptist university affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Opportunity employer, Baylor encourages minorities, women, veterans and persons with disabilities to apply

**GEOCHRONOLOGY/GEOCHEMISTRY/  
PETROLOGY/MINERAL PHYSICS  
DEPT. OF EARTH SCIENCE  
UNIVERSITY OF CALIFORNIA  
AT SANTA BARBARA**

Provision #: GEOL13.

The Dept. of Earth Science at the University of California at Santa Barbara seeks a broadly educated geoscientist who conducts creative research on the long-term evolution of the solid Earth. A strong field orientation combined with expertise in analytical tools, such as electron-probe micro-analysis, electron-backscatter diffraction or mass spectrometry, is required. The appointee is expected to develop a vigorous, externally funded research program and teach a broad spectrum of undergraduate and graduate courses. This tenure-track appointment will be as an Assistant Professor to begin 1 July 2013.

A Ph.D. is required at the time of appointment. Review of applications will begin 15 Oct. 2012. Applicants should request three referees to send letters of evaluation by 15 Oct. Applicants should submit a PDF containing a letter of application, curriculum vita, a description of teaching and research objectives and accomplishments, and the contact information of the referees who are providing letters. The application file and letters of reference should be submitted to [betancourt@geol.ucsb.edu](mailto:betancourt@geol.ucsb.edu). Queries about this application can be directed to Bradley Hacker ([hacker@geol.ucsb.edu](mailto:hacker@geol.ucsb.edu)).

The department is especially interested in candidates who can contribute to the diversity and excellence of the academic community through research, teaching and service. For more information about the department, visit our webpage ([www.geol.ucsb.edu](http://www.geol.ucsb.edu)). UCSB is an Equal Opportunity/Affirmative Action employer.

**TENURE TRACK FACULTY POSITION  
HYDROGEOLOGY, COLLEGE  
OF EARTH & MINERAL SCIENCES,  
DEPT. OF GEOSCIENCES, THE  
PENNSYLVANIA STATE UNIVERSITY**

The Dept. of Geosciences at The Pennsylvania State University invites applications for a tenure-track faculty position in hydrogeology at the rank of Assistant Professor. We seek a colleague who will continue a strong departmental legacy in hydrologic sciences, complement highly active and diverse research programs in the Department and College through the development of a vigorous externally funded research program, and teach undergraduate and graduate courses in subsurface fluid flow. The successful candidate will also have the opportunity to participate in several campus-wide initiatives in water resources through the Penn State Institute for

Energy and the Environment ([www.psiee.psu.edu](http://www.psiee.psu.edu)) and the Earth and Environmental Systems Institute ([www.eesi.psu.edu](http://www.eesi.psu.edu)).

Applicants should have a Ph.D. in geosciences or related field, with a research focus in physical, chemical, or biological hydrogeology. Potential areas of expertise include, but are not limited to, environmental hydrogeology, reactive flow and transport, global groundwater fluxes, water resources and energy, groundwater-Earth surface interaction, impacts of climate change on groundwater resources, cryospheric hydrogeology, and related areas. Outstanding candidates who creatively apply theoretical, observational, and/or experimental approaches in their research are especially encouraged to apply.

The Dept. of Geosciences is part of the College of Earth and Mineral Sciences, and houses top-ranked research programs in environmental and climate sciences, geology, geophysics, and geochemistry (further information is available at [www.geosc.psu.edu](http://www.geosc.psu.edu)). The Department and College also host research centers with foci on climate, environment, energy, and policy, including the Shale Hills Critical Zone Observatory; Earth System Science Center; the Penn State Ice and Climate Research Center; the Riparia Center; and the Center for Geomechanics, Geofluids, and Geohazards. There are wide-ranging opportunities for collaboration in hydrogeology research and education in the College's Dept. of Energy and Mineral Engineering and Energy Institute, and in departments within the Colleges of Engineering and Agricultural Sciences.

Candidates should send a complete curriculum vita, statements of research and teaching interests, and the names and contact information of four references to: Chair, Hydrogeology Search, 503 Deike Building, The Pennsylvania State University, University Park, PA 16802; application materials can also be sent electronically to: [hydrosearch@psu.edu](mailto:hydrosearch@psu.edu). Appointment could begin as early as August 2013. Review of applications will begin on 15 Dec. 2012 and continue until the position is filled. For further information or questions, please email us at: [hydrosearch@psu.edu](mailto:hydrosearch@psu.edu).

Penn State is committed to affirmative action, equal opportunity and the diversity of its workforce. Women and members of underrepresented groups are encouraged to apply.

**GEOCHEMIST/PETROLOGIST  
ASSOCIATE/ASSISTANT PROFESSOR  
OCCIDENTAL COLLEGE**

The Dept. of Geology at Occidental College invites applications for a tenure-track/tenured faculty position in geochemistry/petrology. We seek a broadly educated geologist with the academic training to teach mineralogy, petrology, and geochemistry and contribute to teaching introductory geology and in Occidental's Core Program. Courses taught by the successful applicant should enhance students' understanding of chemical processes acting on the earth, and increase students' expertise in quantitative and instrumental methods. The successful applicant will be expected to sustain an active research program involving undergraduates and mentor students through completion of their Senior theses.



Applications including (1) a letter of interest demonstrating a commitment to academic excellence in a diverse liberal arts environment, highlighting teaching and research interests; (2) a curriculum vitae; (3) 1–3 significant publications; and (4) contact information for three referees should be submitted to the Search Committee at [geosearch1@oxy.edu](mailto:geosearch1@oxy.edu). Applicants may meet with search committee members at the GSA and AGU meetings; contact the search committee in advance. Address inquiries to: Dr. James Sadd, Chair, [jsadd@oxy.edu](mailto:jsadd@oxy.edu). **Review of applications will begin 15 Oct. 2012 and will continue until the search closes on 10 Dec. 2012.**

Occidental is a nationally ranked liberal arts college recognized for its diverse student body and outstanding undergraduate research program. Occidental College is an equal opportunity employer. Members of underrepresented groups are strongly encouraged to apply.

#### TENURE TRACK FACULTY POSITION STRUCTURAL GEOLOGY, DEPT. OF GEOLOGY CALIFORNIA STATE UNIVERSITY SACRAMENTO

The Geology Department at California State University, Sacramento, invites applications for a tenure-track faculty position at the Assistant Professor level, beginning Fall 2013. Applicants must hold a Ph.D. in geology by the time of appointment. Enthusiasm and a demonstrated commitment to teaching and mentoring are required. We encourage applicants with field-based research interests and strong skills in geologic mapping. Proficiency in active tectonics, neotectonics, GPS, GIS, LiDAR, and/or other remote sensing applications is preferred.

The successful candidate will embrace the opportunity to teach general education courses to a diverse student population, conduct a field-based research program that involves undergraduate and graduate geology students, and be a full-engaged participant in a small, collegial department.

Applicants must submit (1) a cover letter that addresses their qualifications for the position, their teaching interests and experience, and their scholarly interests and experience; (2) a curriculum vitae; (3) several examples of the candidates geologic mapping; (4) transcripts of college work (unofficial transcripts are acceptable; to be followed later by official transcripts before hiring); (5) three letters of reference (which may be sent directly to the search committee); and (6) the contact information (mailing address, phone number and email address) for three references who can speak to the professional qualifications of the applicant. Send application material to Chair of Search Committee, Dept. of Geology, California State University, Sacramento, 6000 J Street, Sacramento, CA 95819-6043. Screening of applications will begin **2 Nov. 2012**.

Additional information can be found at [www.csus.edu/geology](http://www.csus.edu/geology).

#### REMOTE SENSING BOWLING GREEN STATE UNIVERSITY

The School of Earth, Environment & Society at Bowling Green State University invites applications for a tenure-track Assistant/Associate Professor in Remote Sensing beginning August 2013. The school

is comprised of the Departments of Geography, Geology, and Environment & Sustainability. We are seeking a person with research experience and teaching interest that is focused on the application of remote sensing to the broad field of energy resources, including exploration, development and environmental stewardship. The position will be filled at the Assistant or Associate Professor level.

Applicants must be committed to teaching courses related to energy resources and demonstrate ability and commitment to develop an independent externally funded research program. Salary for the position is competitive and commensurate with peer institutions for rank and position and in keeping with candidate experience and credentials. Extensive facilities to support research and teaching in GIS/Remote Sensing can be found at [www.bgsu.edu/departments/sees/](http://www.bgsu.edu/departments/sees/).

Applicants must have a Ph.D. from an accredited university. Candidates should send as a single PDF file with the following: a letter of application, curriculum vitae, statements of research and teaching interests, and the names of three references to Dr. Peter Gorsevski, Chair, Faculty Search Committee, School of Earth Environment & Society, Bowling Green State University, Bowling Green, OH 43403, or [peterg@bgsu.edu](mailto:peterg@bgsu.edu). Finalists must provide a transcript for the highest degree. Applications must be post-marked by 14 Dec. 2012. BGSU is an AA/EO institution. Background check required for employment.

#### TWO POSITIONS: SEDIMENTARY PROCESSES AND GLOBAL CHANGE SCIENTIST/ ENVIRONMENTAL BIOGEOCHEMIST, DEPT. OF EARTH AND ENVIRONMENTAL SCIENCES, BOSTON COLLEGE

The Dept. of Earth and Environmental Sciences at Boston College invites applications for two Earth Systems Scientists to start in Fall 2013.

**Sedimentary Processes.** This is a tenure-track position expected to be made at the Assistant Professor level. Areas of expertise might include (but are not limited to): basin analysis, reflection seismology, sediment transport, and biogeochemical processes in sedimentary systems. The successful candidate will be expected to develop a vigorous externally funded research program integrated with excellence in teaching within the geological sciences and environmental geoscience curriculum at both the undergraduate and graduate levels, including teaching courses in Sedimentology and Stratigraphy for majors.

**Global Change Scientist/Environmental Biogeochemist.** Areas of expertise might include (but are not limited to): elemental cycling and associated climate feedbacks, organic geochemistry of marine, freshwater and soil environments, and coupled hydrogeomorphic-ecosystem response to natural and human-caused change and disturbance. The successful candidate will be expected to develop a vigorous externally funded research program integrated with excellence in teaching within the earth and environmental geoscience curriculum at both the undergraduate and graduate levels, including teaching introductory courses in climate change, and upper level electives in the area of the successful candidate's expertise. Applicants at all experience

levels will be considered. A successful candidate at the associate or full professor level will be expected to participate in development of interdisciplinary environmental programs.

Information on the department, its faculty and research strengths can be viewed at [www.bc.edu/eesciences](http://www.bc.edu/eesciences). Applicants should send a curriculum vita, statements of teaching and research interests, and the names and contact information of at least three references as a *single PDF-file e-mail attachment* to either [sedpos@bc.edu](mailto:sedpos@bc.edu) or [globalchange-pos@bc.edu](mailto:globalchange-pos@bc.edu). Review of applications will begin on 12 Nov. 2012. **Department faculty will be available at the GSA and AGU fall meetings to meet with applicants.** Boston College is an academic community whose doors are open to all students and employees without regard to race, religion, age, sex, marital or parental status, national origin, veteran status, or handicap.

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stratigraphy or pop culture?”**  
Jan Zalasiewicz, University of  
Leicester, UK; and 15 others.

### Reply:

doi: 10.1130/GSATG164Y.1; page e23:  
**Reply to Jan Zalasiewicz et al. on  
Response to Autin and Holbrook on  
“Is the Anthropocene an issue of  
stratigraphy or pop culture?”**  
Whitney J. Autin, SUNY College at  
Brockport, Brockport, New York  
14420, USA, [dirtguy@esc.brockport.edu](mailto:dirtguy@esc.brockport.edu); and John M. Holbrook, Texas  
Christian University, Fort Worth,  
Texas 76129, USA.

### Original Article:

**Groundwork:** Is the Anthropocene  
an issue of stratigraphy or pop  
culture? *GSA Today*, v. 22, no. 7, p. 60,  
doi: 10.1130/G153GW.1; online at  
[www.geosociety.org/gsatoday/  
archive/22/7/article/  
i1052-5173-22-7-60.htm](http://www.geosociety.org/gsatoday/archive/22/7/article/i1052-5173-22-7-60.htm).

# Rebuilding Tohoku: A joint geophysical and economic framework for hazard mitigation

**Jerome Stein**, *Applied Mathematics, Brown University, Providence, Rhode Island 02912, USA*; and **Seth Stein**, *Earth and Planetary Sciences, Northwestern University, Evanston, Illinois 60208, USA*, [seth@earth.northwestern.edu](mailto:seth@earth.northwestern.edu)

Japanese authorities face complex issues in reconstructing the Tohoku coast that suffered enormous damage from the tsunami generated by the M9.0 earthquake on 11 March 2011. The tsunami overtopped coastal defenses, primarily 5–10 m seawalls, causing more than 15,000 deaths and US\$210 billion damage (Normile, 2012) (Fig. 1). If and how such defenses should be rebuilt is a challenging question. Here, we outline a framework to find the optimal level of mitigation by balancing its cost against the expected damages. This framework can be applied to exploring policies under various hazard scenarios and mitigating other natural hazards.

Because defenses to withstand tsunamis as large as that of March 2011 are too expensive, those planned are about 12 m high, only a few meters higher than before March (Cyranoski, 2012a). These seawalls should protect against the largest tsunamis expected every 200–300 years, augmented with land-use planning and warning and evacuation procedures to protect against larger tsunamis. The defenses should reduce economic losses, while improved warning and evacuations should reduce fatalities, as shown by the March experience (Ando et al., 2011). However, critics argue that in areas with small and decreasing populations it would be more efficient to relocate communities. Otherwise, “In 30 years there might be nothing here but fancy breakwaters and empty houses” (Onishi, 2011).

A similar issue arises along the Nankai Trough to the south, where new estimates warning of tsunamis 2–5 times higher than in previous models raise the question of what to do, given that the timescale on which such events may occur is unknown (Cyranoski, 2012b). In the words of economist H. Hori (personal commun., 2012), “What should we do in face of uncertainty? Some say we should spend our resources on present problems instead of wasting them on things whose results are uncertain. Others say we should prepare for future unknown disasters precisely because they are uncertain.”

This situation illustrates the common need to decide how much natural hazard mitigation is appropriate. More mitigation can reduce losses in possible future disasters, but at increased cost. Less mitigation reduces costs, but can increase potential losses. Typically, these decisions are made politically, without explicitly

considering the tradeoff between costs and benefits. We thus propose a simple model that minimizes the sum of the expected property losses from tsunamis and the cost of mitigation, which can be generalized to other hazard policy situations.

At some point on the coast, we denote the cost of mitigation as  $C(n)$ , where  $n$  is the height of a seawall, which we use as our example, or a measure of mitigation in another method that increases resilience (Ewing and Synolokis, 2010), such as the width of a no-construction zone. For a tsunami of height  $h$ , the predicted economic loss ( $L$ ) is  $L(h - n)$ , where  $h - n$  is the height to which a tsunami will overtop a seawall or otherwise exceed a design parameter.  $L(h - n)$  is ideally zero for a tsunami smaller than the design value  $n$  and increases for larger tsunamis.  $L$  includes both damage and indirect economic losses, like those resulting from the destruction of the Fukushima power plant. The probability ( $p$ ) of an overtop of height  $h - n$  is  $p(h - n)$ , so the expected loss ( $E$ ) over the life of the wall is

$$Q(n) = E\{L(n)\} = \sum_n p(h - n)L(h - n), \quad (\text{Equation 1})$$

the sum of losses from tsunamis of different heights weighted by their probabilities:  $p(h - n)$  describes the hazard, the occurrence of tsunamis of a certain size, and  $Q(n)$  reflects the risk, the present value of the expected loss, which depends on the mitigation level  $n$ . The expected loss increases less rapidly with tsunami height than the loss itself for the largest events, because these events are rarer.

The optimum level of mitigation,  $n^*$ , minimizes the total cost  $K$ , the sum of the expected loss, and mitigation cost  $C$ ,

$$K(n^*) = \min_n [Q(n) + C(n)]. \quad (\text{Equation 2})$$

$K(n)$  illustrates the tradeoff between mitigation and damage because it has a minimum at the optimum mitigation level (Fig. 2A). More mitigation gives less expected damage but higher total cost, whereas less mitigation decreases construction costs but increases the expected damage and thus total cost.

How this works is shown by the derivatives of the functions (Fig. 2B). The total cost is minimum where  $C'(n^*) = -Q'(n^*)$ . Because increasingly high levels of mitigation are more costly, the marginal cost  $C'(n)$  increases with wall height. Conversely,  $-Q'(n)$ , the reduced loss from a small height increment, decreases. The lines intersect at  $n^*$ , the highest level to which it pays to build the wall. If they intersect where  $n^*$  is positive, building a wall pays.



Figure 1. More than a dozen ships were washed inland by the 11 March 2011 Tohoku tsunami in Kesennuma City, Myagi Prefecture. This massive fishing trawler, the no. 18 *Kyotoku-maru* ship, came to rest on top of a giant debris pile on one of the main roads to City Hall. Photo by Hermann M. Fritz, 16 April 2011. See Fritz et al., 2012, for more about the tsunami's effects.

However, even if when the wall height is zero its incremental cost  $C'(0)$  is greater than the incremental loss reduction  $-Q'(0)$ , building a wall does not pay.

Because the expected loss  $Q(n)$  and mitigation cost  $C(n)$  vary along the coast, the optimal mitigation level also varies. For sparsely populated areas,  $n^*$  shifts leftward, implying less mitigation. Where expected losses are greater, such as urban areas or critical facilities,  $n^*$  shifts rightward, justifying higher mitigation.

This approach requires estimating the probability of a tsunami of a certain height and the effectiveness of the defenses, which are often less than planned (Yalciner et al., 2011). The fact that the March 2011 tsunami was much greater than predicted based on the Japanese earthquake hazard map (Geller, 2012) shows that models that predict future occurrences of these events have large uncertainties (Stein et al., 2011).

Improvements should be forthcoming (Kanamori, 2012) from more effective use of earthquake history information (McCaffrey, 2007; Stein and Okal, 2011), the paleotsunami record (Minoura et

al., 2011), tsunami modeling (González et al., 2009), geodesy (Newman, 2011), and other technologies. However, predictions will still have large uncertainties. In particular, probability estimates are limited by both the length and completeness of the historic record and the fact that different models can be fit to it (Stein and Newman, 2004).

$K(n)$  reflects the mean value of the expected loss but does not include the variance due to its uncertainty. In addition, we are risk averse in hazard mitigation. Risk aversion can be visualized using a game in which the probability of winning or losing a sum is the same, but we place greater weight on avoiding losing than on winning. Risk aversion is the ratio of the gain to the loss necessary to induce the player to bet, which is greater than one.

The combined effects of uncertainty and risk aversion can be included by adding a risk term (Stein, 2012)  $R(n)$  to the loss term  $Q(n)$ .  $R(n)$  is the product of the risk aversion and the variance of the estimated loss as a function of  $n$ . Because the wall height should be increased as long as  $-[Q'(n) + R'(n)]$  exceeds the incremental cost of the wall  $C'(n)$ , the optimum height increases from  $n^*$  to  $n^{**}$ .

Conceptually, society is playing a game against nature “of which we still don’t know all the rules” (Lomnitz, 1989). Nature chooses tsunami heights, and society selects the strategy to minimize the total costs of tsunami losses plus mitigation costs. As in any game of chance, we maximize our expectation value by selecting the best strategy, given our limited ability to estimate the occurrence and effects of future tsunamis. Our framework makes it possible to explore the expected benefits for alternative models of the hazard.

Similar situations arise for other natural hazards, including earthquake ground shaking, river flooding, and hurricanes. The optimal level of mitigation minimizes the total of losses and mitigation costs and depends on the assumed hazard model. Our formulation can thus be used to explore policies under alternative scenarios—for example, scenarios in which the probability of large earthquakes is either constant with time since the previous one or small at first and increases with time (Stein and Hebdon, 2009). It can also be used to explore policies for scenarios in which global warming increases the effects of hurricanes (Emanuel, 2011).

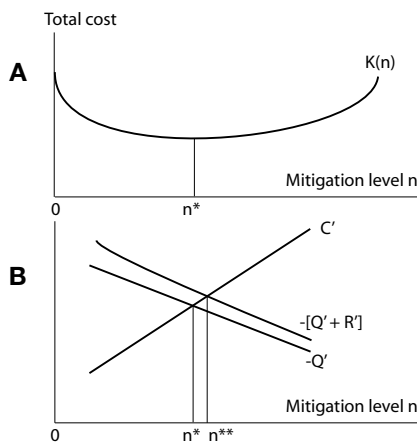


Figure 2. (A) The optimal mitigation level,  $n^*$ , minimizes the total cost, the sum of expected loss and mitigation cost. (B)  $n^*$  occurs when the reduced loss  $-Q'(n)$  equals the incremental mitigation cost  $C'(n)$ . Including the effect of uncertainty and risk aversion, the optimal wall height  $n^{**}$  occurs when the incremental cost equals the sum of the reduced loss and incremental decline in the risk term  $R'(n)$ .

Ultimately, decisions on natural hazard mitigation policy are made through a political process reflecting non-economic factors. Nonetheless, input from combined geophysical and economic analysis can improve the decision making.

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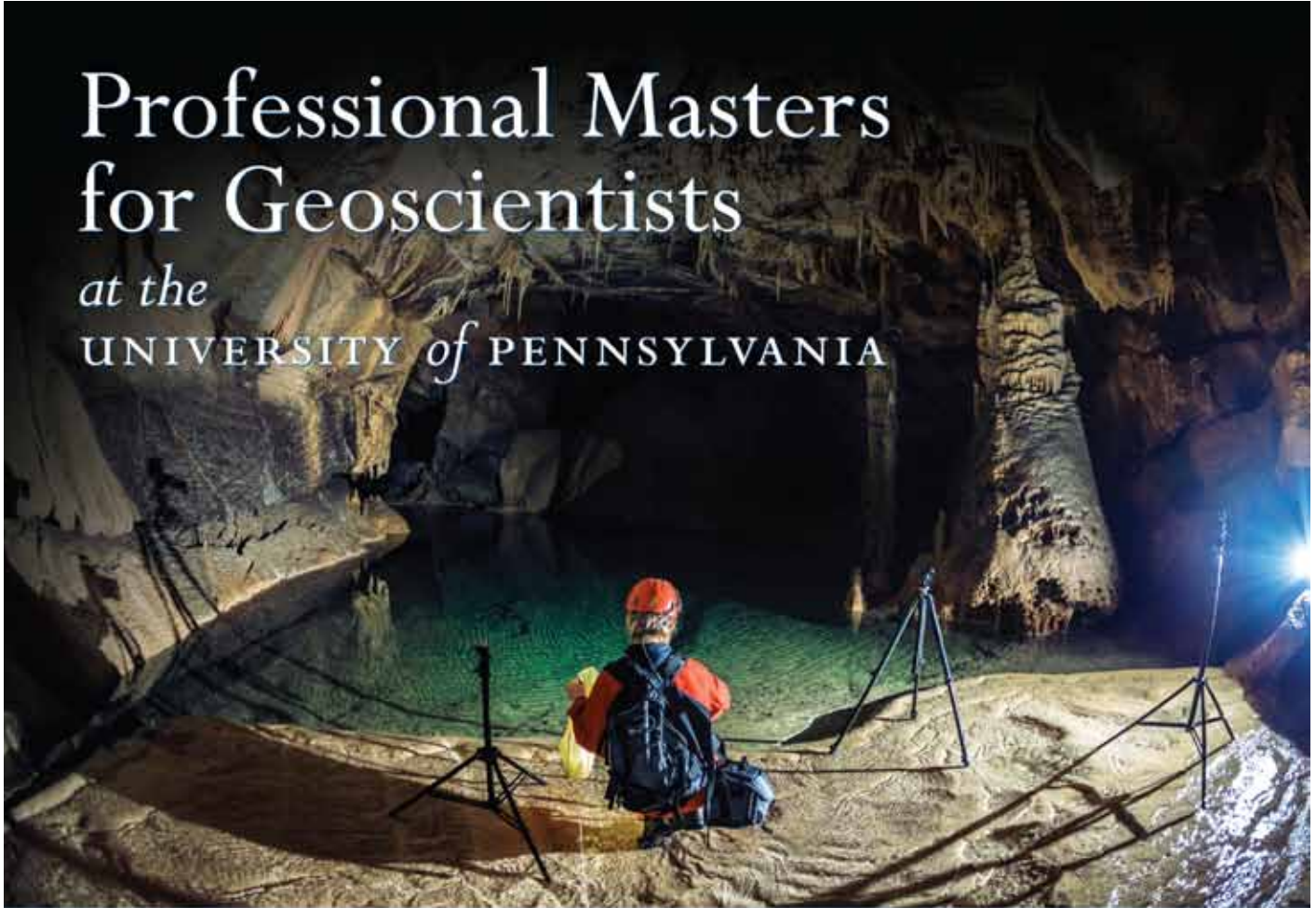
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