

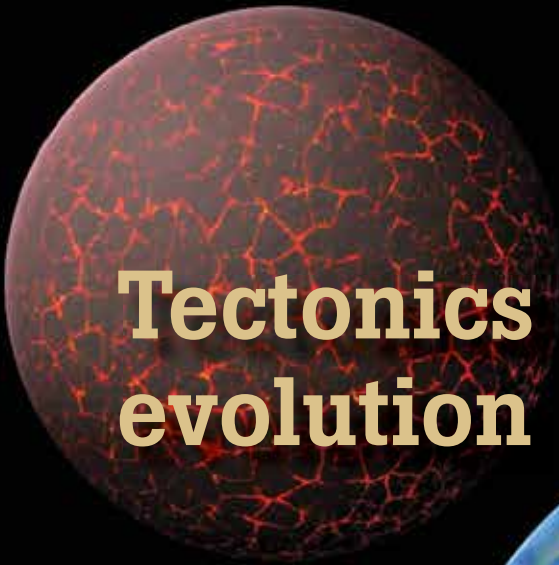
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**Tectonics and crustal  
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Printed in the USA using pure soy inks.

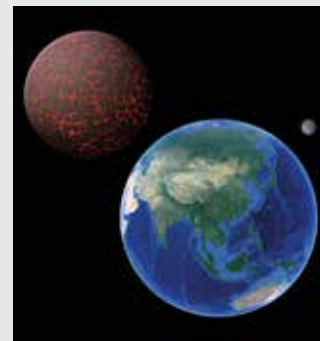


## Featured Article

### SCIENCE

- 4 **Tectonics and crustal evolution**  
Chris J. Hawkesworth, Peter A. Cawood, and  
Bruno Dhuime

**Cover:** Early Earth and present-day Earth and Earth's Moon.  
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**Erratum:** The 2016 new GSA Fellows article (July 2016, v. 26, no. 7, p. 17–21) did not include **Brandon Schmandt**, who advanced to GSA Fellowship as the 2015 GSA Young Scientist (Donath Medal) awardee. GSA regrets this error.

**Cover photo inset:** Denver Museum of Nature & Science, photo by Rich Grant. Used with permission by Visit Denver.

# Tectonics and crustal evolution

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## ABSTRACT

The continental crust is the archive of Earth's history. Its rock units record events that are heterogeneous in time with distinctive peaks and troughs of ages for igneous crystallization, metamorphism, continental margins, and mineralization. This temporal distribution is argued largely to reflect the different preservation potential of rocks generated in different tectonic settings, rather than fundamental pulses of activity, and the peaks of ages are linked to the timing of supercontinent assembly. Isotopic and elemental data from zircons and whole rock crustal compositions suggest that the overall growth of continental crust (crustal addition from the mantle minus recycling of material to the mantle) has been continuous throughout Earth's history. A decrease in the rate of crustal growth ca. 3.0 Ga is related to increased recycling associated with the onset of plate tectonics.

We recognize five stages of Earth's evolution: (1) initial accretion and differentiation of the core/mantle system within the first few tens of millions of years; (2) generation of crust in a pre-plate tectonic regime in the period prior to 3.0 Ga; (3) early plate tectonics involving hot subduction with shallow slab breakoff over the period from 3.0 to 1.7 Ga; (4) Earth's middle age from 1.7 to 0.75 Ga, characterized by environmental, evolutionary, and lithospheric stability; (5) modern cold subduction, which has existed for the past 0.75 b.y. Cycles of supercontinent formation and breakup have operated during the last three stages. This evolving tectonic character has likely been controlled by secular changes in mantle temperature and how that impacts on lithospheric behavior. Crustal volumes, reflecting the interplay of crust generation and recycling, increased until Earth's middle age, and they may have decreased in the past ~1 b.y.

## BACKGROUND

The geological record is incomplete—some rock types are more likely to be preserved than others, and breaks in the rock archive are marked by breaks in the depositional record in the upper crust and deformational and metamorphic events in the deeper crust. The result is an inhomogeneous distribution of ages of rock units, as strikingly seen in the peaks and troughs of U-Pb crystallization ages that appear to be a feature of the geological record (Fig. 1). This distribution of ages is unexpected in a planet whose history is thought to have been dominated by the continuous action of plate tectonics, and there is considerable debate over the causes of the

peaks and troughs of ages. Much of it has focused discussion on the extent to which the generation and evolution of Earth's crust is driven by deep-seated processes, such as mantle plumes, or is primarily in response to plate tectonic processes that dominate at relatively shallow levels.

The cyclical nature of the geological record has been recognized since James Hutton noted in the eighteenth century that even the oldest rocks are made up of “materials furnished from the ruins of former continents” (Hutton, 1785). The history of the continental crust, at least since the end of the Archean, is marked by geological cycles that on different scales include those shaped by individual mountain building events, and by the cyclic development and dispersal of supercontinents in response to plate tectonics (Nance et al., 2014, and references therein). Successive cycles may have different features, reflecting in part the cooling of the earth and the changing nature of the lithosphere. In this contribution, we explore the extent to which changes in tectonic processes have shaped the geological record and the surface environments through Earth's history. Where possible these are linked to changing thermal conditions as the earth cooled.

The cooling earth influenced the depths and hence the geochemical signatures at which melt generation takes place (McKenzie, 1984; Nisbet et al., 1993) and the rheology of the crust and lithosphere (Gerya, 2014; Sizova et al., 2010). That in turn influenced tectonic processes, including the initial onset of subduction and the subsequent onset of “cold” subduction that was prevalent throughout the Phanerozoic (Brown, 2006, 2014; Stern, 2005), which shaped the surface environments on Earth. Subduction and plate tectonics resulted in the development of supercontinents and enhanced cooling that led to thickening of the lithosphere and increased crustal reworking. This, in turn, resulted in higher erosion fluxes, and changes in the Sr isotope ratios of seawater and the chemistry of the oceans (Cawood et al., 2013; Flament et al., 2013; Shields, 2007; Spencer et al., 2014). The development of the continental crust is illustrated schematically in Figure 2. Magma oceans may have persisted for 5–10 m.y. after initial accretion of the earth, and a crust, which is likely to have been mafic in composition, will have developed at a late stage in the differentiation and solidification of the magma ocean (e.g., Elkins-Tanton, 2008). The mafic crust is thought to have been thickened by continuing mafic and ultramafic magmatism until remelting and the generation of felsic magmas could occur, resulting in the bimodal silica distribution that is a feature of Archean crust (Fig. 3; Kamber, 2015; Kamber et al., 2005). The residual garnet signature (low heavy rare earth elements [HREE]) in most tonalite-trondhjemite-granodiorite (TTG) associations indicates that remelting took place at pressures >10–12 kb (Rapp and Watson, 1995). The late Archean was characterized by TTG magmatism, the remelting of intermediate to felsic crust and the generation of more potassic granites, and the stabilization of continental crust and mantle lithosphere (Carlson et al., 2005).

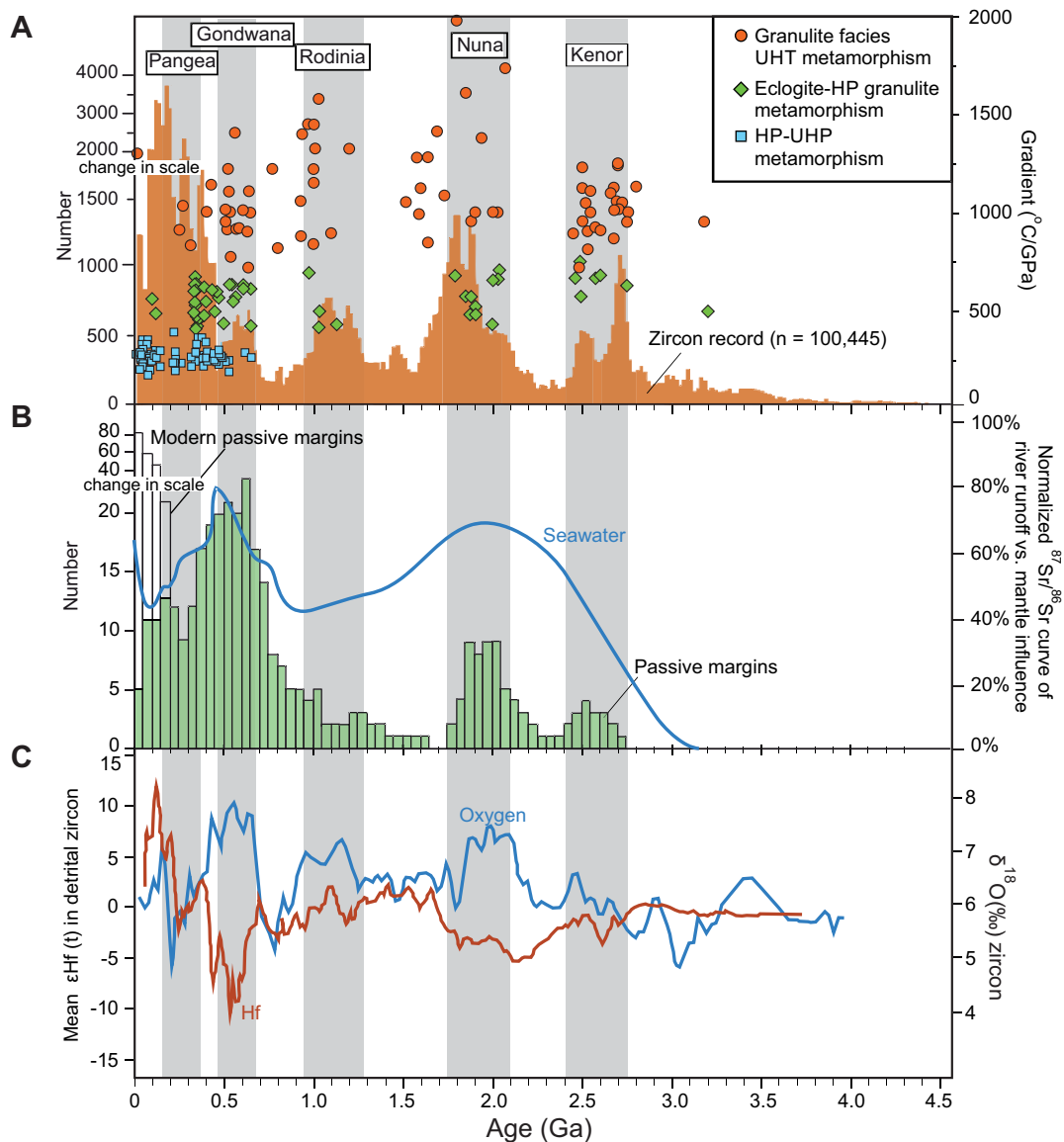


Figure 1. (A) Histogram of more than 100,000 detrital zircon analyses showing several peaks in their U-Pb crystallization ages over the course of Earth's history (Voice et al., 2011), which are very similar to the ages of supercontinents. Also shown is the apparent thermal gradient versus age of peak metamorphism for the three main types of granulite-facies metamorphic belts (Brown, 2007, 2014). UHT—ultrahigh temperature; HP—high pressure; UHP—ultrahigh pressure. (B) Histogram of the ages of ancient and modern passive margins (Bradley, 2008) and normalized seawater  $^{87}\text{Sr}/^{86}\text{Sr}$  curve (Shields, 2007). (C) Running mean of initial  $\epsilon_{\text{Hf}}$  in ~7000 detrital zircons from recent sediments (Cawood et al., 2013) and moving average distilled from compilation of ~3300  $\delta^{18}\text{O}$  analyses of zircon versus U-Pb age (Spencer et al., 2014).

## THE GEOLOGICAL RECORD

Earth's history is one of continuous activity in the generation of igneous, metamorphic, and sedimentary rocks. Yet in terms of stratigraphy, most of geological time is represented by gaps (in unconformities and disconformities) and not by the rocks themselves. Moreover, the geological record is only what remains—what is preserved. Few rocks from the oceans survive, and preservation is shaped by tectonic setting, the development of mountain belts, and erosion. Thus, while geological activity may be continuous, the distribution of different rock units is heterogeneous in both space and time; the ages of igneous crystallization, metamorphism, continental margins, and mineralization are

distributed about a series of peaks and troughs (Fig. 1; and see also Bradley, 2011). The record is incomplete (e.g., Holmes, 1965; Hutton, 1788; Raup, 1972), and incomplete records tend to result in biases, not least because the preservation of the records of different environments and tectonic settings is highly variable.

The implications of bias are well established in the discussions of the fossil record (e.g., Smith and McGowan, 2007). Particular sedimentary facies dominate the rock record, and two-thirds of extant animal species have no hard parts that would lend themselves to being easily fossilized. Most fossils come from lowland and marine habitats where the conditions for fossilization and preservation are most prevalent, and although only 20% of extant

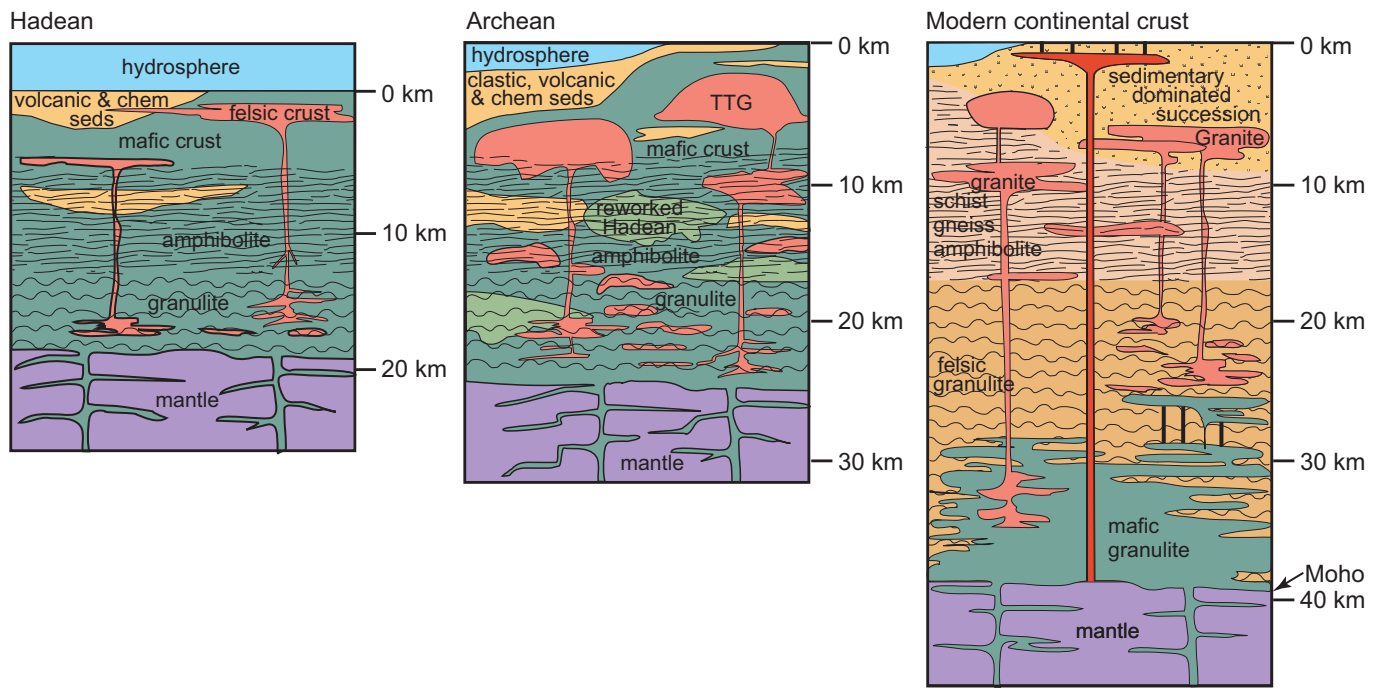


Figure 2. Schematic sections of Hadean, Archean, and modern continental crust. Hadean and Archean sections adapted from Kamber et al. (2005) and modern crust from Hawkesworth and Kemp (2006). TTG—tonalite-trondhjemite-granodiorite.

species are marine (Mora et al., 2011), marine fossils dominate the fossil record. Mineral deposits that form at or near Earth's surface (e.g., epithermal silver-gold deposits) have a lower long-term preservation potential than deeper deposits (orogenic gold; Wilkinson and Kesler, 2007).

It has similarly been argued that the peaks and troughs of crystallization ages that characterize the continental crust (Fig. 1) reflect the better preservation of igneous rocks generated in some tectonic settings compared to others. The peaks of ages are therefore thought to reflect a biasing of the continental record, apparently linked to the development of supercontinents (Cawood et al., 2013; see also Condie et al., 2011; Hawkesworth et al., 2009, 2010). The implication is that they should not be taken as prima facie evidence that in any global context the history of the continental crust is marked by pulses of magmatic activity. Rather, magmatic rocks generated in different tectonic settings have different likelihoods of being preserved over long periods. This is most marked in the contrast between the preservation of igneous rocks generated in continental and oceanic settings. However, these differences in preservation are also a feature of rocks generated in subduction and collision-related tectonic environments in the continents.

Along subduction zones, high volumes of magma are generated, but a number of studies have highlighted that the continental crust is destroyed by erosion, subduction, and in some areas delamination, at rates similar to, or greater than, those at which new crust is generated (Clift et al., 2009; Scholl and von Huene, 2007, 2009; Stern, 2011). Island arcs have higher average rates of magma generation than Andean margins, yet island arcs are more readily subducted and so they are even less likely to be preserved than continental margins (Condie and Kröner, 2013). In contrast, the volumes of magma generated in the final stages of convergence

and continental collision decrease, but the chances of the resultant igneous rocks being preserved is high. Thus, ages from late stage subduction- and collision-related magmatic rocks are likely to be better preserved than those generated more generally above subduction zones, and this results in peaks of ages coincident with the ages of supercontinents. One implication is that the supercontinent cycle tends to bias the rock record (Cawood et al., 2013; Hawkesworth et al., 2009).

Crustal reworking is accentuated by continental collision, and the degree of crustal reworking has changed with time. The temporal distribution of crystallization ages of zircons with Hf model ages greater than their crystallization ages can be used as a proxy for the degree of crustal reworking, and the periods of increased crustal reworking are those of supercontinent assembly (Dhuime et al., 2012). Similarly, there are peaks and troughs in  $\delta^{18}\text{O}$  values in zircons through time, and the periods of elevated  $\delta^{18}\text{O}$  are also those of supercontinent assembly (Fig. 1; Dhuime et al., 2012; Roberts and Spencer, 2014; Spencer et al., 2014). Elevated  $\delta^{18}\text{O}$  values indicate reworking of sedimentary material, and this is most readily achieved in sections of thickened crust in response to continental collision. Thus, this is independent evidence that the peaks of U-Pb crystallization ages are associated with periods of crustal thickening, of continental collision, and the development of supercontinents.

An alternative view is that peaks of ages reflect pulses of magmatic activity, and that as such, they might be associated with mantle plumes (Albarède, 1998; Arndt and Davaille, 2013; Condie, 1998; Parman, 2015; Rino et al., 2004). However, the composition of the continental crust appears to be dominated by minor and trace element features that are characteristic of subduction-related magmas (Rudnick and Gao, 2003), and even for the relatively young age peaks, when the rock record is better

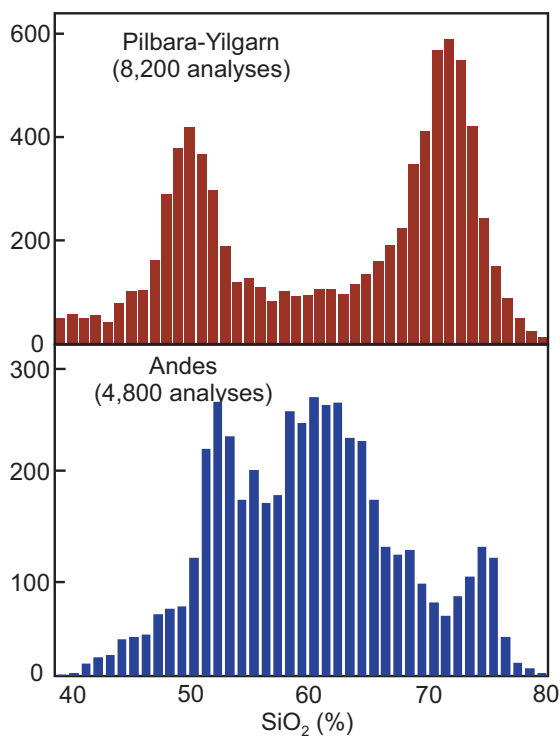


Figure 3. Whole rock  $\text{SiO}_2$  distributions of plutonic and volcanic rocks from Archean Pilbara-Yilgarn and the Andes. Data sources from the Western Australia Geological Survey (<http://geochem.dmp.wa.gov.au/geochem/>) and GEOROC (<http://georoc.mpch-mainz.gwdg.de/georoc/>), respectively.

preserved, there is little evidence that the ages are concentrated in particular areas that might reflect plume activity. There is, for example, a peak of zircon crystallization ages associated with the Grenville at ca. 1 Ga (Fig. 1), and the Grenville is widely regarded as a collisional event (Gower and Krogh, 2002), rather than a time of unusual volumes of magma generation. We conclude that the tectonic settings in which magmas are generated, and the collisional regimes associated with the supercontinent cycle, have shaped aspects of the preserved geological record. Not all collision orogenies are marked by peaks in the ages of zircons; for example, most of the detrital zircons in rivers draining the Appalachian Mountains have ages associated with the Grenville rather than the Paleozoic (Eriksson et al., 2003). The implication is the numbers of zircons of different ages preserved in sediments depend on the depths of erosion of likely source areas, and hence presumably on the amounts of crustal thickening. Alternatively, although collision related magmas contain greater numbers of zircons than convergent plate margin magmas, the volume of such magmas is so small that this cannot explain the co-incidence of the peaks of zircon ages with the times of supercontinent assembly (Cawood et al., 2013; Hawkesworth et al., 2013).

### CRUSTAL THICKNESS (AND VOLUME) THROUGH TIME

A number of different approaches have concluded that 65%–70% of the present volume of the continental crust had been formed by the late Archean (3.0–2.5 Ga; Belousova et al., 2010; Campbell, 2003; Dhuime et al., 2012; Kramers, 2002). It follows that the rates of continental growth (i.e., the rates of increase in the volume of continental crust with time) were significantly

higher before 3.0 Ga than subsequently. The rates of continental growth reflect the balance between the rates of generation and destruction of continental crust, and the change at ca. 3.0 Ga has been taken to indicate that the dominant processes of crust generation changed at about that time (Dhuime et al., 2012). There is a broad consensus about the composition of the bulk/average continental crust as presently preserved (Rudnick and Gao, 2003) and how that is different for Archean terrains (e.g., Fig. 3; Taylor and McLennan, 1985). The challenge has been to obtain information on the composition of *new* continental crust, and whether that has changed with time, because that constrains the conditions under which the continental crust was generated.

Much of the geological record is of magmatic rocks derived from preexisting crustal rocks, but Sr, Nd, and Hf isotope data can be used to estimate the Rb/Sr ratios of those crustal source rocks, which we take to represent new continental crust. Crustal differentiation processes produce a range of fractionated Rb/Sr ratios, and there is therefore a strong positive correlation between Rb/Sr and the  $\text{SiO}_2$  contents of crustal rocks and, in recent geological settings, with the thickness of the continental crust (Dhuime et al., 2015).

Dhuime et al. (2015) combined crystallization ages, Nd model ages, and initial Sr isotope ratios of igneous rocks to calculate the Rb/Sr ratios of their crustal source rocks in the period between the model ages, taken to reflect the time those crustal source rocks were derived from the mantle, and the time of generation and crystallization of the magmatic rocks analyzed. These time-integrated Rb/Sr ratios are thought to reflect those of new continental crust, because they are calculated from the time of their model Nd ages. The Rb/Sr ratios of new continental crust are highly scattered prior to 3.0 Ga, but the median is  $\sim 0.03$ , and it increased to a maximum value of  $\sim 0.08$  from 3.0 to 1.7 Ga, before decreasing to values of  $\sim 0.065$  in the past  $\sim 1$  b.y. (Fig. 4A). The implication is that the  $\text{SiO}_2$  contents of new crust increased from  $\sim 48\%$  before 3.0 Ga to more intermediate compositions, with  $\text{SiO}_2$  up to  $\sim 57\%$ . This is attributed to a shift from broad-scale mantle melting and diffuse magma injection prior to 3.0 Ga to a subsequent plate tectonic regime involving subduction-related magmatism at plate boundaries (e.g., Sizova et al., 2010).

The Rb/Sr ratios of igneous rocks in modern-day Central and South America increase with crustal thickness, and so the temporal increase in the Rb/Sr ratio of new continental crust may also indicate that the thickness of the crust at the sites of crust generation increased from 20 km at 3.0 Ga to almost 40 km at ca. 1.7 Ga. The estimated thickness then decreased to nearer 30 km since ca. 1 Ga (Dhuime et al., 2015). The predominantly mafic character of Earth's crust before 3.0 Ga (see also Kemp et al., 2010; Tang et al., 2016) means that it would have had a higher density and been less buoyant than modern continental crust, resulting in a greater probability for its recycling into the mantle. Recent geodynamic modeling of Archean crust generated under higher mantle temperatures suggests that it would have been gravitationally unstable and susceptible to recycling through delamination (Johnson et al., 2013).

The curves for crustal growth rates from Belousova et al. (2010) and Dhuime et al. (2012) are based on the proportion of juvenile to reworked crust at different times. Such cumulative growth curves cannot decrease with time (Fig. 4B), and so the curve of changing crustal thickness through time offers a different

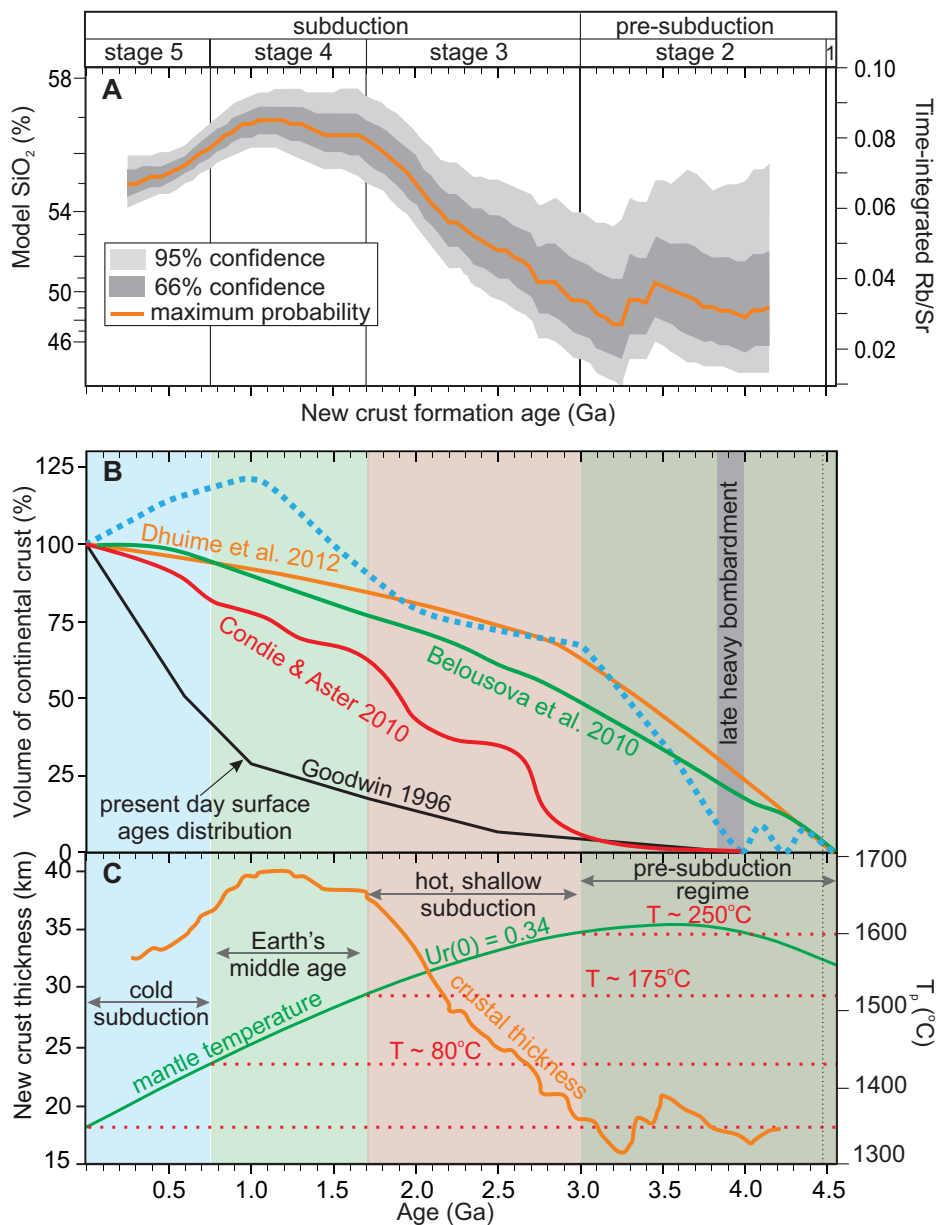


Figure 4. (A) Variation in the estimated Rb/Sr ratios, and SiO<sub>2</sub> contents, of new continental crust from Dhuime et al. (2015). (B) A preliminary model for the changes in volume of the continental crust (dotted blue curve) compared with the crustal growth curves of Belousova et al. (2010) and Dhuime et al. (2012), the model age distribution of Condie and Aster (2010), and the present-day surface age distribution of Goodwin (1996). The preliminary model is illustrative, and it is not unique. It assumes two types of crust generated before and after 3.0 Ga, and rates of crust generation and destruction for each. It is constrained by the volume of continental crust at the present day and 70% at 3.0 Ga, and by the present-day curve of Condie and Aster (2010). (C) Variation in the thickness of new continental crust through time (orange curve) as estimated from the Rb/Sr ratio of new continental crust (Dhuime et al., 2015), and thermal models for ambient mantle for Urey (Ur) ratio of 0.34 (Korenaga, 2013).

perspective (Fig. 4C; Dhuime et al., 2015). The high crustal growth rates before 3.0 Ga were marked by relatively thin continental crust, and at that time there is no link between estimated crustal thickness and crustal growth rates. However, by 3.0 Ga the estimated volume of crust was at least ~70% of the present-day volume, and the crustal thickness was ~50% of the present-day crustal thickness. It therefore appears that before 3.0 Ga the area of continental crust increased with crustal volume, but that since

then the thickness (and volume) of the crust may have increased with little or no increase in area.

One issue is the extent to which the crustal thickness at the sites of generation of new crust can be linked to crustal volume. Our preliminary models suggest that the predominantly mafic crust generated before 3.0 Ga was largely destroyed by 2.0 Ga, and that since that time the crust predominantly consisted of post-3.0 Ga crust generated in subduction-related settings. Because the relation



between Rb/Sr and crustal thickness is observed in subduction settings (Dhuime et al., 2015), it implies that crustal thickness may be a reasonable proxy for crustal volume at least over the past 2.0 b.y.

Figure 4B (dotted blue curve) illustrates such a model for the changes in crustal volumes through time. It is constrained by the present volume of the continental crust, the presence of 70% of that volume at 3.0 Ga, and the present-day distribution of crust with different model ages (Condie and Aster, 2010). It starts at the end of the heavy bombardment ca. 3.9 Ga; it assumes that the rate of crust generation was greater before 3.0 Ga than subsequently, and that the compositions of the crust generated before and after 3.0 Ga were different. Pre-3.0 Ga crust was preferentially recycled from 3.0 to 1.5 Ga following the onset of subduction at 3.0 Ga. Such models are not unique, but they indicate that changing volumes of continental crust can be modeled with two types of crust that are destroyed at different rates. The model outlined here predicts that nearly twice the present volume of the continental crust has been recycled since the end of the heavy bombardment.

The increase in thickness at the sites of crust generation from 3.0 to 1.7 Ga indicates that more of the continental crust was elevated above seawater (Flament et al., 2013), and hence susceptible to sub-aerial weathering and erosion. This increase in crustal thickness is accompanied by a steady increase in the Sr isotope ratios of seawater (Fig. 1; Shields and Veizer, 2002), implying increased continental runoff, which would increase the amounts of CO<sub>2</sub> draw down due to continental weathering (e.g., Kramers, 2002). Preliminary models indicate that in the mid-Proterozoic the volume of continental crust may have been up to 20% greater than at the present day, and since 1.0 Ga the crust has become thinner, and we infer that the crust decreased in volume (Fig. 4). The rates of crustal growth appear to have decreased as Earth cooled, and “cool” subduction began to dominate, which, on the basis of preserved metamorphic and other rock units, is taken to have commenced around 0.75 Ga (Brown, 2006; Cawood and Hawkesworth, 2014), such that the rates of crustal recycling were greater than the rates at which new crust was generated.

## DISCUSSION

There appears to have been five stages in Earth’s evolution, with the last four being recorded in the geology of the continental crust (Fig. 4). Stage 1 included the initial accretion of the Earth, core/mantle differentiation, the development of a magma ocean, and of an undifferentiated mafic crust. Most models suggest that a magma ocean may have persisted on Earth for 5–10 m.y., and continuing volcanism, along with deformation, would have progressively thickened the initial mafic crust (Kamber, 2015; Kamber et al., 2005). Once the crust was at least 15–20 km thick, remelting could take place (Fig. 2; Kamber et al., 2005), and the resultant felsic magmas represented the high silica component in the distinctive bimodal silica distribution that characterizes the Archean crust (Fig. 3). This second stage was marked by elevated mantle temperatures compared to the present day (Fig. 4C) that resulted in lithosphere weakened by the emplacement of melts (Gerya, 2014; Sizova et al., 2010). This inhibited subduction, and hence plate tectonics, and magmatism were driven by mantle upwellings that percolated the lithosphere. These might have been associated with deep-seated mantle plumes, but such models

remain difficult to test, and the upwellings may have been more localized and likely originated at shallower levels, perhaps as in a heat-pipe model (Moore and Webb, 2013). In today’s world, such magmatism would be regarded as intraplate; it has no association with subduction, but in a time before plates, such terminology is arguably misleading. Destruction and recycling of early crust occurred through a combination of delamination (Johnson et al., 2013) and meteorite impact, the latter continuing until the end of the late heavy bombardment ca. 3.9 Ga (Gomes et al., 2005; Marchi et al., 2014), and so perhaps we are fortunate to have the few zircon grains that have survived from the Hadean.

The onset of stage 3 is taken to be the stabilization of Archean cratons and the change in crustal growth rates ca. 3.0 Ga. It is envisaged that Earth had cooled sufficiently for “hot” subduction to take place (Sizova et al., 2010) from ca. 3.0 Ga to ca. 1.7 Ga (Fig. 4). The continental crust became thicker and more evolved, plate tectonics resulted in collisional orogenies, supercontinent cycles developed, and there was increased erosion to the oceans due to thickening and subaerial exposure of continental crust resulting in an increase in Sr isotope ratios in seawater (Fig. 1B). Models in which ~70% of the present volume of the continental crust was present at 3.0 Ga also require that large volumes of continental crust have been destroyed, presumably in the late Archean and the Proterozoic (Hawkesworth et al., 2013). However, the net growth of crust requires the rate of crust generation to exceed that of recycling (Fig. 4).

The fourth stage is from 1.7 to 0.75 Ga, referred to as the “boring billion” (Holland, 2006), and more recently as Earth’s middle age (Cawood and Hawkesworth, 2014). It is marked by a paucity of preserved passive margins, an absence of significant anomalies in the paleoseawater Sr isotope record and in Hf isotopes in detrital zircon (Fig. 1), a lack of orogenic gold and volcanic-hosted massive sulfide deposits, and an absence of glacial deposits and iron formations (Cawood and Hawkesworth, 2015). It appears to have been a period of environmental, evolutionary, and lithospheric stability, which has been attributed to a relatively stable continental assemblage that was initiated during assembly of the Nuna supercontinent by ca. 1.7 Ga and continued until breakup of its closely related successor, Rodinia, ca. 0.75 Ga. It is also marked by abundant anorthosites and related rocks perhaps linked with the secular cooling of the mantle. The overlying continental lithosphere was strong enough to be thickened and to support the emplacement of large plutons into the crust, yet the underlying mantle was still warm enough to result in widespread melting of the lower thickened crust and the generation of anorthositic magmas (Ashwal, 2010).

The termination of Earth’s middle age, and onset of stage 5, corresponds with Rodinia breakup at 0.75 Ga and the development of “cold” subduction. The latter is recognized by the onset of high- to ultrahigh-pressure metamorphic rocks (Brown, 2006). Falling mantle temperatures enabled deeper levels of slab breakoff in collision zones and the resultant greater depths to which continental crust was subducted prior to exhumation, allowing the development of the ultrahigh-pressure metamorphic assemblages (Brown, 2006; Sizova et al., 2014). Stage 5 is marked by a strongly episodic distribution of ages linked to the supercontinent cycles of Gondwana and Pangea (Fig. 1). Oxygen levels in both the atmosphere and deep oceans increased, phosphate and evaporate deposits

became widespread, and these provided a major spurt for meta-zoan evolution.

The changing thermal structure of Earth resulted in changes in the properties of the lithosphere, and hence in tectonics and ultimately in surficial processes. As Earth cooled from the late Archean (Fig. 4C), the continental and oceanic lithospheres strengthened because they contained less melt and were characterized by lower temperatures. Subduction and plate tectonics caused profound changes with the onset of significant horizontal tectonics, the development of thickened mountain belts and increased erosion, a change in crustal compositions, and the recycling of continental crust back into the mantle. Secular cooling of Earth impacted lithospheric rheology, magmatic activity, and thickness, which in turn influenced surficial processes and features. Secular changes in the rheology of the lithosphere determine how it behaves in terms of global tectonics, the magmas generated, and the differential preservation of rocks generated in different settings that have shaped the geological record.


## ACKNOWLEDGMENTS

We thank the Natural Environment Research Council (grants NE/J021822/1 and NE/K008862/1) for funding, and Mike Brown, Adrian Lenardic, and Brendan Murphy for their detailed and helpful reviews.

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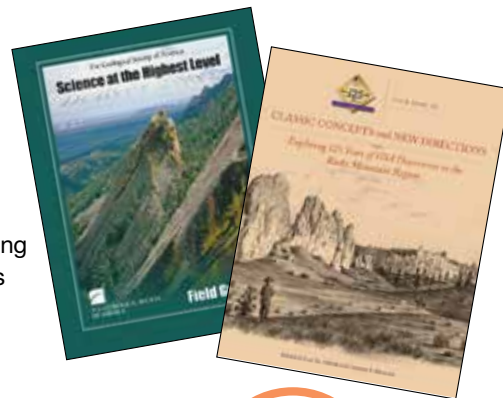
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Manuscript received 12 Nov. 2015; accepted 1 Apr. 2016. 

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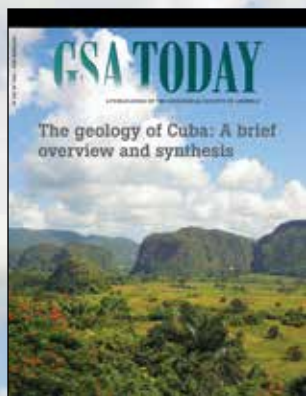
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## Publications Highlights



### **SPECIAL HIGHLIGHT**

## **October's Science Article Covers the Geology of Cuba, Ties into Annual Meeting Pardee Symposium**

In next month's issue of *GSA Today* (v. 26, no. 10), Manuel A. Iturralde-Vinent and colleagues describe "The geology of Cuba: A brief overview and synthesis," as a companion to their GSA 2016 Annual Meeting Pardee Symposium, **Geologic Evolution of Cuba**. The symposium, from 8 a.m. to noon on Wed., 28 Sept., at the Colorado Convention Center, Mile High Ballroom 2A/3A, includes several invited speakers. **Cover image:** Valle de Viñales, Pinar del Río Province, western Cuba. Photo by Antonio Garcia Casco, 31 July 2014.

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Now that the abstracts are in, we can tell you that you'll have more than 4,700 talks to choose from, and we expect that nearly 7,500 geoscientists from around the world will come to Denver this year. Don't miss your opportunity to weigh in on discussions, find project and job opportunities, and have a bit of fun! See you in Denver!

## GSA Presidential Address: Mission-Driven Geoscience

► Sun., 25 Sept., noon–1:30 p.m. Colorado Convention Center (CCC), Mile High Ballroom 2A/3A

Geoscientists work across the spectrum, from the fundamental research that dominates academic departments to the applied science driving oil and gas exploration, mining, and environmental protection. Within a number of federal agencies, especially the U.S. Department of Energy, geoscientists mesh fundamental and applied science to focus on *mission-driven geoscience*. Here the goal is to develop the basic understanding necessary to solve complex problems in support of the nation's energy and national security, and its environmental health. This address will explore some of the complex challenges being addressed by geoscientists within our national laboratories, from the detection and characterization of clandestine nuclear weapons testing to resolving the longstanding question of what to do with radioactive waste, both legacy and recent. The challenges also encompass the efficient and environmentally sustainable development of our many energy resources, and improving our ability to predict the impacts of climate change at global and regional scales. Harnessing scientific understanding to resolve large, complex problems is fundamentally important to a healthy, safe, and prosperous nation and will remain a challenge to future *geo*-generations.

**Claudia I. Mora**, GSA President  
*Group Leader, Earth Systems Observations, Earth and Environmental  
Sciences Division, Los Alamos National Laboratory*

# Awards & Medals

## GSA AWARDS CEREMONY

Sun., 25 Sept., noon–1:30 p.m. CCC, Mile High Ballroom 2A/3A



**PRESIDENT**  
Claudia I. Mora

Please join GSA President **Claudia I. Mora** and GSA Vice-President/  
President-Elect **Isabel P. Montanez** to honor and greet the  
2016 GSA Medals & Awards recipients at the Presidential Address and  
Awards Ceremony. You will also have the privilege of hearing Mora  
give her Presidential Address, “**Mission-Driven Geoscience.**”  
Following this address, **Vicki S. McConnell**, Executive Director of  
GSA, will provide a presentation on the state of the Society and  
**Jack Hess** will provide a GSA Foundation update.



**VICE PRESIDENT/  
PRESIDENT-ELECT**  
Isabel P. Montanez

## 2016 GSA MEDAL & AWARD RECIPIENTS



John T. Andrews



Donald B. Dingwell



Whitney M. Behr



Sarah Andrews



Rex Buchanan



Kathleen R. Johnson



J. Christopher Hepburn



Lori L. Summa



Christine A. Regalla



Marc Robert St-Onge

### PENROSE MEDAL

**John T. Andrews**, University of Colorado

### ARTHUR L. DAY MEDAL

**Donald B. Dingwell**, University of Munich

### YOUNG SCIENTIST AWARD (DONATH MEDAL)

**Whitney M. Behr**, The University of Texas at Austin

### PRESIDENT’S MEDAL

**Sarah Andrews**, Geologist and Author

### GSA PUBLIC SERVICE AWARD

**Rex Buchanan**, Kansas Geological Survey

### RANDOLPH W. “BILL” AND CECILE T. BROMERY AWARD FOR MINORITIES

**Kathleen R. Johnson**, University of California Irvine

### GSA DISTINGUISHED SERVICE AWARD

**J. Christopher Hepburn**, Boston College  
**Lori L. Summa**, ExxonMobil Upstream Research Company

### DORIS M. CURTIS OUTSTANDING WOMAN IN SCIENCE AWARD

**Christine A. Regalla**, Boston University

### GEOLOGIC MAPPING AWARD IN HONOR OF FLORENCE BASCOM

**Marc R. St-Onge**, Geological Survey of Canada



## LUNCHTIME ENLIGHTENMENT

### Jen Russel-Houston, Osum Oil Sands Corp.

GSA 2016 Michel T. Halbouty Distinguished Lecture:  
*Contemporary Oil Sands: Retrospect and Future Potential*

► Monday, 26 Sept., 12:15–1:15 p.m.

Colorado Convention Center, Mile High Ballroom 2A/3A



The oil sands in Canada are the third largest accumulation of crude oil in the world and are part of the diverse energy mix that meets the world's growing needs. The bitumen deposits are hosted in siliciclastic sandstones deposited during the Cretaceous in fluvial to marine settings of the foreland basin east of the Rocky Mountains and in underlying Paleozoic carbonates. Natural bitumen is a high-density oil that is too viscous to flow at reservoir conditions. About 20% of the bitumen is found in shallow deposits and excavated using surface mining techniques. During this talk, Dr. Jen Russel-Houston will focus on the remaining 80% of the bitumen, which is hosted in reservoirs deeper than 75 m and is recovered *in situ* using wellbores. Typically, steam is injected into the pores of the reservoir to heat the oil and thus reduce the viscosity of the bitumen to enable it to flow to producing wells. Early applications of steam injection to produce oil took place in the 1960s in California, where steam was

flooded through the reservoir in a pattern of injection and production wells. This method and others were adapted to the Canadian reservoirs and entirely new technological approaches were advanced, with steam assisted gravity drainage (SAGD) being the most successful. Effective adaptation and application of these technologies is linked directly to understanding and integrating geological information with engineering design. This has led to investment of over \$200 billion, and growth in production to over 1.3 million barrels per day. This spirit of innovation continues as recovery technologies are being piloted, optimized, and commercialized to further reduce the energy intensity and environmental footprint of future developments.

Jen Russel-Houston, P.Geol., obtained a Ph.D. in geology from Dalhousie University in 2001 and completed a thesis that examined the graptolite taphonomy of a Silurian-aged carbonate ramp in the Arctic of Canada. Prior to joining Osum Oil Sands Corp. in 2008, Russel-Houston worked for Shell on both onshore and offshore projects where she developed expertise in reservoir evaluation, thermal production geology, and leading technical teams. As vice president of geoscience, she oversees Osum's geoscience evaluations as they relate to current assets and guides the assessment of potential opportunities of interest to Osum. Russel-Houston is Director of the Canadian Society of Petroleum Geologists, Associate Editor of the *Canadian Bulletin of Petroleum Geology*, and was Vice General Chair of the American Association of Petroleum Geology Annual Convention and Exhibition in June 2016.

## GSA 2016 on Social Media



**GSA'S CONNECTED COMMUNITY**—Connect with your colleagues at [community.geosociety.org/gsa2016/attendeeinfo/network/directory](http://community.geosociety.org/gsa2016/attendeeinfo/network/directory).



**FACEBOOK**—Join more than 237,000 GSA fans worldwide at [www.facebook.com/GSA.1888](http://www.facebook.com/GSA.1888).



**TWITTER**—Join more than 26,000 tweeps who follow @geosociety, and tweet the meeting using hashtag #GSA2016.



**YOU TUBE**—Learn more about GSA and careers in the geosciences at [www.youtube.com/user/geosociety](http://www.youtube.com/user/geosociety).



**LINKEDIN**—Network and stay connected to your professional peers at <http://linkd.in/1HsYwni>.

**BLOG ROLL**—Will you be blogging about the meeting? Get on the Blog Roll at [community.geosociety.org/gsa2016/press/news/blogroll](http://community.geosociety.org/gsa2016/press/news/blogroll).

*Note:* GSA meeting policy prohibits the use of cameras or sound-recording equipment in technical sessions.



25-28 SEPTEMBER

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Denver, Colorado, USA





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With deepest appreciation, the Museum acknowledges Kathryn W. Davis for her generous founding support of the MAT Program.

Leadership support for the MAT program is provided by The Shelby Cullom Davis Charitable Fund.

The MAT program is supported in part by the National Science Foundation under Grant Numbers DRL-1119444 and DUE-1340006, and the U.S. Department of Education under Grant Number U3365140026.

[amnh.org/mat](http://amnh.org/mat)

mat@amnh.org | 212-313-7464 | [@amnh](https://twitter.com/amnh) | [facebook.com/amnhmat](https://facebook.com/amnhmat)

# Hotel Map

Downtown Denver Hotels		Distance to Colorado Convention Center	Single/Double Rate
1	Hyatt Regency Denver at CCC ( <b>HQ Hotel</b> )	50 Steps	\$223
2	Crowne Plaza Denver Downtown	2 Blocks	\$179
3	Denver Marriott City Center	3 Blocks	\$199
4	Grand Hyatt Denver ( <b>Co-HQ Hotel</b> )	3 Blocks	\$205
5	Hampton Inn & Suites Convention Center	1 Block	\$199
6	Hilton Garden Inn Downtown Denver	1 Block	\$195
7	Holiday Inn Express Denver Downtown	5 Blocks	\$161
8	Homewood Suites Denver/Downtown—Convention Center	1 Block	\$199
9	HYATT house	1 Block	\$199
10	Hyatt Place	1 Block	\$199
11	Sheraton Denver Downtown Hotel	3 Blocks	\$199



# Housekeeping

## Hotels

Orchid Event Solutions/GSA Housing Bureau will continue to assist you with hotel reservations through 15 September. If rooms are not available at the hotels in the GSA block, OES will provide you with a list of hotels in the area that have availability. [community.geosociety.org/gsa2016/attendeeinfo/accommodations/reservations](http://community.geosociety.org/gsa2016/attendeeinfo/accommodations/reservations)

## Critical Dates

**15 Sept.:** All changes, cancellations, and name substitutions must be finalized through Orchid Event Solutions by this date.

**16 Sept.:** Beginning on this date, you must contact the hotel directly for all changes, cancellations, and new reservations.

## Before You Arrive in Denver

Review the arrival/departure dates on your hotel acknowledgement for accuracy. **If you do not show up on the date of your scheduled arrival, the hotel will release your room AND you will be charged for one night's room and tax.** If you have travel delays and cannot arrive on your scheduled arrival date, contact the hotel directly to make them aware of your new arrival date.

## Child Care

KiddieCorp is providing childcare services for GSA attendees Sat.–Wed., 7 a.m.–6 p.m. The program is open to children six months to 12 years old and the cost is only US\$9 per hour per child (two-hour min.). KiddieCorp must receive the registration form and payment in full to hold any advance reservations. You are also welcome to register on-site; however, there is no guarantee and it is not recommended. [community.geosociety.org/gsa2016/attendeeinfo/needs](http://community.geosociety.org/gsa2016/attendeeinfo/needs).

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## Registration

► You still have time to register for GSA 2016!

Register online at [community.geosociety.org/gsa2016/registration](http://community.geosociety.org/gsa2016/registration) throughout the meeting, or visit the onsite registration desk in the Colorado Convention Center (CCC). Space is available on some tours, ticketed events, field trips, and short courses.

Badges will be available at the registration desk starting at 7 a.m. on Saturday, 24 Sept. Ribbons are available at the CCC Information Desk during onsite registration hours. Eligible attendees should inquire there.

### GSA Section Travel Grants

Recipients of GSA Student Travel Grants will need to check in at the Annual Meeting office (room 210/212), show identification, verify their address, and sign the check-in sheet to receive their check. The checks will be mailed to recipients after the meeting. If you do not check in, you will not receive your grant.

## Organizing Committee

**General Chair:** Karen Berry

**Technical Program Chair:** Paul Baldauf

**Technical Program Vice-Chair:** Dick Berg

**Field Trip Co-Chairs:** Steve Keller, Matt Morgan

**Education and Outreach Chair:** Rick Aster

**K–12 Education Chair:** Samantha Richards

**Student Committee:** Hank Matthew Cole, Rachel Glade, Jay Merrill, Annette Patton, Charles Shobe, Sean Smith



## Pardee Keynote Symposia

These Pardee Keynote Symposia will take place Sun.–Wed., 25–28 Sept., in Mile High Ballroom 2A/3A at the Colorado Convention Center. Read symposia descriptions and learn more about the featured speakers and cosponsors at [community.geosociety.org/gsa2016/science/sessions/pardee](http://community.geosociety.org/gsa2016/science/sessions/pardee).



Joseph T. Pardee

## GSA 2016 September

### 25 SUNDAY

**P1. Mastery of the Subsurface: The Challenge to Improve Subsurface Energy Systems**

1:45–5:30 p.m.

### 26 MONDAY

**P2. When Oil and Water Mix: Understanding the Environmental Impacts of Shale Development**

8 a.m.–5:30 p.m.

### 27 TUESDAY

**P5. The High Plains Aquifer: Can It be Managed for Today and the Future?**

8 a.m.–noon

**P3. Exploring the Third Zone: The Geology of Pluto, Charon, and the Kuiper Belt**

1:30–5:30 p.m.

### 28 WEDNESDAY

**P4. Geologic Evolution of Cuba**

8 a.m.–noon

# 30<sup>th</sup> Anniversary SAGEEP 2017

SPECIAL ANNOUNCEMENT



EEGS is pleased to announce SAGEEP and the National Ground Water Association's (NGWA)



Hydrogeophysics and Deep Groundwater Conference will co-locate for two days next spring. Attendees will benefit from the expanded program and additional short courses.

	2	0	1	7	
Save the Dates!	M	A	R	C	H
	19	20	21	22	23
	DENVER, COLORADO USA				

Call for Session Topics and Abstracts Soon!

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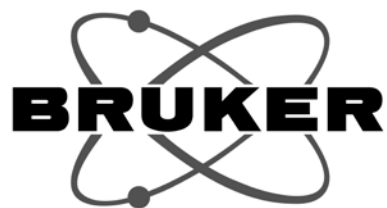


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[WWW.EEGS.ORG/SAGEEP 2017](http://WWW.EEGS.ORG/SAGEEP 2017)



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# GSA 2016 Meeting App



## Build Your Own Schedule

- Install it as a native app on iOS or Android phones and tablets to browse and search the entire meeting without an Internet connection. This app is available in the Apple Store and Play Store —search for GSA 2016.
- Use the Web app, which can run in your favorite web browser, works well on screens of any size.

## Everything you need to know about the meeting, always at your fingertips!

- Search the full technical program;
- Locate the sessions and individual talks you want to hear;
- See who is exhibiting and add them as favorites;
- Find speakers and add them as contacts;
- Select events to attend and add them to your calendar; and
- View uploaded presentations.

Visit  
[community.geosociety.org/gsa2016/mobileapp](http://community.geosociety.org/gsa2016/mobileapp)  
 for download links.

# Getting around Denver



## Bus

The Regional Transportation District (RTD) skyRide makes hourly runs to/from Denver International Airport and to/from 18 free park-n-rides around the city. Fares are US\$7, US\$9, or US\$11, depending on location, and drivers assist with luggage. All RTD services, maps, routes, park-n-rides, and fares are detailed on the RTD website at [www.rtd-denver.com](http://www.rtd-denver.com).



## Taxi

Taxis are readily available and provide service to the Denver metro area and surrounding counties. The flat-rate charge (one-way fare, airport access fee already included) for downtown Denver is US\$55.57; rides to Boulder are US\$88.57. Taxis pick up and drop off from level 5 of the main terminal at DIA.



## Rail

Denver's new airport rail (A line) runs between Denver International Airport (DIA) and downtown Denver for US\$9 each way. It has six stops and takes about 37 minutes to get to Union Station. Tickets can be purchased at ticket vending machines on rail line platforms. Catch the train at DIA outside the Westin Denver International Airport Hotel.

### Schedule

3:15 a.m.–4:15 a.m.: Every 30 minutes

4:15 a.m.–6:30 p.m.: Every 15 minutes

6:30 p.m.–12:30 a.m. (1 a.m. Fri./Sat.): Every 30 minutes

\*The last train leaves Denver International Airport at 1:26 a.m. (1:56 a.m. Fri./Sat.)



## 16th Street Shuttle

This free hybrid bus runs up and down the 16-block tree-lined retail core of downtown Denver. Hop on at any intersection on 16th Street between Civic Center Station at Broadway near the Colorado State Capitol (200 E. Colfax Ave.) and Union Station on the west end.



## GSA Meetings Bulletin Board


Find other meeting attendees on GSA's secure Connected Community at [community.geosociety.org/gsa2016/roommates](http://community.geosociety.org/gsa2016/roommates) and talk about whatever you want, whenever you want. Meet new people, coordinate your schedules, share travel and lodging expenses, and plan activities while in Denver. Make sure to include GSA2016 in the subject line.

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## Denver Activities

### Neighborhood Spotlight

#### The Highlands/Lower Highlands (LoHi)

- **Dining:** Enjoy rooftop seating, craft beer and cocktails, innovative cuisine concepts, and unique flavors!
- **Navajo Street Art District:** Experience this tucked-away district in LoHi. With amazing galleries, fine dining, great performance art, and ample parking, it's truly one of the best-kept secrets in town.
- **REI:** Stop in the impressive, three-story flagship store, housed in a building formerly home to Denver's streetcars and right along the Platte River. Inside you'll find a rock-climbing wall; outside is a small river for testing out kayaks.
- **Craft Beer:** Try the Graham Cracker Porter at the Denver Beer Company while you consult the Denver Beer Trail map for more breweries to sample in the neighborhood.

#### Saturday Icebreaker

- ▶ Sat., 24 Sept., 5–7 p.m., Colorado Convention Center (CCC), Mile High Ballroom I

Join thousands of industry professionals, students, academics, GSA Divisions, and GSA Associated Societies to kick off the Annual Meeting with beer and great company.

#### Coffee

Your Caffeine Fix is complimentary in the mornings (while it lasts!).

- ▶ Sun, 25 Sept.: 10–10:30 a.m. Exhibit Hall, posters area
- ▶ Mon.–Wed. 10–10:30 a.m. Exhibit Hall

Coffee will also be available for purchase at the Blue Bear Café and the Little A Café.

#### Libations and Collaborations

- ▶ Mon.–Wed., 26–28 Sept., 4:30–6:30 p.m., CCC, Exhibit Halls

Be a part of the conversation! Enjoy beer or your choice of non-alcoholic beverages while making time to meet with poster presenters.

#### 2016 Annual Meeting Pint Glasses

Get your 2016 swag here! Limited-edition pint glasses were available for pre-order through 22 Aug. If you missed this, limited quantities will be available for purchase at the GSA Store to commemorate the meeting.

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# GEOLOGY

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# Student Information and Activities

[community.geosociety.org/gsa2016/students](http://community.geosociety.org/gsa2016/students)

## Student Volunteers

*GSA student members:* Get free meeting registration when you volunteer for ten hours—plus get an insider's view of the meeting! Sign up online at [community.geosociety.org/gsa2016/students/volunteers](http://community.geosociety.org/gsa2016/students/volunteers) and then register for the meeting as a student volunteer. You'll be able to see the available jobs via the online schedule.

## A Night at the Denver Museum of Nature & Science: A Reception for Students and Early Career Professionals

► Sun., 25 Sept., 7–9:30 p.m.

Denver Museum of Nature & Science. Buses leave from Lobby F of the Colorado Convention Center at 7 p.m. and return at 9:45 p.m. Fee: US\$10.

Enjoy an evening with your peers at the Denver Museum of Nature & Science. Light hors d'oeuvres and a cash bar will be available. If you didn't register for this event in advance, please contact GSA Sales & Service at +1-888-443-4472.

## Student Downtown Deal Night

► Mon., 26 Sept., 7 p.m.

Join other students as they visit local pubs in downtown Denver. Some of the local pubs are offering great deals for students wearing official wristbands. Pick up those wristbands and pub maps just outside the Student Volunteer Office (Room 206) at the Colorado Convention Center beginning on Monday at noon and ending when all the wristbands are gone. Get there early and be prepared to show ID.

## Best Student Geologic Map Competition

► Tues., 27 Sept., 5–6:30 p.m., CCC Exhibit Hall E/F

Please join us for the *Best Student Geologic Mapping Competition Poster Session* (T207). The competition will highlight student research from around the world that utilizes field mapping and the creation of geologic maps as a major component.



## Let's Celebrate Diversity!

### On To the Future Events

GSA welcomes the new cohort of On To the Future (OTF) award recipients. OTF supports students from underrepresented groups to attend their first GSA Annual Meeting.

OTF Welcome: Sat., 24 Sept., 4:45 p.m., CCC, Room 401 (Invitation Only)

Diversity in the Geosciences: Sun., 25 Sept., CCC, Exhibit Hall, GSA Foundation Booth (Open to Everyone)

OTF Group Photo: Sun., 25 Sept., 6:15 p.m., CCC, Exhibits Hall, GSA Foundation Booth

OTF Gatherings: Mon.–Wed., 26–28 Sept., 7:30 a.m., CCC, Mile High Ballroom 1F (Invitation Only)

Diversity and OTF Alumni Reception: Tues., 27 Sept., 5:30 p.m., CCC, Mile High Ballroom 1A (Open to Everyone)

### Diversity and On To the Future Alumni Reception

Tues., 27 Sept., 5:30–7 p.m., Colorado Convention Center (CCC), Mile High Ballroom 1A (Open to Everyone)

The GSA Diversity in the Geosciences Committee invites everyone to attend this reception to share ideas and celebrate diversity within the geoscience community. The 2016 OTF and Minority Scholarship Awardees will be recognized with a special keynote from the Bromery Awardee. Appetizers and a cash bar provided.

[community.geosociety.org/otf/home/myhome](http://community.geosociety.org/otf/home/myhome)





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## DEVIL Duke Environmental Stable Isotope Laboratory

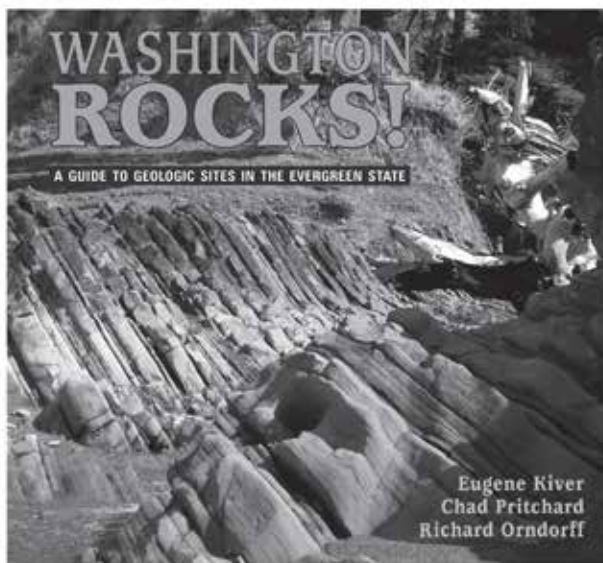


Stable isotope lab at Duke (DEVIL) analyzing for <sup>13</sup>C, <sup>15</sup>N, <sup>18</sup>O, <sup>2</sup>H in plants, animal tissues, soils, carbonates, phosphates, waters, carbon dioxide, methane (dissolved gases or mixtures in air).

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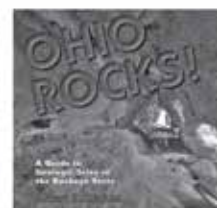
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*If you have already registered for the meeting, please call GSA Sales & Service at +1-888-443-4472 to add any of the events below that require additional registration.*

**SCIENCE COMMUNICATION****“Be Heard & Be Interesting”**

Sat., 24 Sept., 8 a.m.–noon.

Colorado Convention Center (CCC), Room 204.

Registration is required. Professionals: US\$35; students: US\$25; includes continental breakfast. Limited seating.

**STUDENT GEOCAREERS DAY**

Sun., 25 Sept., 8 a.m.–2 p.m.

CCC, Mile High Ballroom 1.

All-inclusive fee: US\$25. Registration is required. Be sure to bring your résumé.

**Career Workshop:** 8–9 a.m.

This workshop is divided into three 20-minute power sessions. US\$10 if not registered for GeoCareers Day.

**Career Information Session:** 9–11 a.m.

Talk one-on-one with corporate and government representatives.

**Career Mentor Roundtables:** 11 a.m.–2 p.m.

Mentors from a variety of sectors will be on hand to answer your career questions.

**Career Pathways Panel:** noon–1 p.m.

GeoCareers Day registrants will be admitted first; non-registered students will be accepted on a first-come, first-served basis.

**EARLY CAREER PROFESSIONALS COFFEE**

Mon., 26 Sept. 9:30–10:30 a.m.

CCC, Mile High Ballroom 1A.

No registration required. This informal gathering will feature remarks from representatives of several non-profits, with time for networking and sharing ideas on how these organizations can best serve you.

**STUDENT NETWORKING RECEPTION**

Mon., 26 Sept., 11:30 a.m.–1 p.m.

Hyatt CCC, Centennial Ballroom A.

This reception provides students and early career professionals with an exciting opportunity to network with more than 40 geoscience professionals. The mentors will answer questions, offer advice about career plans, and comment on job opportunities within their fields.

**ASK A GEOSCIENTIST**

Mon., 26 Sept., 1:30 p.m.; Tues., 27 Sept., 1 p.m. & 4 p.m.

CCC, Exhibit Hall.

No registration required. Stop by the Foundation Booth in the Exhibit Hall for 30-min. Q&A sessions each with a geoscientist from a different sector.

**THE PALEONTOLOGICAL SOCIETY****Mentors in Paleontology Careers Luncheon**

Mon., 26 Sept., noon–1 p.m.

Hyatt Regency at the CCC, Mineral Hall D-E

No registration required. Enjoy lunch and meet with a panel of mentors from a variety of geoscience organizations. First come, first served.

**WOMEN IN GEOLOGY CAREER PATHWAYS RECEPTION**

Sun., 25 Sept., 5:30–7 p.m.

CCC, Mile High Ballroom 1. No registration required.

This informal gathering begins with remarks from a few key women speakers. A roundtable mentoring session follows, providing time for networking, sharing ideas, and getting to know other geoscientists.



# Guest Program

- Sun.–Wed., 8 a.m.–5:30 p.m., Colorado Convention Center (CCC), Penrose Guest Hospitality Suite

The guest or spouse registration fee of US\$90 is for a non-geologist accompanying a professional or student meeting registrant, and it does not include access to technical sessions. Be sure to wear your **meeting badge** for access to the CCC, the Penrose Guest Hospitality Suite, and the Exhibit Hall. If you would like to see a specific presentation, please go to the registration desk at the CCC, Lobby F, to request a special access badge.

We welcome all registered Guests and Penrose Circle Invitees to stop by the Hospitality Suite for rest and relaxation. The suite will offer complimentary refreshments, educational seminars, and local experts ready to answer your questions about Denver. You can also register for local tours for an additional fee.

## Guest Seminars

The following seminars are free for registered guests and Penrose Circle Invitees.

1. **Introduction to Smartphone Photography:** Sun., 25 Sept., 10 a.m., Penrose Guest Hospitality Suite.
2. **Cherry Creek Shuttle:** Mon., 26 Sept., 10 a.m.–3 p.m.; depart from the Penrose Guest Hospitality Suite. Lunch is on your own.
3. **Life Cleanse:** Wed., 28 Sept., 10 a.m., Penrose Guest Hospitality Suite.



## Local Tours

(for Everyone)

101. **A Colorado Hike:** Sun., 25 Sept., 8 a.m.–noon. US\$150. Offers beginner and intermediate trail options. Snacks and water included.
102. **Denver Bike Bar Microbrewery Tour:** Mon., 26 Sept., 2 p.m.–4 p.m. US\$76. Experience the city in a whole new way, pedaling to each brewery to discover why Denver has been dubbed the “Napa Valley of Beer.”
103. **Denver “Foodie” Tour:** Tues., 27 Sept., 11 a.m.–2 p.m. US\$99. Experience some of the best Denver “foodie” restaurants on this lunchtime walking tour.
104. **Denver City Swing:** Wed., 28 Sept., 9 a.m.–noon US\$55. Enjoy this three-hour swing through unique and vibrant areas around the Mile High City.
- All tours depart from CCC, Lobby F.



Blue Bear, photo by Steve Crecelius. Used with permission by Visit Denver.

Connecting the deep-time community

# STEPPE

Earth's Past, Our Future

GSA 2016 Annual Meeting & Convention  
Colorado Convention Center (CCC), Exhibit Hall  
Visit us at Exhibit Hall Booth 150 in Paleo Alley.

**“Seds and Suds”**  
Tues., 27 Sept., 6–8 p.m., CCC, location TBA

Join us for the GSA Sedimentary Geology Division and GSA Limnogeology Division Joint Meeting and Awards Reception (cosponsored by SEPM [Society for Sedimentary Geology]).

THE GEOLOGICAL SOCIETY OF AMERICA

**STEPPE**  
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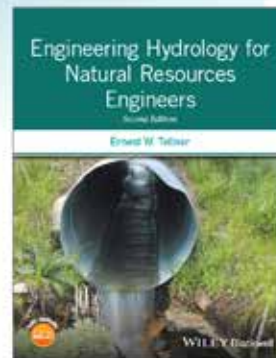
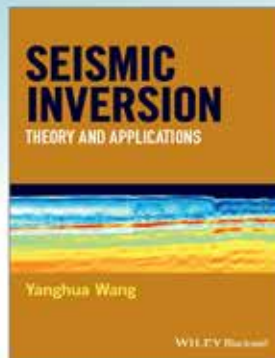
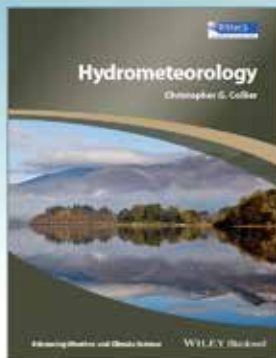
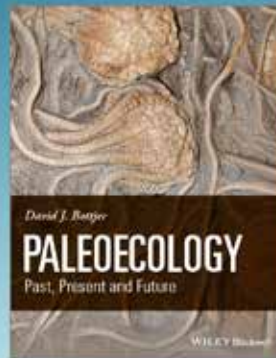
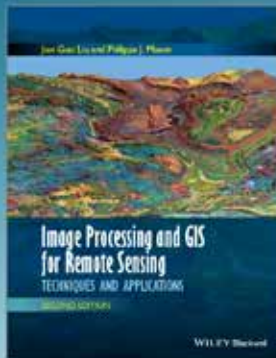
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| ✓ Geology Today                  | ✓ Palaeontology            |
| ✓ Acta Geologica Sinica          | ✓ Sedimentology            |
| ✓ Boreas  BOREAS                 | ✓ JGR: Earth Surface       |
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# New Textbooks

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# Scientific Field Trips

## *These trips start soon!*

Check online at [community.geosociety.org/gsa2016/science-careers/fieldtrips](http://community.geosociety.org/gsa2016/science-careers/fieldtrips) or contact GSA Sales & Service at +1-888-443-4472 to take advantage of these adventures as part of your GSA 2016 experience. All trips begin and end at the Colorado Convention Center unless otherwise noted, and transportation is provided unless otherwise noted. ECP—early career professional; B—Breakfast; L—Lunch; D—Dinner; R—Refreshments; ON—Overnight Lodging. GSA thanks VISIT DENVER and the GSA Hotel Partners for helping to support field experiences and education.

## Before the Meeting

**401. GSA International Student Field Trip to National Parks in the Western U.S.** Sixteen days: Wed.–Thurs., 7–22 Sept. US\$1,000 (14 L/D/R, 15 ON). *Cosponsor: GSA International.* Trip begins and ends in Las Vegas, Nevada.

**402. A Visit to the Regional Aluminum Silicate Triple-Point Metamorphic Rocks of Northern New Mexico: A Field Trip to Honor the Career Contributions of Lincoln Hollister to Petrology and Tectonics.** Four days: Wed.–Sat., 21–24 Sept. US\$499; limited student/ECP price: US\$250 (R, 4 L, 1 D, 3 ON). *Cosponsors: GSA Structural Geology and Tectonics Division; GSA Mineralogy, Geochemistry, Petrology and Volcanology Division.*

**403. Transect of Mesoproterozoic Belt Basin, Glacier National Park, Montana.** Two days: Thurs.–Fri., 22–23 Sept. US\$275; limited student/ECP price: US\$145 (R, 1 ON). Trip begins and ends in Kalispell, Montana.

**404. Dynamic Topography, Regional Uplift, and Integration History of the Colorado–Green River Systems.** Four days: Wed.–Sat., 21–24 Sept. US\$585; limited student/ECP price: US\$325 (R, 3 L/D/ON). *Cosponsor: GSA Quaternary Geology and Geomorphology Division.*

**405. Sequence Stratigraphy, Stratal Patterns, and Hydrodynamics of the Upper Cretaceous Iles (Mount Garfield) and Williams Fork (Hunter Canyon) Formations, Grand Junction Area, Colorado.** Four days: Wed.–Sat., 21–24 Sept. US\$495; limited student/ECP price: US\$250 (3 L/ON).

**406. Getting to the Bottom of the High Plains Aquifer: New Insights into the Depositional History, Stratigraphy, and Paleocology of the Cenozoic High Plains.** Three days: Thurs.–Sat., 22–24 Sept. US\$399; limited student/ECP price: US\$200 (R, 2 ON). *Cosponsors: GSA Sedimentary Geology Division; SEPM (Society for Sedimentary Geology); GSA Soils and Soil Processes Interdisciplinary Interest Group; GSA Geology and Public Policy Committee; GSA Geology and Society Division.*

**407. Exploring the Ancient Volcanic and Lacustrine Environments of the Oligocene Creede Caldera and Environs, San Juan Mountains, Colorado.** Three days: Thurs.–Sat., 22–24 Sept. US\$325; limited student/ECP price: US\$175 (R, 2 ON).

**408. Depositional Systems of the Rockies.** Three days: Thurs.–Sat., 22–24 Sept. US\$560; limited student/ECP price: US\$295 (R, 3 L, 2 D, 2 ON). *Cosponsor: Energy and Geoscience Institute, University of Utah.* Trip departs Salt Lake City, Utah, and ends in Denver.

**409. From Terraces to Terroir: Exploring Geology and Wineries on Colorado's Western Slope.** Three days: Thurs.–Sat., 22–24 Sept. US\$390 (3 L/ON, 1 D).

**410. Geomorphic Evolution of the San Luis Basin and Rio Grande.** Three days: Wed.–Fri., 21–23 Sept. US\$290; limited student/ECP price: US\$145 (R, 2 L/ON). *Cosponsor: GSA Quaternary Geology and Geomorphology Division.* Trip begins and ends in Alamosa, Colorado.

**411. Geoheritage along the Gold Belt Byway, Colorado: Initiatives to Promote the Legacy of Geologic History for Local Communities.** Two days: Fri.–Sat., 23–24 Sept. US\$345; limited student/ECP price: US\$175 (R, 2 L, 1 D/ON). *Cosponsors: William Smith Bicentenary Committee; GSA History and Philosophy of Geology Division.*

**412. Cretaceous Ocean–Climate Perturbations Revealed in Cenomanian–Campanian Strata of Colorado: Field Trip Associated with Symposium Honoring the Scientific Contributions of Michael A. Arthur.** Two days: Fri.–Sat., 23–24 Sept. US\$299; limited student/ECP price: US\$150 (R, 2 L, 1 D/ON).

**413. Stromatolite Variability in the Nash Fork Formation, Southeastern Wyoming: A Walking Tour across a Paleoproterozoic Carbonate Shelf.** Two days: Fri.–Sat., 23–24 Sept. US\$325; limited student/ECP price: US\$175 (R, 1 L/D/ON). Trip begins and ends in Laramie, Wyoming.

**414. Overview of the Eocene Castle Rock Conglomerate, East-Central Colorado: Remapping the Fluvial System and Implications for the History of the Colorado Piedmont and Front Range.** One day: Sat., 24 Sept. US\$89; limited student/ECP price: US\$45 (1 L/R). *Cosponsor: Colorado Geological Survey.*

**415. Unconventional Reservoirs and Stratigraphy of the Southern Denver Basin: Graneros, Greenhorn, Carlile, and Niobrara Formations.** Two days: Sat.–Sun., 24–25 Sept. US\$425; limited student/ECP price: US\$225 (R, 2 L, 1 ON). *Cosponsor: GSA Energy Geology Division.*

**416. Geology along the Colorado Front Range near Morrison and Golden.** One day: Sat., 24 Sept. US\$99; limited student/ECP price: US\$50 (R, 1 L). *Cosponsor: GSA Members of the Friends of Dinosaur Ridge.*

417A. **An Accessible Journey through Geologic Time in Central Colorado.** For higher education students with disabilities and geoscience faculty. **Must apply to attend; check the meeting website.** One day: Sat., 24 Sept. US\$50; limited student/ECP price: US\$25 (R, 1 L). *Cosponsors: GSA Geoscience Education Division; International Association for Geoscience Diversity.*

417B. **An Accessible Journey through Geologic Time in Central Colorado.** For middle and high school students with disabilities and science teachers. **Must apply to attend; check the meeting website.** One day: Sat., 24 Sept. (R, 1 L). *Cosponsors: GSA Geoscience Education Division; International Association for Geoscience Diversity.*

418. **Geology, Hydrology, Water Rights, and History of the Mineral Waters of Manitou Springs.** One day: Sat., 24 Sept. US\$120; limited student/ECP price: US\$60 (R, 1 L).

419. **Management of Acid Mine Drainage in the Colorado Mineral Belt.** One day: Sat., 24 Sept. US\$195; limited student/ECP price: US\$99 (1 L/D). *Cosponsor: Hatch Associates Consultants, Lakewood, Colorado, USA.*

420. **Pinedale Glacial History of the Upper Arkansas River Valley: New Moraine Chronologies, Modeling Results, and Geologic Mapping.** One day: Sat., 24 Sept. US\$85; limited student/ECP price: US\$45 (R, 1 L). *Cosponsor: GSA Quaternary Geology and Geomorphology.*

421. **Restoring the Headwaters of the Arkansas River: A Bike and Underground Tour of the Leadville Mining District and Modern Reclamation Efforts to Minimize the Effects of Acid Mine Drainage.** One day: Sat., 24 Sept. US\$99; limited student/ECP price: US\$50 (R, 1 B). *Cosponsor: Colorado Mountain College, Leadville, Colorado, USA.*

422. **Roadside Faults, Folds, Fossils, Crystals, and Diamond Pipes—Sampling the Geologic Diversity of Northern Colorado.** One day: Sat., 24 Sept. US\$99; limited student/ECP price: US\$50 (R).

423. **The Consequences of Living with Geology.** One day: Sat., 24 Sept. US\$110; limited student/ECP price: US\$55 (R, 1 L). *Cosponsors: American Institute of Professional Geologists; Association of Engineering and Environmental Geologists.*

## During the Meeting

424. **Kirk Bryan Field Trip: Quaternary Landslides, Fluvial Terraces, and Recent Geomorphic Events along the Colorado Front Range.** One day: Tues., 27 Sept. US\$99; limited student/ECP price: US\$50 (R, 1 L). *Cosponsors: GSA Quaternary Geology and Geomorphology Division; Boulder Creek Critical Zone Observatory; Colorado Scientific Society.*

## After the Meeting

425. **Late Holocene Landscape Evolution in the White River Badlands.** Four days: Fri.–Sun., 29 Sept.–2 Oct. US\$525; limited student/ECP price: US\$275 (R, 4 L, 3 D/ON).

426. **Middle to Late Cenozoic Geology and Geomorphology of the Laramie Mountains, Wyoming.** Two days: Thurs.–Fri., 29–30 Sept. US\$199; limited student/ECP price: US\$99 (R, 2 L, 1 ON). *Cosponsor: Colorado Scientific Society.*

427. **Progressive Development of Basement-Involved Foreland Thrust Belts: Results from the NSF/EarthScope Bighorn Project Applied to the Laramide Orogeny in the Colorado Front Range.** One day: Thurs., 29 Sept. US\$75; limited student/ECP price: US\$40 (R, 1 L).

428. **South Park: Complex Structure and Stratigraphy Create One of Colorado's Crown Jewels.** One day: Thurs., 29 Sept. US\$99; limited student/ECP price: US\$50 (R, 1 L). *Cosponsors: Colorado Geological Survey; Colorado Scientific Society; Coalition for the Upper South Platte.*

429. **Large Hydrothermal Systems above the Yellowstone Magma Chamber.** Five days: Thurs.–Mon., 29 Sept.–3 Oct. US\$599; limited student/ECP price: US\$300 (R, 5 L, 1 D, 4 ON).

430. **New Perspectives on a 140-Year Legacy of Mining and Abandoned Mine Cleanup in the San Juan Mountains, Colorado.** Four days: Thurs.–Sun., 29 Sept.–2 Oct. US\$650; limited student/ECP price: US\$325 (R, 4 L, 3 D/ON). *Cosponsors: U.S. Geological Survey Central Mineral and Environmental Resources Science Center; Navarro Research and Engineering Inc. (contractor to the U.S. Dept. of Energy Office of Legacy Management).*

431. **Slime, Redbeds, and Evaporites in an Eolianite Sandwich: The Permian-Triassic of Colorado & Southeastern Wyoming.** One day: Thurs., 29 Sept. US\$85; limited student/ECP price: US\$45 (R, 1 L).

432. **Conodonts and Early Fish in Colorado's Shallow, Early Paleozoic Seas.** One day: Thurs., 29 Sept. US\$110; limited student/ECP price: US\$55 (R, 1 L).

433. **Sandstones and Utah's Canyon Country: Deposition, Diagenesis, Exhumation, and Landscape Evolution.** Four days: Thurs.–Sun., 29 Sept.–2 Oct. US\$575; limited student/ECP price: US\$295 (R, 4 L, 3 ON). *Cosponsor: SEPM (Society for Sedimentary Geology).* Trip begins and ends in Grand Junction, Colorado.

434. **U.S. Geological Survey Collections: Understanding the Past to Create a Future—Tour Three Federal Repositories, Paleontological Collections, Core Research Center, National Ice Core Laboratory.** One day: Thurs., 29 Sept. US\$10; limited student/ECP price: US\$5. No transportation included. *Cosponsor: U.S. Geological Survey.*

435. **How to Make the Lights Turn on with a Clap—A Tour of Colorado's Energy Grid.** One day: Thurs., 29 Sept. US\$99; limited student/ECP price: US\$50 (R, 1 L). *Cosponsors: Colorado School of Mines Energy and Minerals Field Institute; Colorado Geological Survey.*

## *A critical resource for anyone wrestling with Young Earth Creationism*

To extensive media attention and fanfare, Ken Ham's \$102-million *Ark Encounter* opened this summer in Kentucky, claiming to prove that the Earth is only a few thousand years old, and that the Earth's fossil-bearing layers and landforms can be explained by a catastrophic flood in the recent past. Young Earth Creationism remains a popular movement within Christian circles.

Perfect as a classroom resource or a coffee-table book, *The Grand Canyon, Monument to an Ancient Earth* directly challenges young-earth claims. With its lavish illustrations and conversational tone, the book focuses on the wonders of the Grand Canyon to address questions such as:

- How do geologists know what they claim to know?
- Why are there no dinosaur, bird, mammal, or flowering plant fossils in the canyon's layers?
- How do we know radiometric dating methods are reliable?
- How can we determine what happened in the "unobserved" past?
- How long did it take to carve the canyon?
- Is Young Earth Creationism really biblical?

Written in a tone that does not insult religious belief, the book has received acclaim from prominent geologists and theologians alike:

"It is a fabulous defender of the geology that we know in the Grand Canyon and Grand Staircase."

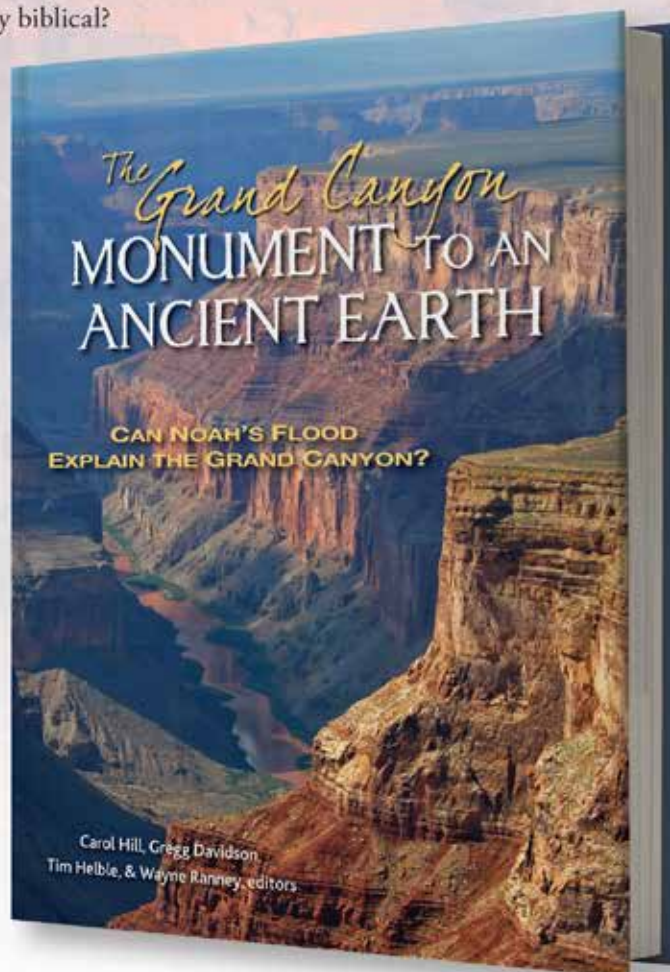
— **John Warme,**  
Professor Emeritus,  
Colorado School of Mines

"This important book must be carefully considered by everyone involved in the debate about the age of the earth."

— **Wayne Grudem,**  
Phoenix Seminary

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# Short Courses

GSA-sponsored professional development short courses will be held immediately before and during the annual meeting and are open to members and nonmembers. A course-only registration fee is required if you are not attending the meeting. This fee may be applied toward meeting registration if you decide to attend. **On-site registration is based on availability and costs an additional US\$30.** All prices listed below reflect this increased fee. CCC—Colorado Convention Center.

## FAQs

- *Can I take a short course if I am not registered for the meeting?* YES! You're welcome to—just add the meeting nonregistrant fee of US\$40 when you pay for the course. Should you then decide to attend the meeting, your payment will be applied toward meeting registration.
- *GSA K–12 teacher member?* You're welcome to take short courses without registering for the meeting or paying the US\$40 nonregistrant fee.
- *Do you offer CEUs?* Yes. You can earn continuing education credits (CEUs) for technical sessions, short courses, and field trips. Ten contact hours are required for one CEU; for example, one day (8 hours) of technical sessions = 0.8 CEUs. When your course ends, fill out the online course evaluation, then download your CEU certificate.
- *More questions?* See [community.geosociety.org/gsa2016/science-careers/courses](http://community.geosociety.org/gsa2016/science-careers/courses) or contact Jennifer Nocerino, [jnocerino@geosociety.org](mailto:jnocerino@geosociety.org), for course abstracts and information.

### 501. Introduction to Terrestrial Laser Scanning (Ground-Based LiDAR) for Earth Science Research and Education

**When:** Fri., 23 Sept., 8 a.m.–5 p.m.  
**Where:** UNAVCO, Boulder  
**Cost:** US\$80, includes lunch

### 502. Sequence Stratigraphy for Graduate Students

**When:** Fri.–Sat., 23–24 Sept., 8 a.m.–5 p.m.  
**Where:** CCC, Room 708/710  
**Cost:** US\$55

### 503. Structural and Stratigraphic Concepts Applied to Basin Exploration

**When:** Fri.–Sat., 23–24 Sept., 8 a.m.–5 p.m.  
**Where:** CCC, Room 102  
**Cost:** US\$55, includes lunch

### 504. Advanced Sequence Stratigraphic Applications for Exploration

**When:** Fri.–Sat., 23–24 Sept., 8 a.m.–5 p.m.  
**Where:** CCC, Room 101  
**Cost:** US\$352

### 505. GIS-Based Spatial Mathematical Modeling for Mineral Exploration

**When:** Fri.–Sat., 23–24 Sept., 8 a.m.–5 p.m.  
**Where:** CCC, Room 103  
**Cost:** US\$237

### 506. Facilitating Effective STEM Learning and Public Engagement in Paleontology

**When:** Fri., 23 Sept., 1–5 p.m.  
**Where:** CCC, Room 104  
**Cost:** US\$55

### 507. Digital Technology across the Earth Science Curriculum—A Short Course for Preservice and In-Service Teachers and Undergraduate Instructors

**When:** Sat., 24 Sept., 8 a.m.–4 p.m.  
**Where:** CCC, Room 701  
**Cost:** US\$55

### 508. Ground-Penetrating Radar: Principles, Practice, and Processing

**When:** Sat., 24 Sept., 8 a.m.–5 p.m.  
**Where:** CCC, Room 112  
**Cost:** US\$100

### 509. Using Laser Ablation Split Stream (LASS) Geochronology and Petrochronology to Address Tectonic & Petrologic Questions

**When:** Sat., 24 Sept., 8 a.m.–5 p.m.  
**Where:** CCC, Room 709  
**Cost:** US\$80, includes lunch

### 510. Geochemical Applications of pXRF: Environmental, Exploration, and Geology

**When:** Sat., 24 Sept., 8 a.m.–5 p.m.  
**Where:** CCC, Room 105  
**Cost:** US\$70, includes lunch

### 511. Practical Techniques for Using Temperature as a Tracer in Hydrological Research

**When:** Sat., 24 Sept., 8 a.m.–5 p.m.  
**Where:** CCC, Room 711  
**Cost:** US\$180

### 512. Acid Rock Drainage (ARD) Characterization: A Critical Component of Life Cycle Planning and Management of Metal Mines

**When:** Sat., 24 Sept., 8 a.m.–5 p.m.  
**Where:** CCC, Room 712  
**Cost:** US\$155

*continued on next page*

**513. Vapor Intrusion: Scientific, Regulatory, and Field Perspectives**

**When:** Sat., 24 Sept., 8 a.m.–5 p.m.  
**Where:** CCC, Room 107  
**Cost:** US\$279

**514. The Essentials to Building Realistic and Reliable 3D Geological Models**

**When:** Sat., 24 Sept., 8 a.m.–5 p.m.  
**Where:** CCC, Room 108  
**Cost:** US\$160, includes lunch

**515. Organic, Light, and Clumped Stable Isotope Geochemistry in the Twenty-First Century: Principles, Practices and Novel Applications**

**When:** Sat., 24 Sept., 8 a.m.–5 p.m.  
**Where:** University of Colorado, Boulder  
**Cost:** US\$80, includes lunch

**516. Preparing for a Career in the Geosciences**

**When:** Sat., 24 Sept., 8 a.m.–noon.  
**Where:** CCC, Room 702/704  
**Cost:** US\$80

**517. Teaching about Climate Change and Hazards: Data-Rich Teaching Modules for Introductory Courses**

**When:** Sat., 24 Sept., 8 a.m.–noon.  
**Where:** CCC, Room 703  
**Cost:** US\$55

**518. Teaching the Anthropocene: Controversial Issues 1**

**When:** Sat., 24 Sept., 8 a.m.–noon.  
**Where:** CCC, Room 705  
**Cost:** US\$65

**519. Interactive Strategies for the Classroom: A How-To Guide Using Examples about Igneous Rocks**

**When:** Sat., 24 Sept., 1–5 p.m.  
**Where:** CCC, Room 106  
**Cost:** US\$65

**520. Making Plate Reconstructions with GPlates: Applications for Teaching and Research**

**When:** Sat., 24 Sept., 8 a.m.–noon.  
**Where:** CCC, Room 706  
**Cost:** US\$105

**521. Top Tips for Publishing Success**

**When:** Sat., 24 Sept., 8 a.m.–noon.  
**Where:** CCC, Room 707  
**Cost:** US\$40

**522. Using Terrestrial Laser Scanning (TLS) and Structure from Motion (SfM) in Undergraduate Field Courses**

**When:** Sat., 24 Sept., 8 a.m.–noon.  
**Where:** CCC, Room 104  
**Cost:** US\$55

**523. U-Th-Pb Geochronology Using ET\_Redux (Data Reduction) and Geochron (Database)**

**When:** Sat., 24 Sept., 9 a.m.–5 p.m.  
**Where:** CCC, Room 109  
**Cost:** US\$60

**524. Introduction to Numerical Modeling of Lithospheric Deformation in Matlab**

**When:** Sat., 24 Sept., 9 a.m.–5 p.m.  
**Where:** CCC, Room 111  
**Cost:** US\$50

**525. Introduction to Structure from Motion (SfM) Photogrammetry for Earth Science Research and Education**

**When:** Sat., 24 Sept., 9 a.m.–5 p.m.  
**Where:** CCC, Room 110  
**Cost:** US\$60, includes lunch

**526. High-Resolution Site Characterization (HRSC) for Complex Contaminant Sites**

**When:** Sat., 24 Sept., 1–5 p.m.  
**Where:** CCC, Room 706  
**Cost:** US\$140

**527. Analyzing Active Tectonics with LiDAR, InSAR, and GPS: Using Geodetic Data in Major-Level Courses**

**When:** Sat., 24 Sept., 1–5 p.m.  
**Where:** CCC, Room 703  
**Cost:** US\$55

**528. Teaching the Evolution of Life & Earth: Controversial Issues 2**

**When:** Sat., 24 Sept., 1–5 p.m.  
**Where:** CCC, Room 705  
**Cost:** US\$65

**529. Microbially Induced Sedimentary Structures (MISS)—Introduction to Reconnaissance and Interpretation**

**When:** Sat., 24 Sept., 8 a.m.–5 p.m.  
**Where:** CCC, Room 106  
**Cost:** US\$121

**530. Introductory-Level InTeGrate Geoscience Classroom Activities that Blend Student Decision Making with Important Societal Issues**

**When:** Sat., 24 Sept., 1–5 p.m.  
**Where:** CCC, Room 104  
**Cost:** US\$75

**531. Ethics on the Edge: Scientific Integrity and Geoethics for a Changing World**

**When:** Sat., 24 Sept., 1–4 p.m.  
**Where:** CCC, Room 702/704  
**Cost:** US\$40

**532. Bridging Science to Society in the Classroom: Tectonic Motions, Earthquakes, and Shake-Resistant Buildings**

**When:** Sat., 24 Sept., 1–5 p.m.  
**Where:** CCC, Room 707  
**Cost:** US\$55

# GSA Associated Society Course

## PALEONTOLOGICAL SOCIETY

### Virtual Paleontology

**When:** Sat., 24 Sept., 9 a.m.–6 p.m.

**Where:** CCC, Mile High Ballroom 4AB

**Cost:** FREE, with no registration needed and no course attendance limit



**Sat., 24 Sept.,** at the GSA Annual Meeting & Exposition in Denver

EarthCaching gets people out in the field to learn about their planet first-hand.

Come meet EarthCachers from around the globe, learn more about EarthCaching, find local caches, and participate in other exciting and educational activities. This is a unique opportunity for GSA members and other GSA Annual Meeting attendees to connect with the EarthCaching and Geocaching communities.

If you would like to give a presentation about Colorado's geology, please email Matt Dawson at [mdawson@geosociety.org](mailto:mdawson@geosociety.org).

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## Notice of GSA Council Meetings

GSA 2016 ANNUAL MEETING & EXPOSITION  
DENVER, COLORADO, USA

- ▶ **Day 1:** Saturday, 24 Sept., 8 a.m.–noon
- ▶ **Day 2:** Wednesday, 28 Sept., 8 a.m.–noon.

**Location:** GSA Headquarters Hotel—Hyatt Regency Denver at CCC, 650 15th Street, Denver, Colorado 80202, USA. Mineral Hall B-C.

All GSA members are invited to attend the open portions of these meetings.

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# Exhibitors

## Exhibitor Categories

*This list is as of press time; exhibitors may fall under other categories.*

### COMPUTER SOFTWARE

Mount Sopris Instruments Inc.: Booth 163  
The Geochemist's Workbench: Booth 108  
The Paleobiology Database: Booth 145

### ENVIRONMENTAL

Center for Applied Isotope Studies,  
University of Georgia: Booth 673  
Meinhard and Elemental Scientific Inc.:  
Booth 407

### GEMS/MINERAL DEALERS/JEWELRY/GIFTS

Crystals Unlimited: Booth 401  
Gems & Crystals Unlimited: Booth 121  
Janice Evert Opals: Booth 258  
Komodo Dragon: Booth 220  
Natural Earth Craft LLC – Heidi Scheirer  
McGrew: Booth 300  
Nature's Own: Booth 621

### GENERAL EDUCATIONAL PRODUCTS

American Geosciences Institute: Booth 608  
Environmental and Engineering  
Geophysical Society (EEGS): Booth 363  
ESRI: Booth 408  
Howard Hughes Medical Institute:  
Booth 267  
McGraw-Hill Education: Booth 116  
New Mexico Bureau of Geology: Booth 471  
Pearson: Booth 337  
Science Is Never Settled: Booth 564  
Space Science Institute: Booth 158  
The FOSSIL Project: Booth 152  
The Paleobiology Database: Booth 145

### GEOLOGICAL AND GEOPHYSICAL INSTRUMENTATION

Bruker: Booth 500  
Brunton Outdoor: Booth 538  
Isomass/SelFrag: Booth 307  
Jasper Canyon Research: Booth 253  
Little River Research & Design: Booth 243  
Meinhard and Elemental Scientific Inc.:  
Booth 407  
Mount Sopris Instruments Inc.: Booth 163  
Sensors & Software Inc.: Booth 439  
Ward's Science: Booth 716

### GEOLOGICAL SOCIETY OF AMERICA

Bookstore: Booth 223  
GSA Energy Geology Division: Booth 134

## Exhibit Hall Hours & Opening Reception

### Colorado Convention Center

Sun., 2–7 p.m.; Opening Reception: 5:30–7 p.m.  
Mon.–Tues., 10 a.m.–6:30 p.m.  
Wed., 10 a.m.–2 p.m.

GSA Karst Division: Booth 704  
GSA Planetary Geology: Booth 120  
GSA Membership: Booth 213  
STEPPE: Booth 150

### GOVERNMENT AGENCIES (FEDERAL, STATE, LOCAL, INTERNATIONAL)

NASA: Booth 113  
National Science Foundation: Booth 356  
New Mexico Bureau of Geology: Booth 471  
SubTER: Subsurface Technology &  
Engineering Research, Development &  
Demonstration: Booth 306

### OTHER

Estwing Manufacturing Company:  
Booth 554  
IRIS Consortium: Booth 359  
The Paleobiology Database: Booth 145

### PROFESSIONAL SOCIETIES AND ASSOCIATIONS

American Geophysical Union (AGU):  
Booth 600  
American Geosciences Institute: Booth 608  
American Institute of Professional  
Geologists (AIPG): Booth 604  
American Meteorological Society:  
Booth 247  
Association of Earth Science Editors (AESE):  
Booth 714  
Council on Undergraduate Research:  
Booth 456  
Environmental and Engineering  
Geophysical Society (EEGS): Booth 363  
European Geosciences Union (EGU):  
Booth 367  
Geochemical Society: Booth 609  
Geoscience Information Society (GSIS):  
Booth 131  
International Association for Geoscience  
Diversity (IAGD): Booth 466  
Japan Geoscience Union: Booth 570  
Mineralogical Society of America:  
Booth 266  
National Association of Geoscience  
Teachers: Booth 457  
National Association of State Boards of  
Geology (ASBOG®): Booth 562  
New Mexico Bureau of Geology: Booth 471  
SEPM Society for Sedimentary Geology:  
Booth 342

Sigma Gamma Epsilon: Booth 566  
STEPPE: Booth 150  
The Clay Minerals Society: Booth 264  
The FOSSIL Project: Booth 152

### PUBLICATIONS, MAPS, FILMS

ESRI: Booth 408  
McGraw-Hill Education: Booth 116  
New Mexico Bureau of Geology: Booth 471  
Oxford University Press: Booth 244  
Taylor & Francis Group: Booth 110  
Wiley: Booth 601

### SERVICES (EXPLORATION, LABORATORIES, CONSULTING, AND OTHERS)

American Geosciences Institute: Booth 608  
Beta Analytic Inc.: Booth 508  
Center for Applied Isotope Studies,  
University of Georgia: Booth 673  
DirectAMS: Booth 708  
Environmental Isotope Laboratory:  
Booth 406  
GIA (Gemological Institute of America  
Inc.): Booth 129  
GNS Science / Rafter Radiocarbon:  
Booth 106  
ICA (International Chemical Analysis):  
Booth 712

### UNIVERSITIES/SCHOOLS

Center for Applied Isotope Studies,  
University of Georgia: Booth 673  
Colorado School of Mines, Dept. of Geology  
& Geology Engineering: Booth 650  
Department of Geology and Geophysics,  
Texas A&M University: Booth 558  
LSU Department of Geology & Geophysics:  
Booth 655  
New Mexico Bureau of Geology: Booth 471  
Syracuse University: Booth 744  
University of Connecticut: Center for  
Integrative Geosciences: Booth 557  
University of Michigan: Booth 746  
University of North Carolina–Charlotte:  
Booth 547  
University of Puerto Rico: Booth 772  
University of Southern California  
Department of Earth Sciences: Booth 748  
Virginia Tech Department of Geosciences:  
Booth 556



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# SCIENCE EDITOR

## OPENINGS FOR 2018

GSA is soliciting applications and nominations for science co-editors for *Geology*, *GSA Bulletin*, *Geosphere*, and *GSA Today* with four-year terms beginning 1 January 2018. Duties include: ensuring stringent peer review and expeditious processing of manuscripts; making final acceptance or rejection decisions after considering reviewer recommendations; and maintaining excellent content through active solicitation of diverse and definitive manuscripts.

### POSITIONS AVAILABLE

**GSA TODAY** The editor of *GSA Today*, one of the most widely read earth science publications in the world, must have a wide range of interests and expertise along with the ability to identify research topics of both high quality and broad appeal. Prior editing experience and a publication record in a wide range of journals is key.

**GSA BULLETIN** Research interests that would complement those of the continuing editors include, but are not limited to: stratigraphy; geomorphology; geochemistry; tectonics; structural geology; deformation; and paleoclimatology.

**GEOSPHERE** Research interests that would complement those of the continuing editors include, but are not limited to: geochronology; geochemistry; volcanology; petrology; sedimentary geology; remote sensing/GIS; tectonics, structural geology; geosciences education; and dynamic content.

**GEOLOGY** Research interests that would complement those of the continuing editors include, but are not limited to: hard-rock geology; tectonics; geodynamics; geochemistry; tectonophysics; volcanology; marine geology; structural geology; geophysics; and planetary geology.

Note that candidates should not feel they must have expertise in every area listed; however, editors will sometimes need to handle papers outside of their main disciplines.

### INTERESTED?

- ▶ Please submit a curriculum vitae and a letter describing why you are suited for the position to Jeanette Hammann, [jhammann@geosociety.org](mailto:jhammann@geosociety.org).
- ▶ To nominate another, submit a nomination letter and the person's written permission and CV.

Editors work out of their current locations at work or at home. The positions are considered voluntary, but GSA provides an annual stipend and funds for office expenses. **DEADLINE** First consideration will be given to nominations or applications received by **15 February 2017**.

*GSA Today* ▶ 1 position

*GSA Bulletin* ▶ 1 position

*Geosphere* ▶ 1 position

*Geology* ▶ 1 position

### A SUCCESSFUL EDITOR WILL HAVE

- ▶ a broad interest and experience in geosciences, including familiarity with new trends;
- ▶ international recognition and familiarity with many geoscientists and their work;
- ▶ a progressive attitude and a willingness to take risks and encourage innovation;
- ▶ experience with online manuscript systems and the ability to make timely decisions; and
- ▶ a sense of perspective and humor.

Preliminary Announcement and Call for Papers

# SOUTH-CENTRAL SECTION

51st Annual Meeting of the South-Central  
Section, GSA

San Antonio, Texas, USA

13–14 March 2017

[www.geosociety.org/Sections/sc/2017mtg/](http://www.geosociety.org/Sections/sc/2017mtg/)



Aerial overview of the Canyon Lake spillway of south-central Texas. Photo by Larry Walther.

## Geosciences in the Heart of Texas

### LOCATION

San Antonio is a vibrant, multicultural city with scenic waterways, culinary treasures, and easy access to geology ranging from urban caves to Precambrian rocks of the Llano Uplift. The city boasts a wide range of local attractions, including the Spanish Missions National Historic Park, the Riverwalk, Six Flags Fiesta Texas, world-class museums, and a thriving culinary scene ranging from street food to five-star fare. We have developed a technical program that explores a wide range of geologic processes and related topics, and our meeting coincides with some of the best weather of the year, providing opportunities for spectacular field trips across the south Texas region.

### CALL FOR PAPERS

**Abstract deadline:** 6 Dec. 2016

**Submit online:** [www.geosociety.org/sections/sc/2017mtg/](http://www.geosociety.org/sections/sc/2017mtg/).

**Abstract submission fee:** US\$18 for students and US\$30 for all others.

For additional information, please contact the Technical Program Chair, David Turner, [dturner2@stmarytx.edu](mailto:dturner2@stmarytx.edu).

### Theme Sessions

- T1. **Advances in Understanding Precambrian to Cenozoic Magmatic and Metamorphic Processes and their Bearing on Lithospheric Evolution of Southern Laurentia.** Elizabeth Catlos, Univ. of Texas at Austin; [ejcatlos@gmail.com](mailto:ejcatlos@gmail.com); Michael DeAngelis, Univ. of Arkansas Little Rock, [mtdeangelis@ualr.edu](mailto:mtdeangelis@ualr.edu); Richard Hansen, Texas Christian Univ., [r.hanson@tcu.edu](mailto:r.hanson@tcu.edu).
- T2. **Advances in the Application and Development of Terrestrial Paleoclimate Proxies.** *Cosponsored by Soils and Soil Processes Interdisciplinary Interest Group; GSA Geobiology and Geomicrobiology Division; GSA Karst Division.* Marina Suarez, Univ. of Texas at San Antonio, [Marina.Suarez@utsa.edu](mailto:Marina.Suarez@utsa.edu); Steven Driese, Baylor Univ., [Steven\\_Driese@baylor.edu](mailto:Steven_Driese@baylor.edu); Dan Brecker, Univ. of Texas at Austin, [breecker@jsg.utexas.edu](mailto:breecker@jsg.utexas.edu).
- T3. **Advances in Sedimentology, Stratigraphy, and Geochemistry of Carbonates and Mixed Carbonate Clastic Systems.** *Cosponsored by GSA Karst Division; GSA Sedimentary Geology Division.* Dan Lehrmann, Trinity Univ., [dlehrmann@trinity.edu](mailto:dlehrmann@trinity.edu); Andre Droxler, Rice Univ., [andre@rice.edu](mailto:andre@rice.edu).
- T4. **The Impact of Oceanographic Conditions, Oaes, and Volcanism on an Unconventional Reservoir System: The Late Cretaceous Eagle Ford and Austin Chalk Groups of the Gulf Coast.** *Cosponsored by GSA Sedimentary Geology Division.* Alexis Godet, Univ. of Texas at San Antonio, [Alexis.Godet@utsa.edu](mailto:Alexis.Godet@utsa.edu); Michael Pope, Texas A&M Univ., [mcpope@tamu.edu](mailto:mcpope@tamu.edu); Robert Stern, Univ. of Texas at Dallas, [rjstern@utdallas.edu](mailto:rjstern@utdallas.edu); Jon Snow, Univ. of Houston, [jesnow@uh.edu](mailto:jesnow@uh.edu); Steve Bergman, Shell International Exploration and Production (Houston), [scbergman@sbcglobal.net](mailto:scbergman@sbcglobal.net).
- T5. **Micro- to Macroscopic Evidence of Life and its Implications for the Evolution and Interpretation of the Biosphere in Earth Systems.** *Cosponsored by GSA Geobiology and Geomicrobiology Division; GSA Karst Division.* Stephen Hasiotis, Univ. of Kansas, [hasiotis@ku.edu](mailto:hasiotis@ku.edu); Thomas Adams, Witte Museum, [thomasadams@wittemuseum.org](mailto:thomasadams@wittemuseum.org); William Foster, Univ. of Texas at Austin, [wfoster@jsg.utexas.edu](mailto:wfoster@jsg.utexas.edu); Sophie Warny, Louisiana State Univ., [swarny@lsu.edu](mailto:swarny@lsu.edu).
- T6. **Karst: From Sinkholes to Springs and Everything in Between.** *Cosponsored by GSA Karst Division.* Geary Schindel, Edwards Aquifer Authority, [gschindel@edwardsaquifer.org](mailto:gschindel@edwardsaquifer.org); Jon Sumrall, Sam Houston State Univ., [karst@shsu.edu](mailto:karst@shsu.edu); Brian Hunt, Barton Springs/Edwards Aquifer Conservation District, [brianh@bseacd.org](mailto:brianh@bseacd.org).
- T7. **Planetary Geology.** *Cosponsored by GSA Karst Division.* Danielle Wyrick, Southwest Research Institute, [danielle.wyrick@swri.org](mailto:danielle.wyrick@swri.org).



- T8. **Subsurface Exploration Techniques in the South-Central U.S.** *Cosponsored by GSA Archaeology Geology Division; GSA Geophysics Division.* Evelyn Mitchell, Saint Mary's Univ., emitchell1@stmarytx.edu; Ronald Green, Southwest Research Institute, ronald.green@swri.org.
- T9. **Fostering Cultures of Deliberate Inclusion in Geosciences.** *Cosponsored by GSA Geoscience Education Division; International Association for Geoscience Diversity.* Stephen K. Boss, Univ. of Arkansas, sboss@uark.edu.
- T10. **Late Paleozoic Tectonic Framework of the South-Central Region and Evolution of the Permian Basin.** *Cosponsored by GSA Structural Geology and Tectonics Division.* Robert Stern, Univ. of Texas at Dallas, rjstern@utdallas.edu; Thomas Ewing, Frontera Exploration Consultants, tewing@fronteraexploration.com; Lowell Waite, Pioneer Natural Resources, lowell.waite@pxd.com.
- T11. **Petroleum and Water Interactions in Mexico's South-Central Region.** *Cosponsored by GSA International Interdisciplinary Interest Group.* Antonio Cardona, Oklahoma State Univ., antonio.cardona\_benavides@okstate.edu; Todd Halihan, Oklahoma State Univ., todd.halihan@okstate.edu; Martin Carlos Vidal García, Mexican Geohydrologic Assoc. and Universidad Nacional Autónoma de México, martincarlosv@yahoo.com.mx.
- T12. **Upper Crustal Deformation across Continental Interiors from the Mesozoic to the Present.** *Cosponsored by GSA Structural Geology and Tectonics Division.* Keith Gray, Wichita State Univ., k.gray@wichita.edu; M. McKay, Missouri State Univ., matthewpaulmckay@gmail.com; B. Surples, Trinity Univ., bsurples@trinity.edu.
- T13. **Texas Water Research Network: A Statewide Initiative to Integrate and Advance Water Research from Inception to Application.** *Cosponsored by GSA Hydrogeology Division; GSA Karst Division.* Suzanne A. Pierce, Texas Advanced Computing Center, spierce@tacc.utexas.edu; Kevin Wagner, Texas A&M Univ., kwagner@ag.tamu.edu; Suzanne Schwartz, Univ. of Texas at Austin, SSchwartz@law.utexas.edu; Jay Banner, Environmental Science Institute, Univ. of Texas at Austin, banner@jsg.utexas.edu.
- T14. **Groundwater Availability in Texas: Rule of Capture and Sustainable to Consensus Yield.** *Cosponsored by GSA Hydrogeology Division; GSA Karst Division.* Brian Hunt, Barton Springs Edwards Aquifer Conservation District, brianh@bseacd.org; Jack Sharp, Jackson School of Geosciences, Univ. of Texas at Austin, jmsharp@jsg.utexas.edu; Suzanne A Pierce, Texas Advanced Computing Center, sawpierce@gmail.com.
- T15. **Undergraduate Student Research (Posters).** *Cosponsored by Council on Undergraduate Research Geosciences Division; GSA Geoscience Education Division.* Elizabeth A. Heise, School of Earth, Environmental and Marine Sciences, Univ. of Texas at Rio Grande Valley, elizabeth.heise@utrgv.edu.
2. **South-Central Texas Underground.** *Cosponsored by GSA Karst Division.* Geary Schindel, Edwards Aquifer Authority, gschindel@edwardsaquifer.org; Jess Buckles, Univ. of Texas at San Antonio, suddsu@gmail.com; and members of the Bexar Grotto of the National Speleological Society.
3. **Traversing the Trinity and Edwards Aquifers along the Blanco River, Central Texas.** *Cosponsored by GSA Karst Division.* Marcus Gary, Edwards Aquifer Authority, mgary@edwardsaquifer.org; Brian Hunt, Barton Springs Conservation District, brianh@bseacd.org.
4. **The Eagle Ford and Austin Chalk Groups in and around San Antonio.** *Cosponsored by GSA Sedimentary Geology Division.* Alexis Godet, Univ. of Texas at San Antonio, alexis.godet@utsa.edu; John Cooper, Univ. of Texas at San Antonio, jcgolf.cooper@gmail.com; Michael Pope, Texas A&M Univ., mcpoppe@tamu.edu.
5. **Cretaceous Sedimentary Succession, Dinosaur Tracksites, and Structural Geology of the Canyon Lake Gorge and Heritage Museum of the Hill Country.** *Cosponsored by GSA Sedimentary Geology Division.* Marina Suarez, Univ. of Texas at San Antonio, Marina.Suarez@utsa.edu; Thomas Adams, Witte Museum, thomasadams@wittemuseum.org.
6. **Precambrian Geology of the Western Llano Uplift.** Mark Helper, Univ. of Texas at Austin, helper@jsg.utexas.edu; Sharon Mosher, Univ. of Texas at Austin, smosher@jsg.utexas.edu.
7. **Cambrian Microbialites and Associated Marine Facies, Llano River, Mason County.** *Cosponsored by GSA Sedimentary Geology Division.* Andre Droxler, Rice Univ., andre@rice.edu; Dan Lehrmann, Trinity Univ., dlehrmann@trinity.edu.

## WORKSHOPS

1. **Cutting-Edge Mapping with Drones: Practical and Cost Effective!** Robert Youens, Camera Wings Aerial Photography, CameraWings@aol.com.
2. **Ethics Training Seminar for Texas Board of Professional Geoscientists Continuing Education.** T. Wesley McCoy, P.G., Texas Board of Professional Geoscientists, wmccoy@tbpge.state.tx.us.

## OPPORTUNITIES FOR STUDENTS AND EARLY CAREER PROFESSIONALS

### Roy J. Shlemon Mentor Program in Applied Geoscience

Students and early career professionals will have the opportunity to discuss career prospects and challenges with applied geoscientists from various sectors over a FREE lunch.

### John Mann Mentors in Applied Hydrogeology Program

Students and early career professionals interested in applied hydrogeology or hydrology as a career will have the opportunity to network with professionals in these fields over a FREE lunch.

## GEOSCIENCE CAREER WORKSHOPS

### Part 1: Career Planning and Informational Interviewing.

Your job-hunting process should begin with career planning, not when you apply for jobs. This workshop will help you begin this process and will introduce you to informational interviewing.

## FIELD TRIPS

For additional information, please contact the Field Trip Chair, Dan Lehrmann, dlehrmann@trinity.edu.

1. **The Edwards Aquifer—A System under Stress.** *Cosponsored by GSA Karst Division.* Geary Schindel, Edwards Aquifer Authority, gschindel@edwardsaquifer.org.

### Part 2: Geoscience Career Exploration.

What do geologists in various sectors earn? What do they do? What are the pros and cons to working in academia, government, and industry? Workshop presenters, and when possible, professionals in the field, will address these issues.

### Part 3: Cover Letters, Résumés, and CVs.

How do you prepare a cover letter? Does your résumé need a good edit? Whether you are currently in the job market or not, learn how to prepare the best résumé possible. You will review numerous examples to help you learn important résumé dos and don'ts.

### Early Career Professionals

Have you graduated in the last five years and are either a working professional or still looking for a job? GSA would like to support you in pursuing your professional goals. During this 45-minute session, you'll be asked for your input regarding potential programming and activities that GSA could offer to help you reach your professional goals.

### ACCOMMODATIONS

**Hotel registration deadline:** 13 Feb. 2017

A block of rooms has been reserved at the Omni Hotel at the Colonnade, 9821 Colonnade Blvd., San Antonio, Texas 78230, USA, and the meeting rate is US\$165 per night plus tax. Reservations should be made by calling Omni Hotels and Resorts at +1-800-843-6664 (toll free) or +1-210-691-8888 (local). Please be sure to mention that you are attending the GSA meeting.

### REGISTRATION

**Early registration deadline:** 6 Feb. 2017

**Cancellation deadline:** 13 Feb. 2017

Registration opens in December. For further information or if you need special accommodations, please contact the meeting Chair, Ben Surpless, [bsurples@trinity.edu](mailto:bsurples@trinity.edu).

### LOCAL COMMITTEE

**Chair:** Ben Surpless, [bsurples@trinity.edu](mailto:bsurples@trinity.edu)

**Technical Session Chair:** David Turner, [dturner2@stmarytx.edu](mailto:dturner2@stmarytx.edu)

**Field Trip Chair:** Dan Lehrmann, [dlehrmann@trinity.edu](mailto:dlehrmann@trinity.edu)

For questions about exhibits or sponsors, contact Ben Surpless, [bsurples@trinity.edu](mailto:bsurples@trinity.edu).

## Why GSA Membership is Important to Me



Kelsi Ustipak on the Brushy Canyon Formation, Texas, USA.

Membership with GSA has been an invaluable part of my growth as a geoscientist. It was the first professional society I joined as an undergraduate and the one I have consistently participated with over the last five years. As a student attending GSA Annual Meetings, I benefited from presenting posters, attending talks, and participating in lunchtime seminars. But in truth, my favorite part of GSA has always been the networking. I know that will make some people positively cringe, but the casual, friendly atmosphere of the meetings can be very welcoming. When I was uncertain of my next step after undergrad, I was able to visit with recruiters for graduate schools, informally discuss different career paths with exhibitors, and attend career panel luncheons to hear about different types of employment for geologists. The diverse experiences of members, whether students, professors, or professionals, became a source of advice and wisdom during my progression from undergraduate to graduate to early career professional. The impact of this community support was so strong that I have in turn volunteered to mentor On To the Future students, seeing in them many of the same questions and insecurities I dealt with as a student. GSA membership is important to me because the people and programs were a great resource for me during uncertain times, and I am committed to being a part of that resource for others in the future.

**Kelsi Ustipak**

Junior Clastic Reservoir Geologist  
Badley Ashton America Inc.  
GSA Member since 2011

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## ***Annual Review of Earth and Planetary Sciences***

[earth.annualreviews.org](http://earth.annualreviews.org) • Volume 44 • May 2016

Co-Editors: **Katherine H. Freeman**, *Pennsylvania State University*  
**Raymond Jeanloz**, *University of California, Berkeley*

The *Annual Review of Earth and Planetary Sciences*, in publication since 1973, covers significant developments in all areas of Earth and planetary sciences, from climate, environment, and geological hazards to the formation of planets and the evolution of life.

## ***Annual Review of Ecology, Evolution, and Systematics***

[ecolsys.annualreviews.org](http://ecolsys.annualreviews.org) • Volume 47 • November 2016

Editor: **Douglas J. Futuyma**, *State University of New York, Stony Brook*

The *Annual Review of Ecology, Evolution, and Systematics*, in publication since 1970, covers significant developments in the fields of ecology, evolutionary biology, and systematics, as they apply to all life on Earth. Reviews cover topics ranging from phylogeny, speciation, and molecular evolution through behavior and evolutionary physiology to population dynamics, ecosystems processes, and applications in invasion biology, conservation, and environmental management.

## ***Annual Review of Environment and Resources***

[environ.annualreviews.org](http://environ.annualreviews.org) • Volume 41 • October 2016

Co-Editors: **Ashok Gadgil**, *Lawrence Berkeley National Laboratory*  
**Thomas P. Tomich**, *University of California, Davis*

The *Annual Review of Environment and Resources*, in publication since 1976, provides authoritative reviews of significant topics within environmental science and engineering, including ecology and conservation science, water and energy resources, atmosphere, oceans, climate change, agriculture and living resources, and human dimensions of resource use and global change.

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## Preliminary Announcement and Call for Papers

### Joint Meeting

# NORTHEASTERN and NORTH-CENTRAL SECTIONS

52nd Northeastern Section Annual Meeting

51st North-Central Section Annual Meeting

Pittsburgh, Pennsylvania, USA

19–21 March 2017

[www.geosociety.org/Sections/ne/2017mtg/](http://www.geosociety.org/Sections/ne/2017mtg/)



## Shale Gas Production: Views from the Energy Roller Coaster

### LOCATION

Pittsburgh is a thriving city with a vibrant community, great restaurants, and many museums. The Omni William Penn is a grand hotel centrally located near dozens of bistros, eateries, and shops. The meeting area offers a variety of geologically interesting venues—excellent examples of the Allegheny Front separating the Valley and Ridge and Appalachian Plateau Provinces, including terminal Laurentide moraines, as well as oil, gas, coal, aggregates, and a wealth of additional natural resources, overprinted with myriad geotechnical hazards.

### CALL FOR PAPERS

**Abstract deadline:** 3 Jan. 2017

Submit online at [www.geosociety.org/sections/ne/2017mtg/](http://www.geosociety.org/sections/ne/2017mtg/).

**Abstract submission fee:** US\$18 for students and US\$30 for all others. If you cannot submit an abstract online, please contact Heather Clark, +1-303-357-1018, [hclark@geosociety.org](mailto:hclark@geosociety.org).

### Theme Sessions

Direct your theme session proposals to technical chairs Richard Becker (NC, [richard.becker@utoledo.edu](mailto:richard.becker@utoledo.edu)) or Wendell Barner (NE, [wendell.barner@gmail.com](mailto:wendell.barner@gmail.com)).

1. **New Strategies and Best Practices for Teaching Climate and Energy.** Karen Cercone, Indiana Univ. of Pennsylvania, [kercerone@iup.edu](mailto:kercerone@iup.edu).
2. **Teaching Climate and Energy to a K–12 Audience.** Laura Guertin, Pennsylvania State Univ., [uxg3@psu.edu](mailto:uxg3@psu.edu); Polly Rott Sturgeon.
3. **Back to the Basics: Focusing on Fieldwork in Today's Geological Studies.** Wes Buchanan, Colorado School of Mines, [wbuchana@mines.edu](mailto:wbuchana@mines.edu); Sean Regan.
4. **Karst Studies from the Appalachians to the Mid-Continent.** Douglas Gouzie, [douglasgouzie@missouristate.edu](mailto:douglasgouzie@missouristate.edu).
5. **Engineering and Environmental Geology of Karst Terranes.** Wendell Barner, Barner Consulting, LLC, [wendell.barner@gmail.com](mailto:wendell.barner@gmail.com); Bill Kochanov.
6. **FOSSIL Collaborations: Enhancing Paleontology through Professional and Amateur Partnerships.** Eleanor Gardner, [egardner@flmnh.ufl.edu](mailto:egardner@flmnh.ufl.edu); Bruce MacFadden; Cathy Young; Jayson Kowlinsky; Daniel Krisher.
7. **Fluvial Geomorphology of Post-Glacial Rivers.** Amanda Schmidt, Oberlin College, [aschmidt@oberlin.edu](mailto:aschmidt@oberlin.edu); Anne Jefferson; Karen Gran.
8. **The Geomorphology and Hydrogeology of the Appalachian Plateau.** Daniel Bain, Univ. of Pittsburgh, [dbain@pitt.edu](mailto:dbain@pitt.edu); Katie Farnsworth.
9. **Remote Sensing Applications in Geology.** Richard Becker, Univ. of Toledo, [richard.becker@utoledo.edu](mailto:richard.becker@utoledo.edu).
10. **A View of Some Significant Geologists or Discoveries in the Late Nineteenth and Early Twentieth Centuries.** Jeri Jones, Jones Geological Services, [jonesgeo@comcast.net](mailto:jonesgeo@comcast.net); Jon Inners.
11. **Improving Undergraduate STEM Education and Advancing Diversity in the Geosciences—How Are We Doing?** Jonathan Lewis, Indiana Univ. of Pennsylvania, [jclewis@iup.edu](mailto:jclewis@iup.edu); Sharon Cooper; Karen Thomson.
12. **Undergraduate Research Session (Posters).** *Cosponsored by Council on Undergraduate Research Geosciences Division.* Robert Shuster, Univ. of Nebraska–Omaha, [rshuster@unomaha.edu](mailto:rshuster@unomaha.edu).
13. **Changing Agricultural Landscapes and Impacts on Groundwater Quality and Quantity.** Jana Levison, Univ. of Guelph, [jlevison@g360group.org](mailto:jlevison@g360group.org); Marie Larocque.
14. **There's an App for That: Using Technology Developments, Innovations, Resources, and Applications to Enhance Undergraduate Geoscience Education.** *Cosponsored by National Association of Geoscience Teachers.* C. Renee Sparks, Calvin College, [crs38@calvin.edu](mailto:crs38@calvin.edu); Joseph Reese; Steven Linberg.
15. **Conodonts Solving Stratigraphic Problems.** Christopher Waid, Univ. of Iowa, [christopher-waid@uiowa.edu](mailto:christopher-waid@uiowa.edu); D. Jeffrey Over; John Repetski.
16. **Research Associated with The Marcellus Shale Energy and Environment Laboratory (MSEEL).** Tim Carr, West Virginia Univ., [tim.carr@mail.wvu.edu](mailto:tim.carr@mail.wvu.edu); Dan Billman.
17. **Fundamental Measurements of Shale Properties and Identifying Data Gaps.** Angela Goodman, [Angela.Goodman@netl.doe.gov](mailto:Angela.Goodman@netl.doe.gov).

18. **Wellbore Integrity: Subsurface Issues and Solutions.** Barbara Kutchko, Barbara.kutchko@netl.doe.gov.
19. **Geology of Marcellus-Utica Shale and How it Relates to Oil and Gas Production.** Wendell Barner, Barner Consulting, LLC, wendell.barner@gmail.com
20. **Environmental and Engineering Problems and Solutions Associated with the Marcellus-Utica Shale Play.** Wendell Barner, Barner Consulting, LLC, wendell.barner@gmail.com.
21. **Passive Seismic Monitoring of Brittle and Non-Brittle Deformation during the Stimulation of Unconventional Shale Reservoirs.** Richard Hammack, richard.hammack@netl.doe.gov; Abash Kumar; Erich Zorn.
22. **Understanding and Assessing Potential Hazard/Risk from Induced Seismicity in the North-Central and Northeastern United States.** Michael Rosenmeier, RIZZO Associates, Michael.rosenmeier@rizzoassoc.com; Doug Raszewski.
23. **Telling Histories of Shale.** Conevery Bolton Valencius, Univ. of Massachusetts, conevery.valencius@umb.edu; Brian Frehner.
24. **Urban Biogeochemistry and Geochemistry.** Emily M. Elliott, eelliott@pitt.edu; Daniel J. Bain.
25. **Biogeochemistry & Geobiology of Anoxic/Euxinic Systems.** Molly O'Beirne, Univ. of Pittsburgh, mdobeirne@pitt.edu; Joseph Werne; William Gilhooly.
26. **Biogeochemical Cycling and Biomineralization: Observations at the Microscale.** Dawn Cardace, Univ. of Rhode Island, cardace@uri.edu.
27. **Precambrian Assembly of a Continent from the Northeast to the Mid-Continent to the Southwest: Modern Approaches to Study Ancient Crust.** Benjamin Hallett, Univ. of Wisconsin—Oshkosh, hallettb@uwosh.edu; Christopher Daniel.
28. **Recent Advances in Volcano Observation and Monitoring.** Loÿc Vanderkluyzen, Drexel Univ., loyc@drexel.edu.
29. **Paleolimnological Studies of Climate Variability and Environmental Response.** Arielle Woods, Univ. of Pittsburgh, ariellewoods@pitt.edu; Mark Abbott.
30. **Application of Organic Geochemical Proxies to (Paleo) Environmental Studies.** Dervla Kumar, Univ. of Pittsburgh, dmk81@pitt.edu; Joseph Werne.
31. **Progress Toward Understanding Present and Past River Responses to Climate in Eastern and Midwestern North America.** J. Steven Kite, West Virginia Univ., jkrite@wvu.edu; Todd Grote; Bill Monaghan.
32. **Redeveloping in the Urban Landscape—Expected and Unexpected Challenges.** Frank Benacquista, KU Resources, Inc., fbenacquista@kuresources.com.
33. **Shoreline Behavior, Paralic Architecture, and Lake-Level Change in the Great Lakes.** John W. Johnston, Univ. of Waterloo, jwjohnston@uwaterloo.ca; Todd Thompson; Erin Argyilan.
34. **Quaternary Paleolimnology of the Laurentian Great Lakes Region.** Joe Ortiz, Kent State Univ., jortiz@kent.edu; Beverly Saylor.
35. **Quaternarists' Perspectives on the Anthropocene.** Francine McCarthy, Brock Univ., fmccarthy@brocku.ca.
36. **Applications of OSL and TCN to Chronologic Problems along the Margins of the LIS.** *Cosponsored by GSA Quaternary Geology and Geomorphology Division.* Kenneth Lepper, North Dakota State Univ., ken.lepper@ndsu.edu.
37. **The Future of Glacial Chronostratigraphy in the U.S.: Pre–Late Wisconsinan Glaciation East of the Mississippi River.** Charles Rovey, Missouri State Univ., charlesrovey@missouristate.edu.
38. **Quaternary Interglacials in North America.** Martin Head, Brock Univ., mjhead@brocku.ca.
39. **Regional Geophysical Studies in the Central and Eastern U.S.** Kevin Mickus, Missouri State Univ., kevinmickus@missouristate.edu; Sourav Nandi.
40. **Applied Geology, Environmental, Engineering, Hydrogeology, and Applied Geophysics.** Terry West, Purdue Univ., trwest@purdue.edu.
41. **Geoarchaeology.** Harry Jol, Univ. of Wisconsin, jolhm@uwec.edu.
42. **Surficial Geologic Mapping.** *Cosponsored by Great Lakes Geologic Mapping Coalition; Great Lakes Section SEPM.* Kevin Kincaid, USGS, Kkincaid@usgs.gov; Gary Fleeger.

#### FIELD TRIPS

Direct your field-trip proposals to Joe Hannibal (NC, JHannibal@cmnh.org) or Kyle Fredrick (NE, fredrick@calu.edu).

1. **New Insights and Lessons Learned from the Johnstown (Pennsylvania) Flood of 1889.** Carrie Davis Todd, Baldwin-Wallace Univ., cdavisto@bw.edu.
2. **From Fort Pitt to Coal Hill: Geological, Archaeological, and Historical Aspects of Downtown Pittsburgh and Mount Washington.** Joe Hannibal, Cleveland Museum of Natural History, jhannibal@cmnh.org; Albert Kollar, Carnegie Museum of Natural History.
3. **The Old, the Crude, and the Muddy: Oil History in Western Pennsylvania.** Kristin M. Carter, Pennsylvania Geological Survey, krcarter@pa.gov; Kathy J. Flaherty.
4. **Abandoned Mine Drainage in the Pittsburgh Area: Occurrence and Passive Treatment.** Bob Hedin, Hedin Environmental, info@hedinenv.com.
5. **Pleistocene Features of the Laurel Highlands and Upper Youghiogheny Basin.** Rebecca Kavage Adams, Maryland Geological Survey, rebecca.adams@maryland.gov; David K. Brezinski.

#### WORKSHOPS

Direct your workshop proposals to the workshop coordinator: Timothy Fisher, timothy.fisher@utoledo.edu

1. **3D Printing of Terrain Models.** Chris Harding, Iowa State Univ., charding@iastate.edu.
2. **Geologic Overview and Environmental Considerations in Marcellus and Utica-Point Pleasant Exploration & Production.** Jeffrey Dick, Youngstown State Univ.; Dan Billman, dan@billmangeologic.com
3. **Ground-Penetrating Radar for the Earth Sciences.** Harry M. Jol, Univ. of Wisconsin, jolhm@uwec.edu.

*continued on next page*

## OPPORTUNITIES FOR STUDENTS AND EARLY CAREER PROFESSIONALS

### Roy J. Shlemon Mentor Program in Applied Geoscience

Students and early career professionals will have the opportunity to discuss career prospects and challenges with applied geoscientists from various sectors over a FREE lunch.

### John Mann Mentors in Applied Hydrogeology Program

Students and early career professionals interested in applied hydrogeology or hydrology as a career will have the opportunity to network with professionals in these fields over a FREE lunch.

## GEOSCIENCE CAREER WORKSHOPS

### Part 1: Career Planning and Informational Interviewing.

Your job-hunting process should begin with career planning, not when you apply for jobs. This workshop will help you begin this process and will introduce you to informational interviewing.

### Part 2: Geoscience Career Exploration.

What do geologists in various sectors earn? What do they do? What are the pros and cons to working in academia, government, and industry? Workshop presenters, and when possible, professionals in the field, will address these issues.

### Part 3: Cover Letters, Résumés, and CVs.

How do you prepare a cover letter? Does your résumé need a good edit? Whether you are currently in the job market or not, learn how to prepare the best résumé possible. You will review numerous examples to help you learn important résumé dos and don'ts.

## Early Career Professionals

Have you graduated in the last five years and are either a working professional or still looking for a job? GSA would like to support you in pursuing your professional goals. During this 45-minute session, you'll be asked for your input regarding potential programming and activities that GSA could offer to help you reach your professional goals.

## REGISTRATION

**Early registration deadline:** 13 Feb. 2017

**Cancellation deadline:** 21 Feb. 2017

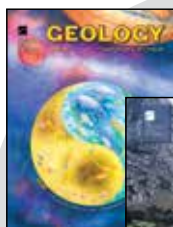
Online registration begins in December. For more information, or if you have special requirements, please contact the local committee chairs: Timothy Fisher (NC), [timothy.fisher@utoledo.edu](mailto:timothy.fisher@utoledo.edu); Patrick Burkhart (NE); [patrick.burkhart@sru.edu](mailto:patrick.burkhart@sru.edu). Updates and details will be posted online at [www.geosociety.org/Sections/ne/2017mtg/](http://www.geosociety.org/Sections/ne/2017mtg/) when they become available.

## ACCOMMODATIONS

A block of rooms has been reserved at the historic Omni William Penn Hotel in Pittsburgh at US\$159/night single or double, with \$10 extra for the third and the fourth occupants. This convention rate is guaranteed until 24 February 2017. Parking in adjacent lots is US\$9–US\$15 per day for self-park.

## STUDENT VOLUNTEERS

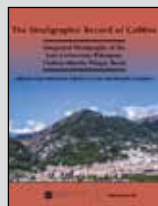
The committee and officers of GSA's North-Central and Northeastern Sections rely on student volunteers to help meetings run smoothly, and we are pleased to offer student volunteers complimentary registration for the meeting in return for ~7 hours of volunteer work. Contact student volunteer coordinators Jonathan Warnock (NE), [jwarnock@iup.edu](mailto:jwarnock@iup.edu), or Donald Stierman (NC), [Donald.stierman@utoledo.edu](mailto:Donald.stierman@utoledo.edu), for more information.



## Browse GSA's Journals & Books at [www.gsapubs.org](http://www.gsapubs.org).

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# Geoscience Jobs & Opportunities

Ads (or cancellations) must reach the GSA advertising office no later than the first of the month, one month prior to the issue in which they are to be published. Contact advertising@geosociety.org, +1.800.472.1988 ext. 1053, or +1.303.357.1053. All correspondence must include complete contact information, including e-mail and mailing addresses. Rates are in U.S. dollars.

Classification	Per Line for 1st month	Per line each addtl' month (same ad)
Positions Open	\$9.20	\$8.95
Fellowship Opportunities	\$9.20	\$8.95
Opportunities for Students		
First 25 lines	\$0.00	\$5.00
Additional lines	\$5.00	\$5.00

## Positions Open

### SEDIMENTARY BASIN ANALYSIS AND MODELING POSITION BERG-HUGHES CENTER AND DEPT. OF GEOLOGY AND GEOPHYSICS TEXAS A&M UNIVERSITY

The Berg-Hughes Center for Petroleum and Sedimentary Systems (BHC) and the Dept. of Geology and Geophysics at Texas A&M University invite applications from individuals for a non-tenure track, three-year renewable contract position as a Research Professor in Sedimentary Basin Analysis and Modeling beginning January 16, 2017. This position will be a joint appointment with teaching, research and service responsibilities in the Berg-Hughes Center and Dept. of Geology and Geophysics. This is a 9-month annual appointment.

The principal responsibility of this position is to lead the collaborative research and teaching programs in the Chevron-TAMU/BHC Basin Modeling Center of Research Excellence in the BHC and Dept. of Geology and Geophysics. This responsibility includes leading in the development of a robust externally funded research program in basin analysis and modeling that includes research collaboration with researchers in the petroleum industry; teaching integrative courses that introduce advanced concepts and technologies needed for unraveling the geo-history of sedimentary basins and the origin and location of unconventional and conventional petroleum resources inherent to sedimentary basins, and supervising graduate students and mentoring faculty in the use of sophisticated computational and applied research approaches and techniques to solve complex geologic problems.

We seek candidates who have had extensive experience in sedimentary basin analysis and modeling and in serving as a team leader on multidisciplinary research projects, and who have demonstrated the ability to develop and maintain an externally funded research program. Applicants must have a record of success in working collaboratively with researchers in academia and the petroleum industry and be enthusiastic about teaching integrative courses and supervising graduate students in basin analysis, basin architecture, basin modeling, basin geodynamics, and related areas.

Applicants must have an earned Ph.D. at the time of appointment. Successful applicants will be expected to teach effectively at the graduate level in basin analysis and modeling and related fields and in team-taught courses, 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. Applicants are expected to build and maintain a collaborative research program with colleagues in the College of Geosciences, the Berg-Hughes Center, the Dept. of Geology and Geophysics, the Dept. of Petroleum

Engineering, and other energy related groups at Texas A&M University and the Texas A&M University System and with geoscientists and petroleum engineers in the oil and gas industry and national and international research institutions.

Interested candidates should submit electronic versions of a letter of application, curriculum vita, teaching philosophy, statement of research vision, strategies to implement that vision, and accomplishments, and the names and email addresses of at least three references to the Chair of the Basin Analysis and Modeling Search Committee, cdengo@tamu.edu. Screening of applications for the position will begin immediately and will continue until the position is filled. The Berg-Hughes Center (berg-hughes.tamu.edu) and the Dept. of Geology and Geophysics (geoweb.tamu.edu) are part of the College of Geosciences, which also includes the Departments of Atmospheric Sciences, Geography, and Oceanography; the Geochemical and Environmental Research Group (GERG); and the Integrated Ocean Drilling Program (IODP). Texas A&M University, a land-, sea-, and space-grant university, is located in a metropolitan area with a dynamic and international community of 227,000 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 American with Disabilities Act. The University is dedicated to the goal of building a culturally diverse and pluralistic faculty and staff committed to teaching and working in a multicultural environment. We strongly encourage applications from women, underrepresented ethnic groups, veterans, and persons with disabilities. Texas A&M University also has a policy to address the needs of dual-career partners (<https://advance.tamu.edu/dual-career-program-information/>).

### TENURE-TRACK ASSISTANT PROFESSOR, IGNEOUS PROCESSES UNIVERSITY OF UTAH

The Dept. of Geology & Geophysics at the University of Utah invites applications for a tenure-track Assistant Professor position in Igneous Processes beginning fall semester 2017. Applicants must have a Ph.D., and the successful candidate will be expected to build a productive and internationally visible research program. We will consider candidates in a broad range of igneous specialties, including one or more of igneous petrology, volcanology, igneous geochemistry including radiogenic isotopes/geochronology, and magma physics/fluid dynamics (e.g., physical processes of magma formation, diffusive and advective mass transfer in magmas, eruption and crystallization processes). We particularly welcome candidates applying integrated field, laboratory and computational approaches to igneous systems. The Dept. of Geology and Geophysics

is housed in the Frederick A. Sutton Building, a new state of the art teaching and research facility. Available research tools include LA-MC-ICP-MS, the SIRFER stable-isotope facility, noble-gas mass spectrometry, electron microprobe, QEMSCAN, paleomagnetic and rock magnetic facilities, and access to the University's Surface Analysis Center and the Center for High Performance Computing. Opportunities also exist for professional interactions outside the department with personnel at the University of Utah's Energy and Geoscience Institute, the Utah Geological Survey and the United States Geological Survey. Applications should be received by September 30, 2016, for full consideration; however, applications received after that time may be considered until the position is filled. To apply, upload a statement of teaching and research interests, curriculum vitae, names and contact information for three references to: [utah.peopleadmin.com/postings/52715](mailto:utah.peopleadmin.com/postings/52715). If you have specific questions about the position please contact J.R. Bowman [[john.bowman@utah.edu](mailto:john.bowman@utah.edu)]. Information about the Dept. of Geology and Geophysics can be found at <http://www.earth.utah.edu>.

The University of Utah is an Equal Opportunity/Affirmative Action employer and educator. Minorities, women, and persons with disabilities are strongly encouraged to apply, and the University provides reasonable accommodation to the known disabilities of applicants and employees. Veteran's preference is extended to qualified applicants. The University of Utah values candidates who have experience working in settings with students from diverse backgrounds, and who possess a strong commitment to improving access to higher education for historically underrepresented students.

### TENURE TRACK ASSISTANT PROFESSOR OF APPLIED GEOPHYSICS CENTRAL MICHIGAN UNIVERSITY

The Dept. of Earth and Atmospheric Sciences at Central Michigan University invites applications for a tenure-track position in applied geophysics at the Assistant Professor level, beginning Fall 2017. We seek candidates who use a combination of field-based geophysical methods and quantitative methods to examine crustal or lithosphere dynamics; earthquake processes; petroleum or metal exploration geophysics; subsurface fracturing and fluid flow; or environmental geophysics. Information about the department can be found at <http://www.eas.cmich.edu>.

Candidates must hold a Ph.D. in geophysics, geological sciences, or a related field. In addition, candidates must demonstrate (1) the potential for outstanding teaching, (2) the potential to develop a vigorous research program that involves students and attracts external funding, and (3) strong oral and written communication skills. Preference will be given to candidates who have postdoctoral experience (academic or industry), a demonstrated record of receiving external funding, and teaching experience.

Review of applications will begin October 15th. Applicants should submit a CV, cover letter, statement of research interests, statement of teaching philosophy, and the names and contact information



for 3 referees through an online process at <http://www.jobs.cmich.edu>.

*Note CMU faculty will be at the Denver GSA 2016 Annual Meeting and can arrange to meet potential applicants. Contact for Larry Lemke for details at [L.D.Lemke@cmich.edu](mailto:L.D.Lemke@cmich.edu).*

Classified by the Carnegie Foundation as a research high (R2) doctoral university, CMU is recognized for strong undergraduate education and a range of focused graduate and research programs. CMU, an AA/EEO institution, strongly and actively strives to increase diversity within its community (see [www.cmich.edu/aaeo/](http://www.cmich.edu/aaeo/)).

**TENURE-TRACK ASSISTANT PROFESSOR  
MINERALOGY/PETROLOGY  
FORT HAYS STATE UNIVERSITY**

Fort Hays State University seeks applications for a tenure-track Assistant Professor to start August 2017. Teaching duties include 12 credit hours per semester, and applicants will teach Mineralogy and Petrology. Preference will be given to those interested in teaching our 4-week capstone Geology Field Camp as well as developing and/or teaching courses for our successful Virtual College. Online and summer teaching offer opportunities for supplemental salary. Faculty are expected to develop independent research programs that involve undergraduate and graduate students, and the university offers annual grant opportunities to support these efforts. Other duties include research, service, and advising of students in our undergraduate and graduate programs.

A Ph.D. in Geology or closely related field is required (ABD considered). The Dept. of Geosciences has eight full-time faculty members in geology and geography. The Department offers B.S. and M.S. degrees in Geosciences. For more information, visit <http://www.fhsu.edu/humanresourceoffice/Positions-Faculty/>. Applications should include a C.V., contact information for three references, and a cover letter specifying: how your credentials match the job description, a statement of teaching philosophy, goals for scholarship, and expectations for student engagement. Review of applications will begin on 30 September 2016. Send completed applications in a single PDF file to Dr. Hendratta Ali ([hnali@fhsu.edu](mailto:hnali@fhsu.edu)).

EEO. Final candidate must pass a criminal background check.

**TENURE-TRACK FACULTY POSITION  
HYDROGEOLOGY AND WATER RESOURCES  
UNIV. OF WISCONSIN-EAU CLAIRE**

The Dept. of Geology is seeking a person to teach water resources, physical hydrogeology, chemical hydrogeology, and introductory geology courses as needed starting Fall 2017. Applicant must also involve students in high-quality collaborative research projects. A Ph.D. in geology or a closely related discipline is required at the time of appointment. The department has modern facilities in hydrogeology (including on-campus well nests), geophysics, geochemistry, and sedimentology.

Only online applications are accepted; go to <http://uwec.ly/jobopenings> to apply. For priority consideration, all application materials must be submitted by October 28, 2016. For a complete position description, call +1-715-836-3732 or visit <http://www.uwec.edu/geology/index.htm>. UW-Eau Claire

is an AA/EEO employer and encourages applications from women and minorities.

**ASSISTANT PROFESSOR  
HYDROGEOCHEMISTRY  
GEOLOGICAL SCIENCES  
SAN DIEGO STATE UNIVERSITY**

The Dept. of Geological Sciences at San Diego State University invites applications for a tenure-track faculty member at the Assistant Professor level in hydrogeology contributing to the Blue Gold, Mitigating Water Scarcity initiative at SDSU (<http://bluegold.sdsu.edu/>), with preference for expertise in geochemical, quantitative techniques and/or geophysical methods in assessing water fluxes and/or rock-water interactions. Candidates must have a PhD in Geological Sciences or a related field at the time of appointment. The full advertisement and directions for application are posted at (<https://apply.interfolio.com/36393>). The successful candidate is expected to establish an independent externally funded research program and teach and supervise student research at graduate and undergraduate levels. Anticipated start date for the position is Fall 2017. Applications received by October 15, 2016 will receive full consideration. The position will remain open until filled. For additional information, contact the co-Chairs of the Search Committee, Kathryn Thorbjarnarson, [ktorbjarnarson@mail.sdsu.edu](mailto:ktorbjarnarson@mail.sdsu.edu) and David Kimbrough, [dkimbrough@mail.sdsu.edu](mailto:dkimbrough@mail.sdsu.edu).

*Note: Search co-Chair David Kimbrough will be at the Denver GSA 2016 Annual Meeting and can arrange to meet potential applicants. Contact for details at [dkimbrough@mail.sdsu.edu](mailto:dkimbrough@mail.sdsu.edu)*

SDSU is a Title IX, equal opportunity employer.

**ASSISTANT PROFESSOR OF  
EARTH AND PLANETARY SCIENCES  
WASHINGTON UNIVERSITY-ST. LOUIS**

The Dept. of Earth and Planetary Sciences at Washington University in St. Louis invites applications for a tenure-track Assistant Professor position in the fields of climate, carbon cycling, or paleoclimatology. The ideal candidate will study climate or the effects of climate change in modern systems and/or over Cenozoic Earth history. Areas of interest include but are not limited to paleoclimatology and records of consequent environmental change; elemental cycling and associated climate feedbacks; the response of terrestrial, marine, and/or freshwater systems to climate change. The candidate is expected to employ quantitative tools and ideally will integrate field observations with laboratory measurements.

The successful candidate is also expected to develop a vigorous, externally funded research program, maintain a strong publication record, teach a range of undergraduate and graduate courses, advise students, and be active in university service. We are seeking candidates who will complement our research programs in biogeochemistry and environmental geology as well as foster collaboration with environmental scientists across the Washington University community.

Candidates must have a Ph.D. with a focus in environmental Earth science, or a related field, at the time of appointment, and should send a letter of application, curriculum vitae, statements of teaching and research interests, and names and contact infor-

mation of at least four references as a single PDF to Alex Bradley, Climate Search Committee Chair, Dept. of Earth and Planetary Sciences, Washington University, Campus Box 1169, 1 Brookings Drive, St. Louis, MO 63130, or via e-mail: [ClimateFacSearch@eps.wustl.edu](mailto:ClimateFacSearch@eps.wustl.edu). The Department seeks an exceptionally qualified and diverse faculty; women, minorities, protected veterans and candidates with disabilities are strongly encouraged to apply. Washington University in St. Louis is committed to the principles and practices of equal employment opportunity and affirmative action. It is the University's policy to recruit, hire, train, and promote persons in all job titles without regard to race, color, age, religion, gender, sexual orientation, gender identity or expression, national origin, veteran status, disability, or genetic information. Applications should be received by November 1, 2016 to ensure full consideration.

**ASSOCIATE OR FULL PROFESSOR  
OF GEOLOGY, HYDROGEOSCIENCE,  
WEST VIRGINIA UNIVERSITY**

Job Number: 03733

The West Virginia University (WVU) Dept. of Geology and Geography invites applications for a tenured faculty position in the area of hydrogeoscience at either the Associate Professor or Full Professor level. Applicants with exceptional qualifications will be nominated for the Eberly Family Distinguished Professorship in Geology. The successful candidate is expected to bring a vigorous program of innovative, externally-funded research; build effective collaborations; and teach at the graduate and undergraduate levels.

Research on fresh water resources is currently an area of strategic growth at WVU (<http://research.wvu.edu/about>) including a new interdisciplinary water research institute. We invite applications from individuals with interests in basic and applied aspects of groundwater flow. Relevant specialties might include physical hydrogeology; fluid flow modeling; hyporheic or vadose zone processes; groundwater-surface water interaction; flow in fractured media; hydrogeology of energy-related activities; groundwater supply and sustainability; contaminant transport; ecohydrology; multiscale hydrologic modeling; critical zone processes; and/or karst hydrogeology.

To apply, please visit <http://jobs.wvu.edu> and navigate to the position title listed above as Job Number 03733. Upload (1) a single PDF file including a statement of research interests, a statement of teaching philosophy, and a curriculum vitae; and (2) pdf files of up to 4 publications. Please also arrange for three letters of reference to be sent to search chair Joseph J. Donovan at [jdonovan@mail.wvu.edu](mailto:jdonovan@mail.wvu.edu). Review of applications will commence on October 15, 2016 and continue until a successful candidate is identified. For additional information, please see <http://geology.wvu.edu>.

*Note: WVU Geology faculty will be at the Denver GSA 2016 Annual Meeting and can arrange to meet potential applicants. Contact for details: Joseph J. Donovan at [jdonovan@mail.wvu.edu](mailto:jdonovan@mail.wvu.edu)*

WVU is an EEO/Affirmative Action Employer and welcomes applications from all qualified individuals, including minorities, females, individuals with disabilities, and veterans.

**TENURE-TRACK FACULTY POSITION  
ENVIRONMENTAL SYSTEMS MODELER  
BOSTON COLLEGE**

The Dept. of Earth and Environmental Sciences at Boston College invites applications for a tenure-track Assistant Professor with an expertise in quantitative/computational modeling of integrated earth systems: A geodynamic and/or hydrologic modeler who explores the physical, chemical, and/or biological interrelationships among diverse environmental and earth systems at the regional to global scale. The candidate should have broad research interests compatible with those of the current faculty in our Dept. of Earth and Environmental Sciences and potentially with faculty in the Biology, Chemistry, Physics, Computer Science and/or Mathematics departments. Areas of research expertise could include (but are not limited to): modeling of the interactions of ice-sheet dynamics, sea-level rise and climate change; modeling the exchange of water, carbon, energy, or pollutants between the terrestrial hydrosphere, cryosphere, ocean, atmosphere, and lithosphere; and modeling crustal deformation and mantle flow as it influences surface topography and climate. The successful candidate will be expected to develop a vigorous externally funded research program integrated with excellence in teaching within the Earth and Environmental Science curriculum at both the undergraduate and graduate levels.

Information on the department, its faculty and research strengths can be viewed at <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 to <https://apply.interfolio.com/36250>. Review of applications will begin on November 1, 2016. Inquiries may be directed to Prof. Noah Snyder, Search Committee Chair ([noah.snyder@bc.edu](mailto:noah.snyder@bc.edu)).

**TENURE-TRACK FACULTY POSITION  
DEPARTMENT OF GEOLOGY  
WASHINGTON AND LEE UNIVERSITY**

The Geology Dept. at Washington and Lee University, Lexington, Virginia, seeks applications for a tenure-track assistant professor in environmental geochemistry starting in fall 2017. PhD required at the time of appointment. Courses taught by the successful candidate will include hydrology, geochemistry, and environmental field methods at the major level, and physical geology at the introductory level. We seek a dynamic, creative teacher/scholar, dedicated to diverse teaching approaches, enthusiastic about teaching intensive field-based geology courses, and able to develop a strong research program including collaboration with undergraduates. W&L and the Geology Dept. value excellence in scholarship, meaningful engagement in professional activities, sustainability, and the development of a campus climate that supports equality and diversity among its faculty, staff, and students. W&L is a nationally ranked, highly selective liberal arts college. The Department ([geology.wlu.edu](http://geology.wlu.edu)) has excellent facilities and resources, makes great use of the Appalachians in field courses and labs, and belongs to the Keck Geology Consortium. Applications should include curriculum vitae; teaching statement including teaching interests/experience;

research statement; and contact information for 3 referees. Apply via email to [wilsons@wlu.edu](mailto:wilsons@wlu.edu). Please address to Lisa Greer, Chair, Geology Dept., Washington and Lee University. Initial review of applications will begin Sept. 1; *we will be available to meet with potential candidates at the fall GSA meeting in Denver*. Review will continue until the position is filled. The University is an Equal Opportunity Employer.

**TENURE-TRACK ASSISTANT  
PROFESSOR POSITIONS,  
FACULTY CLUSTER HIRE  
IN EARTH SURFACE PROCESSES  
UNIVERSITY OF CALIFORNIA  
SANTA BARBARA**

The University of California Santa Barbara announces a multidisciplinary cluster hire of four outstanding scientists, to further strengthen its world class Earth surface process teaching and research mission. We seek dynamic researchers who are at the forefront of advancing theory, measurements and understanding in terrestrial Earth Surface Processes from disciplines including climatology, geochemistry, geology, geomorphology, hydrology and soil science. The cluster hire will build on UC Santa Barbara's foundation strengths in physical geography and Earth and environmental sciences. Successful hires will contribute to improving our understanding of the characteristics and functioning of the entire planet, and especially its terrestrial surface through the study of the complex interactions among atmosphere, geosphere, hydrosphere, biosphere, cryosphere, including their alteration by, and impact on, human activity. We will give preference to candidates with demonstrated expertise in one or more quantitative techniques including field measurement, remote sensing, modeling, and theory and candidates who, based on research and teaching proficiency, would fit into one of the following: the Bren School of Environmental Science and Management, the Dept. of Earth Science, and the Dept. of Geography. Applications will be reviewed starting October 31, 2016 with expected appointments on July 1, 2017. Please see the following website for a more complete description of the positions <http://www.eri.ucsb.edu/escluster>. To be considered for one of the four available positions, apply electronically at: <https://recruit.ap.ucsb.edu/>. Applications completed by October 31st, 2016 will receive fullest consideration, but each department will continue reviewing applicant files until that position is filled.

The school is especially interested in candidates who can contribute to the diversity and excellence of the academic community through research, teaching and service. The University of California is an Equal Opportunity/Affirmative Action Employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability status, protected veteran status, or any other characteristic protected by law.

**HYDROLOGY/HYDROGEOLOGY  
DEPARTMENT OF EARTH SCIENCES  
UNIVERSITY OF MINNESOTA**

The Dept. of Earth Sciences in the College of Science and Engineering at the University of Minnesota —Twin Cities is soliciting applications for a tenure-

track faculty position in hydrology/hydrogeology at the assistant professor level. Exceptional candidates at the associate professor level will also be considered. This position will carry with it additional resources from the Gibson Endowed Fund for research activities over the first five years of the appointment.

Areas of research for this position could include physical, chemical, and/or biological aspects of hydrology or hydrogeology. Frontier topics of interest in this field include, among others, research at non-traditional spatial scales, grand challenges in water resource sustainability and security, novel measurement techniques and datasets, and links between the study of hydrological systems and subsurface geology, other portions of the earth system, and/or other disciplines, as well as other topics. The successful candidate is expected to develop a vigorous research program, attract external funding, and contribute to the instruction, research, and service efforts of the department. A Ph.D. in earth sciences or a related field is required at the time of appointment.

The Dept. of Earth Sciences is a vibrant interdisciplinary department whose research ranges from geobiology to deep earth dynamics. Alongside our commitment to excellence in scholarship, we seek to further the University of Minnesota's land-grant mission through developing ties with industry and/or governmental agencies that benefit the needs of our students, the state of Minnesota, and the broader community. The Department is in the N.H. Winchell School of Earth Sciences (<http://www.esci.umn.edu/>), which also includes the Institute for Rock Magnetism, the Limnological Research Center/National Lacustrine Core Facility/Continental Scientific Drilling Coordination Office, the Minnesota Geological Survey, the National Center for Earth-surface Dynamics, and the Polar Geospatial Center. Other affiliated research units at the University include the Saint Anthony Falls Laboratory and the Institute on the Environment. The appointee will have access to large-scale computing facilities (Minnesota Super-computer Institute, Digital Technology Center) and the interdisciplinary Water Resources graduate program.

Materials Required

- A one-page letter of intent.
- A CV with a list of publications.
- A statement of research and teaching interests.
- Names and contact information of three referees who can address the candidate's research and teaching potential.

Applications must be completed online at <http://www1.umn.edu/ohr/employment/> —Search for Job Opening ID: 311335.

The review of applications will begin October 14, 2016. Applications will continue to be accepted until the position is filled. Questions may be directed to Prof. Jake Bailey ([baileyj@umn.edu](mailto:baileyj@umn.edu)).

The University of Minnesota provides equal access to and opportunity in its programs, facilities, and employment without regard to race, color, creed, religion, national origin, gender, age, marital status, disability, public assistance status, veteran status, sexual orientation, gender identity, or gender expression. The University supports the work-life balance of its faculty.

**DEPARTMENT CHAIR  
GEOSCIENCES AND GEOLOGICAL AND  
PETROLEUM ENGINEERING DEPT.  
(GGPE), MISSOURI UNIVERSITY OF  
SCIENCE AND TECHNOLOGY**

The Dept. of Geosciences and Geological and Petroleum Engineering (GGPE) at Missouri University of Science and Technology invites applications for the position of Department Chair. Candidates should have a record of successful multidisciplinary team leadership with exceptional skills in communication, organization, and promoting collaboration within and among multiple academic and technical programs. Candidates will embrace the values of transparency, inclusion, and collegiality, and possess a strong record of building programs and facilitating the success of personnel. Requirements include: a Ph.D. in Geosciences, Geological Engineering, Petroleum Engineering or a closely related area; experience in academic, industry, or government research sectors; and a successful scholarly record commensurate with appointment at the rank of full professor.

The department has grown by 37% since 2011 to reach 22 full-time faculty, including 21 tenured or tenure-track professors and 1 full-time teaching faculty member. The department offers B.S., M.S., and Ph.D. degrees in each of geology and geophysics, geological engineering and petroleum engineering. The department also offers an online M.E. program in Geotechnics. The department currently has 545

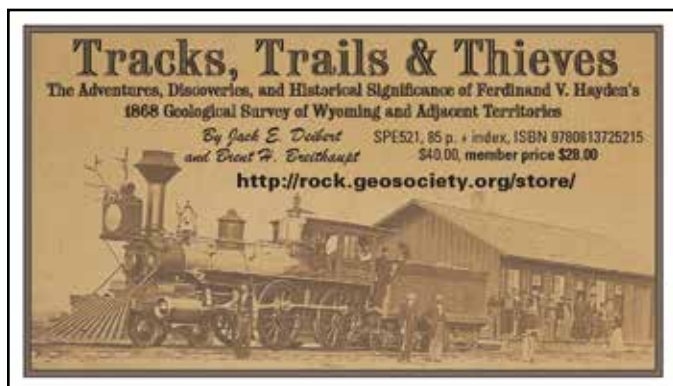
undergraduate students and 297 graduate students in its Ph.D., M.S., and M.E. programs. The department's faculty and students are actively engaged in a wide variety of multi-disciplinary research. Closely associated programs on campus include Civil Engineering, Environmental Engineering and Mining Engineering. Local area establishments with active research collaborations include the U.S. Geological Survey (Mid-continent Geospatial Mapping Center), Missouri Dept. of Natural Resources, Fort Leonard Wood, the Missouri S&T Rock Mechanics and Explosives Research Center, Materials Research Center, Environmental Research Center, and Energy Research and Development Center. More information about the department and campus can be found at <http://ggpe.mst.edu/>. Questions and nominations can be emailed to [robertsst@mst.edu](mailto:robertsst@mst.edu).

Interested candidates should electronically submit an application consisting of a cover letter, current curriculum vitae, statements of teaching and leadership philosophies, a research statement, and complete contact information for five references to Missouri University of Science and Technology's Human Resource Office at <http://hr.mst.edu/careers/academic/>. Application review will begin on October 15, 2016, and will continue until the position is filled. All submitted application materials must have the position number 00066297 in order to be processed. Hardcopy applications will not be accepted.

The final candidate is required to provide copies of official transcript(s) for any college degree(s) listed in application materials submitted. Copies of transcript(s) should be provided prior to the start of employment. In addition, the final candidate may be required to verify other credentials listed in application materials. Failure to provide official transcript(s) or other required verification may result in the withdrawal of the job offer.

All job offers are contingent upon successful completion of a criminal background check.


The University of Missouri is an equal access, equal opportunity, affirmative action employer that is fully committed to achieving a diverse faculty and staff. Equal Opportunity is and shall be provided for all employees and applicants for employment on the basis of their demonstrated ability and competence without unlawful discrimination on the basis of their race, color, national origin, ancestry, religion, sex, sexual orientation, gender identity, gender expression, age, genetic information, disability, or protected veteran status.



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**Tenure Track Faculty**  **PennState**  
**- Sedimentary Geology**

The Department of Geosciences at The Pennsylvania State University invites applications for a tenure-track faculty position at the Assistant Professor level in Sedimentary Geology, broadly defined. We seek a colleague working to understand the chemical, physical or biological evolution of modern or ancient sedimentary systems. We are especially interested in applicants who integrate a combination of field, laboratory, and modeling techniques, and who complement our existing departmental strengths in geobiology, geochemistry, and geophysics. Successful applicants will be expected to contribute to a diverse research and teaching community in the Department of Geosciences through the development of a vigorous, internationally recognized and externally funded research program, and through teaching courses in their discipline at the undergraduate and graduate levels. The Department of Geosciences is part of the College of Earth and Mineral Sciences, and houses research programs spanning a broad spectrum of Earth Science disciplines (further information is available at: <http://www.geosc.psu.edu>). Applicants must have a Ph.D. in geosciences or a related field at the time of appointment. Applicants should submit a cover letter, curriculum vitae, a statement outlining research and teaching interests, and the names and contact information of three references. All materials must be submitted online. Review of applications will begin on November 1, 2016 and continue until the position is filled. Appointment may begin as early as July 1, 2017. For further information or questions, please contact Mark Patzkowsky, Chair of the Search Committee at [mep12@psu.edu](mailto:mep12@psu.edu).

Apply online at <http://apptrkr.com/851450>

**CAMPUS SECURITY CRIME STATISTICS:** For more about safety at Penn State, and to review the Annual Security Report which contains information about crime statistics and other safety and security matters, please go to <http://www.police.psu.edu/clery/>, which will also provide you with detail on how to request a hard copy of the Annual Security Report.

Penn State is an equal opportunity, affirmative action employer, and is committed to providing employment opportunities to all qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national origin, disability or protected veteran status.

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## Supporting Women in Geology

The Geological Society of America's *Women in Geology* mentor program began at GSA's 2008 Annual Meeting. Since then, the popular event has attracted 150–200 people at all career levels each year. While the majority of attendees are women, there has been an increase in men showing support. It is encouraging that more and more people want to be informed about topics related to women in the geosciences.

Through sponsorships secured each year, the GSA Foundation supports this meaningful forum for women to share their experiences and ask questions that may not arise in other settings. The informal gathering features invited female geoscientists to discuss their career trajectories and issues they have faced throughout their careers; this is followed by smaller discussions and mentorship opportunities.

Alicia Kahn, senior biostratigrapher at Chevron and a longtime participant in GSA's GeoCareers program as well as Women in Geology mentoring, believes it to be an important investment of her time.

Women still have a long way to go in the United States as we work towards equality in the workplace. In a male-dominated field like geology where there are abundant female undergraduate and graduate students, attrition remains high once professional jobs hit. The pressure on families is rife and leads to women choosing more family-friendly, less stressful and demanding, careers. I find that taking the mystery out of motherhood and family life as it can couple with science, along with acknowledging the challenges and the need for support among colleagues, allows young female scientists to feel less threatened by strong career choices. Through mentoring programs such as GSA's Women in Geology, we give women the chance to speak up in a safe place and share life experiences. In so doing, we create bonds and networks among each other. I have found good friends this way, and we aid in each other's daily and professional lives. It takes a village to make progress and I'm proud to have been able to participate in some small way through GSA.

Attendees, many of whom are students, find great benefit in the program and describe it as “the most inspirational experience I have had” and “the most helpful program thus far. Please continue to inspire women in this field!” Perhaps Women in Geology is best summarized by this attendee: “Even as our generation leaves undergrad with 50% fellow women geoscientists, role models and mentors are still vital as we look to our futures and make important decisions at this pivotal point in our lives.”

The Women in Geology mentor event will be held at GSA 2016 on Sunday, 25 Sept., at 5:30 p.m. Please join the GSA Foundation in helping to carry on this important program—Contact Debbie Marcinkowski at [dmarcinkowski@geosociety.org](mailto:dmarcinkowski@geosociety.org) to learn more.



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