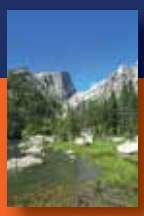

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Virtual Rocks

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Featured Articles

SCIENCE

Cover: COLLADA model of halite lattice viewed directly in a web browser. Purple = Na^+. Green = Cl^-. Online version can be rotated. Background image: Salt evaporation ponds south of the Dead Sea. Photo: NASA. See related article, p. 4–11.

GROUNDWORK

GSA 2016 Annual Meeting & Exposition

GSA News

Cover inset photo: Hallet Peak from Nymph Lake, Colorado, USA. Photo by Kea Giles.

Virtual Rocks

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ABSTRACT

Three-dimensional digital models of geological objects are relatively easy to create and geolocate on virtual globes such as Google Earth and Cesium. Emerging technologies allow the design of realistic virtual rocks with free or inexpensive software, relatively inexpensive 3D scanners and printers, and smartphone cameras linked to point-cloud computing services. There are opportunities for enhanced online courses, remote supervision of fieldwork, remote research collaboration, and citizen-science projects, and there are implications for archiving, peer-review, and inclusive access to specimens from inaccessible sites. Virtual rocks can be gradually altered to illustrate geological processes such as weathering, deformation, and metamorphic mineral growth. This paper surveys applications in a wide range of geoscience subdisciplines and includes downloadable examples. Detailed instructions are provided in the GSA Supplemental Data Repository[1].

INTRODUCTION

In recent decades, numerous virtual field trips have been created to simulate in-person field excursions; however, one aspect of physical fieldwork is not commonly replicated: virtual explorers do not often return to their computer desktops with collections of virtual rocks! There are multiple justifications for creating interactive 3D digital models of rocks, minerals, fossils, drill core, geo-archaeological objects, and outcrops. For example, one can (i) reveal 3D features hidden inside solid specimens; (ii) archive samples destined for destructive testing; (iii) prepare for field trips and reinforce learning and retention after the fact; (iv) aid peer-review and supplement electronic publications; (v) give access to geological materials for disabled and other non-traditional students; and (vi) provide access to collections locked away in storage drawers, given that museums and other repositories display only a small fraction of their holdings.

The concept of a virtual specimen is not new. Following the mechanical tomography of Sollas (1904), Tipper (1976) used a grinding wheel to serial-section fossils. He traced outlines with a digitizing tablet, created 3D models with a mainframe computer, and interacted with them using a graphics storage tube (relatively youthful readers can image-google "graphics storage tube"), exploring previously hidden inner surfaces.

Virtual geological collections already exist online, and readers may simply link content to their own virtual field trips, online courses, and social media pages. Reynolds et al. (2002) and Bennington and Merguerian (2003) used QuickTime Virtual Reality (QTVR) to display interactive digital specimens. The Smithsonian Museum has a large collection of scanned 3D objects (Smithsonian, 2016), and the British Geological Survey (2016) has assembled more than 1,800 virtual fossils. Numerous LiDAR models of outcrops have been made (Clegg et al., 2005; McCaffrey et al., 2008; Buckley et al., 2010; see also Passchier, 2011, and VOG, 2016).

More recently, geoscientists have created many virtual specimens for paleontological functional analysis, digital exchange of research data, and teaching in a range of geoscience subdisciplines. For example, Pugliese and Petford (2001) revealed 3D melt topology of veined micro-diorite, and Bates et al. (2009) estimated dinosaur bone mass from models.

Modelers have long used 3D scanners, and, more recently, 3D printers (Hasiuk, 2014) to create ever-more sophisticated virtual objects. Cohen et al. (2010) reconstructed archaeological vessels from virtual ceramic shards, harnessing the computer's power to solve 3D jigsaw puzzles. Engineering geologists Dentale et al. (2012) used FLOW-3D® software to test a virtual breakwater built out of individual virtual stones and accropodes™. Medical CT-scanning methodologies were used by Hoffmann et al. (2014) to study buoyancy in virtual cephalopods, by Carlson et al. (2000) for igneous texture studies, and by Pamukcu et al. (2013) to examine glass inclusions in quartz crystals. Rohrback-Schiavone and Bentley (2015) employed GIGAmacro™ hardware to create grain-scale sedimentological models. Root et al. (2015) compared models of Neolithic monuments in Ireland and the Middle East, while Mounier and Lahr (2016) created a 3D model of the skull of the common ancestor of humans and Neanderthals. Structural geologists Thiele et al. (2015) gained new insights into en échelon vein formation, and Favalli et al. (2012) modeled outcrops, a volcanic bomb, and a stalagmite. They concluded that the quality of virtual outcrops or specimens is comparable to LiDAR outcrops or laser-scanned specimens, respectively.

In recent years, the most exciting developments in 3D modeling include the availability of smartphone apps and associated point-cloud computing services that non-specialists can quickly master. The purpose of this paper is to highlight the recent, current, and potential future role of virtual specimens in diverse aspects of geoscience education and research.

CREATING VIRTUAL SPECIMENS WITH SKETCHUP

Virtual specimens can be created with a digital camera and SketchUp (2016). SketchUp exports a model as a COLLADA file optionally zipped with a KML document and one or more texture

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[1] GSA Supplemental Data Repository Item 2016173, detailing techniques for creating virtual specimens along with figure animations, is online at www.geosociety.org/pubs/ft2016.htm. If you have questions, please contact *GSA Today*, P.O. Box 9140, Boulder, CO 80301-9140, USA; gsatoday@geosociety.org.

Figure 1. Virtual rock created with SketchUp and geolocated at collection site, Rheems Quarry, Pennsylvania, USA. Online version can be rotated, and is available at http://dx.doi.org/10.1130/GSATG257.S1. ©2016 Google Inc. Image: Landsat. Inset: Photographing hand specimen at arm's length. Background is irrelevant as it will be cropped.

images in a KMZ archive. COLLADA (Arnaud and Barnes, 2006) is the format used to display 3D buildings, bridges, etc., on the Google Earth terrain, but De Paor and Piñan-Llamas (2006) and De Paor and Williams (2006) discovered that they could create much larger crustal models that can be made to emerge from the subsurface (De Paor, 2007) with a slider control (see also Chen et al., 2008; De Paor and Whitmeyer, 2011; Blenkinsop, 2012; Boggs et al., 2012; Karabinos, 2013; St. John, 2014).

Slab-Shaped COLLADA Models

Consider a rock, which we here define as the *verilith* (Latin for "real rock") with two parallel sides and minor thickness, such as slate, shale, flagstone, or any hand specimen sliced thinly by a rock saw. Figure 1 shows a sample collected from a limestone quarry near Rheems, Pennsylvania, USA (De Paor et al., 1991; De Paor, 2009). Photographs of the flat sides were applied to a rectangular block in SketchUp (Fig. 1 inset) following the method of De Paor and Piñan-Llamas (2006; see also De Paor, 2007), and the later rediscovery of the method by Van Noten (2016). Model construction is explained in detail in the GSA Supplemental Data Repository (see footnote 1), but the process can be summarized as the digital equivalent of gluing photographs to plywood and cutting object outlines with a jigsaw. The Rheems model was exported to Google Earth and placed at its collection site. A KML file was scripted to make the specimen rotate about a vertical axis in response to the Google Earth slider. (The COLLADA models in the online versions of all figures respond to mouse drags or touch swipes—see the GSA Supplemental Data Repository [footnote 1]). In lab class, students can clearly see that the limestone bridges crossing calcite veins are not identical in shape on either side of the specimen, and they are challenged to visualize the complex 3D forms in the specimen's interior, which was the purpose of the exercise in this case.

Ovoid- and Hemi-Cylinder–Shaped COLLADA Models

A similar approach was taken with ellipsoidal, or ovoid, and hemi-cylindrical specimens, as illustrated by KMZ downloads accompanying this paper. Six photographs were draped over a model of an ovoidal beach pebble in the ± x, ± y, and ± z directions. To represent cut drill core, cylinders were extruded from circles in SketchUp, then sliced longitudinally, with core photographs applied as textures. When imported into Google Earth, such specimens can be made to rise out of the subsurface at their drill site in response to the slider control. This was done as a proof-of-concept by De Paor (2007) and implemented on a large scale using Big Data IODP repositories by St. John (2014).

COMPLEX SPECIMENS AND 3D SCANNERS

It is possible to create complex models with SketchUp, but for intricate specimen shapes, 3D scanning is less tedious. A relatively inexpensive NextEngine (2016) scanner was used to model pseudotachylite from Vredefort, South Africa—Earth's oldest and largest known impact structure (De Paor et al., 2010; Fig. 2). Rock specimens had been collected during legacy graduate student mapping by Simpson (1978) before the region became a protected World Heritage Site. Specimens were retrieved from long-term storage and scanned. Open-source software (MeshLab, 2016) (zBrush is a sophisticated, albeit expensive alternative [Michael,

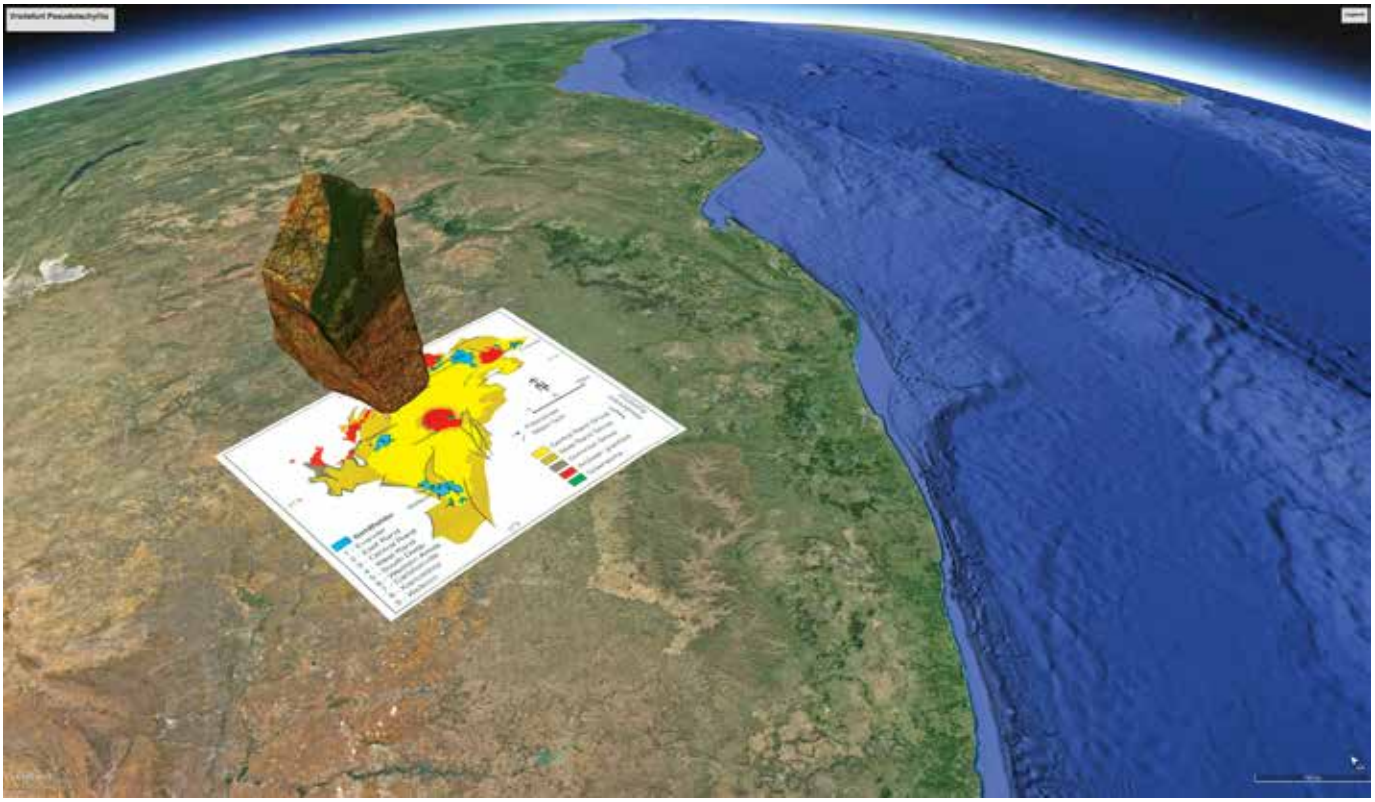

Figure 2. Pseudotachylite specimen from Vredefort impact structure. ©2016 Google Inc. Image: Landsat. Map by Hartwig Frimmel. Online version can be rotated, and is available at http://dx.doi.org/10.1130/GSATG257.S2.

2016; TurboSquid, 2016]) was used to clean scanning errors and reduce model size. Google Earth literally shreds models with more than 64,000 vertices, so reducing the number of vertices is essential for most raw scans. Of the many vertex reduction options in MeshLab, the only one that worked whilst maintaining specimen quality was *Quadric Edge Collapse Decimation* (see the GSA Supplemental Data Repository [footnote 1]). The model was exported from MeshLab in COLLADA format for use with Google Earth.

MULTI-VIEW STEREO AND STRUCTURE FROM MOTION

The most exciting recent modeling innovations are in the field of multi-view stereo (MVS) photogrammetry. Se and Jasiobedzki (2008) used video imagery from an unmanned vehicle and the *Simultaneous Localization and Mapping* (SLAM) algorithm to monitor an active mine. An algorithm called *Structure from Motion* (SfM) uses multiple still images from a smartphone or other digital camera to build 3D models. Snavely et al. (2008) and Enqvist et al. (2011) developed non-sequential SfM, enabling model construction from image searches (Schonberger et al., 2015). However, Sakai et al. (2011) require only two photographs, and Gilardi et al. (2014) created 3D beach pebbles from a single orthogonal photograph.

The bleeding edge of SfM technology is Autodesk® Memento (2016), which at the time of this writing was in public beta-test phase. It was slated for commercial release in May 2016 under the new name Autodesk® ReMake. It promises to accommodate billions of vertices with no limit on the number or resolution of images. Such models will doubtless be too large to embed directly into Google Earth or Cesium virtual globes unless they evolve in tandem, but will be accessible from virtual field trip stops via HTML hyperlinks to modern browsers (Gemmell, 2015), of which the fastest appears to be Waterfox (2016).

VisualSFM (Wu, 2013) is an open-source application with enhanced SfM editing capabilities; however, it requires command-line competency and is not for the faint-of-heart. PhotoScan from Agisoft (2016) is a more popular choice (Pitts et al., 2014; Shackleton, 2015) and whilst not free, is deeply discounted for education. Bemis et al. (2014) review other SfM methodologies, including UAV outcrop mapping. Probably the easiest SfM application for beginners, however, is Autodesk's 123D Catch.

Schott (2012) modeled mud cracks using Autodesk's original SfM application, PhotoFly—since renamed 123D Catch—which is freely available from Autodesk (2016; there is a premium version with a US$10 monthly fee). Karabinos (2013) used it to create outcrop and boulder models. De Paor (2013) described the process of porting 123D Catch models to Google Earth by processing them through MeshLab. Bourke (2015) used SfM to model an indigenous Australian rock shelter; Lucieer et al. (2013) mapped landslide displacement using SfM and UAV photography; and MCG3D (2015) made particularly good use of annotation capabilities in a geo-tourism application.

Figure 3 shows a mantle xenolith from Salt Lake (Āliamanu) Crater, adjacent to Pearl Harbor, Hawaii. The verilith was collected by Michael Bizimis, University of South Carolina, and mailed to the author for SfM modeling. Because the most important part of this specimen is the saw-cut surface, it was possible to

Figure 3. Structure from Motion model of a mantle xenolith from Salt Lake (Āliamanu) Crater, Hawaii. Caldera marked in red. Verilith provided by Mike Bizimis. ©2015 Google Inc. Online version can be rotated, and is available at http://dx.doi.org/10.1130/GSATG257.S4.

reduce the 4 MB raw scan down to less than half a MB without losing any resolution on the cut surface. Peridotite mineralogy is easily identified by most students in the final model despite its modest resolution.

The downloads include a KMZ model of Acasta Gneiss, the oldest whole rock ever dated, at 4.03 Ga. Its verilith was loaned by Sam Bowring, MIT, and the model created with 123D Catch can be viewed in the source location in Northwest Territories by thousands of people who will never go there in person. Instructors can use these and other models that are shared by colleagues in SketchUp's 3D Warehouse (2016), the 123D Catch Gallery (2016), SketchFab (2016), Thingiverse (2016), and other digital repositories. For example, the author downloaded fossil models from Brain (2016), processed them in MeshLab, and geolocated them in Google Earth. Figure 4 shows a virtual ammonite from Semington, Wiltshire, England, and the downloads include a model of *Gryphaea arcuate* from Hock Cliff, England.

Sometimes, people may want to display interactive specimens not linked to a particular location—for example, when the location is not known. There are three approaches: First, COLLADA models can be viewed with software such as Adobe PhotoShop™ or Apple Preview™. Second, Google Earth version 6.0 (or earlier) can be downloaded from a legacy software portal such as FileHippo (2016). In early versions of Google Earth, the *Primary Database* could be selected and made transparent with a slider, hiding the surface imagery. The accompanying KMZ downloads include a rotatable, zoomable apatite crystal in Google Earth v. 6.0. The third approach is to embed a COLLADA model directly in a web page as in the case of the halite crystal lattice in the *GSA Today* cover image (see http://dx.doi.org/10.1130/GSATG257.S3 for interactive online version). This is the best option for viewing on mobile devices. By rotating lattice models with a touchscreen swipe, students can see non-intuitive symmetry elements, such as a cubic crystal's three-fold axes, and the background image adds context. The process of displaying interactive COLLADA models in HTML 5 is far from self-evident, but this paper's sample file, using a 3D library from GitHub (2016), can be downloaded and modified. Readers can simply search for "files/halite.dae," and replace that URL with another file of their choice.

VIEWING VIRTUAL SPECIMENS IN WEB BROWSERS

Manipulating virtual rocks using the Google Earth desktop application is tedious due to the limitations of KML, an XML-based scripting language that has changed little in a decade and lacks basic programming features such as do-loops. Google Earth was available as a more versatile web browser plugin and application program interface (API), but that has been deprecated effective December 2015. A plugin-free API is expected in the not-too-distant future; meanwhile, an alternative approach is to convert models for viewing on the web-based Cesium virtual globe (Cozzi and Ring, 2011) using the glTF file format. A glTF version of the Vredefort specimen may be viewed at GEODE (2016) using the Chrome web browser (Chrome is the only browser that currently handles models in Cesium flawlessly). See the GSA Supplemental Data Repository (footnote 1) for technical details. Viewing in a web browser has distinct advantages because models can be manipulated with several JavaScript controls, such as radio buttons, numeric text fields, and multiple horizontal and

Figure 4. Ammonite from Semington, Wiltshire, England. ©2010 Google Inc. Image GetMapping plc. Online version can be rotated, and is available at http://dx.doi.org/10.1130/GSATG257.S5.

vertical sliders. A web-based virtual globe hides irrelevant menu options that could be distracting to wanderlust-prone students and is accessible via mobile devices. Web-based presentation is important for building large searchable databases of virtual specimens in the future. Because HTML, KML, COLLADA, and glTF files are human-readable (not binary computer code), tags in multiple languages can be added for search purposes.

CHANGING VIRTUAL ROCKS WITH TIME

Many undergraduate students have great difficulty understanding length and time scales of rock formation and change (Kortz and Murray, 2009). Virtual rocks can potentially help them visualize changes such as weathering, deformation, and metamorphism. For example, the KMZ downloads include a Google Earth view of New England with an emergent crustal block that is raised 20 km revealing the depth of garnet grade metamorphism. Students can zoom into the block's base and find a virtual rock in which virtual garnet crystals grow with time. The speed of the simulation can be controlled using the Google Earth time slider. Ultra-slow animations spanning a three-hour lab or a three-month course, during which a specimen's location, shape, or appearance is gradually modified, may help convey geological scales of space and time. This offers the possibility of viewing models of weathering, deformation, metamorphism, etc., in what may feel to students like geological time, because it is so slow compared to the pace of their digital lifestyles.

DISCUSSION

Computer-generated 3D models of rocks cannot fully replace their veriliths, but they can significantly enhance online geoscience education and extend the range of rocks to which both onsite and distance education students are exposed. If online classes are to compete with onsite, we need to give students control over manipulable virtual specimens. Students engaged in physical fieldwork can also benefit, for example, by creating and uploading models for their instructors or peers to help identify. Smartphone technology opens up the possibility of data collection by non-professional citizen scientists. Crowd-sourcing in geoscience (Whitmeyer and De Paor, 2014) has been limited by the need for advanced skills, however, citizens can create 3D models and share them with remote experts. In Project Mosul (2016), archaeologists virtually rebuilt artifacts destroyed by ISIS militants using crowd-sourced tourist photographs. That project has extended to include virtual reconstruction of Katmandu's cultural sites following the 2015 earthquake. Geoscientists with access to vulnerable sites can build image collections in advance of potential destructive events such as earthquakes, fires, floods, etc. (e.g., Ure, 2015). Instructors can ask every student in a class to take a cellphone photo of a specimen or outcrop from a variety of angles and build a model to which all students feel they have contributed.

Another justification for virtual rocks is their potential use in peer review of manuscripts whose analyses and conclusions depend critically on the correct identification of specimens. Reviewers currently rely on authors to interpret rocks. In future, they could ask to see 3D models—a more realistic request than having rocks mailed to them overland. Authors could embed virtual specimens in 3D PDF or HTML5 files as supplementary documents accompanying publications. As one anonymous reviewer of this paper wrote,

"I would not be surprised if in future, journals required 3D representations of outcrops and samples used within their publications. The ability to tag these with locations in a publicly available dataset could revolutionize structural geology and tectonics research. Imagine investigating a new field area and being able to

download samples collected there by previous workers alongside their papers. This could reduce a lot of wheel reinventing!"

Not all rocks are suitable for modeling. The holes in scoriaceous basalt are particularly difficult to handle. Even with photogenic specimens, it may be advisable to wait for overcast conditions in order to avoid deep shadows that will not correspond to the sun's direction in later viewings. If very high resolution is required, and rotation of the viewpoint is not essential, then GIGAmacro scans may be preferable to a 3D model (Bentley, 2015). Some models have gaps in the wireframe where they were in contact with a table or scanner turntable. These can be covered with a plain gray surface in MeshLab, otherwise students may be confused by the view into the interior of the specimen. As with art and sculpture restoration, a plain gray patch is preferable to artistic interpretation of the missing material. If a model does not truly reflect a verilith, that fact should be clearly stated. NextEngine distorts the rock texture into tiger stripes at the turntable contact as seen in the Vredefort specimen. If not cleaned up, these artifacts need to be pointed out to students.

CONCLUSIONS

Every (physical) surfer knows that the key to success is to not be too far ahead nor too far behind the currently breaking wave. It is too soon to tell whether COLLADA models on Google Earth will give way to glTF models on Cesium, or to the next unknown wave. File formats such as .doc and .pdf persist for decades. Others such as .wpd fade away. Currently, the most sharable 3D model formats include .dae and .obj, but this may quickly change.

Examination of rocks in the field remains important—indeed vital—but field geologists face many restrictions. For the author, this has included encounters with armed security guards in Spain, an angry muskox on Ellesmere Island, truculent farmers in western Ireland, and liability-averse coastal homeowners in New England. In many locations, collecting specimens may be difficult, dangerous, prohibited, or environmentally unfriendly. Interactive virtual specimens offer a partial solution to access issues for disabled and non-traditional students as legacy specimens collected in less restrictive times can be taken out of storage and brought back to life. After examining physical specimens in lab class, students can be given access to 3D scans for study time.

Virtual rocks can be combined with other visualizations to fill a gap in the size range between LiDAR outcrops and microscopic visualizations such as virtual thin sections. The terrain represented on virtual globes is rarely resolved even to outcrop scale, so there is a need for background auxiliary visualizations to give hand specimens a geographical context. Common examples include Google Street View, Photo Spheres, and GigaPans (e.g., Dordevic et al., 2015). Richards (2011) pioneered the concept of an "Easter-egg-hunt." Students are presented with digital images such as small-scale cross-bedding samples and are challenged to zoom in on the outcrop location from which the specimen was collected by studying a GigaPan. Bentley (2015) used a comparative GigaPan viewer to combined a GigaPan of the Massanutten Sandstone with an instructor's tracing of fossil tracks. Gessner et al. (2009) studied rock fractures using digital photogrammetry, and Sørensen et al. (2015) demonstrated that point-cloud models of outcrops photographed at 40 m were competitive with LiDAR scans. Outcrop-scale models can benefit from cut-aways following the design principles in Lidal et al. (2012).

Inexpensive Virtual Reality (VR) and Augmented Reality (AR) software and hardware such as FreshAiR, Poppy3D, and Google Cardboard round off an effective, immersive, virtual field trip experience (Cherney, 2015; Crompton and De Paor, 2015). Future possibilities include the use of 3D printers to create tactile models for blind students (Doyle et al., 2016). They could include audio tracks that respond to the model's orientation in a blind student's hands via embedded fiducials.

From the range of applications and future possibilities cited in this paper, it seems likely that members of every division of GSA could benefit from creating and sharing virtual specimens. They can even add an element of Dionysian entertainment to our Apollonian geoscience studies (Kingsbury and Jones, 2009; Petchkovsky, 2012). In conclusion, it is hard to deny the fact that "virtual rocks rock!"

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SUPPLEMENTARY MATERIALS

This paper is supported by a Supplemental Data Repository item (see footnote 1) detailing techniques for creating virtual specimens. There are also KMZ samples that can be downloaded and opened with the Google Earth desktop application, a sample HTML file with an embedded interactive COLLADA model, and a sample 3D PDF contributed by Dr. Alan Pitts.

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Schedule At-a-Glance

Field Trips and Short Courses, along with a variety of business meetings, will take place between Wed., 7 Sept., and Sat., 1 Oct.

Sunday, 25 September

1. Oral Technical Sessions: 8 a.m.–noon
2. Poster Sessions: 9 a.m.–5:30 p.m.
3. **GeoCareers Day:** 8 a.m.–2 p.m.
4. Lunch Break: noon–1:30 p.m.
5. **GSA Presidential Address and Awards Ceremony:** noon–1:30 p.m.
6. Oral Technical Sessions: 1:30–5:30 p.m.
7. **Exhibits Open:** 2–7 p.m.
8. **Exhibits Opening Reception:** 5:30–7 p.m.

Monday, 26 September

1. Oral Technical Sessions: 8 a.m.–noon
2. Poster Sessions: 9 a.m.–6:30 p.m.
3. **Exhibits:** 10 a.m.–6:30 p.m.
4. Lunch Break: noon–1:30 p.m.
5. **Feed Your Brain:** 12:15–1:15 p.m. *(Lunchtime Enlightenment, buy your food and take it in)*
6. Oral Technical Sessions: 1:30–5:30 p.m.
7. **Libations & Collaborations—Posters & Conversations:** 4:30–6:30 p.m.
8. **Alumni Receptions:** evening hours

Tuesday, 27 September

1. Oral Technical Sessions: 8 a.m.–noon
2. Poster Sessions: 9 a.m.–6:30 p.m.
3. **Exhibits:** 10 a.m.–6:30 p.m.
4. Lunch Break: noon–1:30 p.m.
5. **Feed Your Brain:** 12:15–1:15 p.m. *(Lunchtime Enlightenment, buy your food and take it in)*
6. Oral Technical Sessions: 1:30–5:30 p.m.
7. **Libations & Collaborations—Posters & Conversations:** 4:30–6:30 p.m.

Wednesday, 28 September

1. Oral Technical Sessions: 8 a.m.–noon
2. **Exhibits:** 10 a.m.–2 p.m.
3. Poster Sessions: 9 a.m.–6:30 p.m.
4. Lunch Break: noon–1:30 p.m.
5. **Feed Your Brain:** 12:15–1:15 p.m. *(Lunchtime Enlightenment, buy your food and take it in)*
6. Oral Technical Sessions: 1:30–5:30 p.m.
7. **Libations & Collaborations—Posters & Conversations:** 4:30–6:30 p.m.

Registration

- **Early registration deadline:** 22 August
- **Cancellation deadline:** 29 August

REGISTRATION FEES (all fees are in U.S. dollars)

	EARLY	STANDARD/ ONSITE
	June–22 Aug.	after 22 Aug.
Member: Professional, full meeting	$399	$485
Member: Professional, one day	$245	$285
Member: Professional, 70+, full meeting	$285	$370
Member: Professional 70+, one day	$185	$210
Nonmember: Professional, full meeting	$575	$650
Nonmember: Professional, one day	$350	$425
Member: Early Career Professional, full meeting	$250	$320
Member: Early Career Professional, one day	$150	$190
Member: Student, full meeting	$125	$160
Member: Student, one day	$79	$89
Nonmember: Student, full meeting	$175	$215
Nonmember: Student, one day	$115	$130
High School Student	$45	$45
K–12 Professional, full meeting	$55	$65
Field Trip or Short Course only	$40	$40
Guest or spouse	$85	$90
Low Income Country*	50%	50%

*Participants from countries classified as "Low or Lower Middle Income Economies" by the World Bank need only pay 50% of the category fee for full meeting or one day registration. Online registration is not available for "Low or Lower Middle Income Economy" registrants. Please fill out a printable version of the registration form and mail it to GSA, 3300 Penrose Place, Boulder, CO 80301, USA. IMPORTANT: Fees for onsite registration will be collected in U.S. dollars and credit cards only.

Events Requiring Tickets/Advance Registration

Several GSA Divisions and Associated Societies will hold breakfasts, lunches, receptions, and awards presentations that require a ticket and/or advance registration (see the meeting website for a complete list). Ticketed events are open to everyone, and tickets can be purchased in advance when you register. If you are not attending the meeting but would like to purchase a ticket to one of these events, please contact the GSA Meetings Department at meetings@geosociety.org.

Continuing Education Credits (CEUs)

The Annual Meeting offers an excellent opportunity to earn CEUs toward your general continuing education requirements for your employer or K–12 school. Credits are available for technical sessions, short courses, and field trips. Ten contact hours are required for one CEU; for example, one day (eight hours) of technical sessions = 0.8 CEUs. We'll post a link on the Annual Meeting website after the meeting so you can print out your CEU certificate.

Accommodations & Services

GSA strives to create a pleasant and rewarding experience for every attendee. Let us know in advance of the meeting if you have needs that require further attention. Most dietary considerations can be met without any extra charge. Be sure to **check the appropriate box** when registering online, and a GSA staff member will contact you. GSA will also have a **self-care room** on-site for nursing mothers and other needs. Learn more at **community.geosociety.org/gsa2016/registration/needs.**

Student Members: *Volunteer!*

Earn FREE meeting registration when you volunteer for ten hours, plus get an insider's view of the meeting. Sign up at **community.geosociety.org/gsa2016/students/volunteers** for the best selection of jobs, then register for the meeting as a Student Volunteer. You can see the available jobs when you create a schedule. More jobs may be added as we get closer to the meeting, so check back often.

GSA Section Travel Grants

GSA Sections offer travel grants to help students attend the annual meeting. Check online at **www.geosociety.org/grants/travel.htm** for the eligibility requirements for your Section. The application deadline is 22 August.

Event Space Request

31 August is the LAST day to submit a request for event space and event listing. GSA will not assign any additional meeting space after this date and cannot guarantee to list your event on the website or the mobile app. Don't miss out. Go to **community.geosociety.org/gsa2016/spacerequest** to register your request today.

Pardee Keynote Symposia

Joseph Thomas Pardee (1871–1960)

Pardee Keynote Symposia are named in honor of GSA Fellow and benefactor Joseph Thomas Pardee (1871–1960) via a bequest from Mary Pardee Kelly. Pardee is perhaps best known for his work on Glacial Lake Missoula. These symposia consist of invited presentations covering a broad range of topics. All symposia take place at the Colorado Convention Center (CCC).

Sunday, 25 Sept.

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

When/Where: 1:45–5:30 p.m., CCC, Mile High Ballroom 2A/3A
Conveners: Claudia I. Mora, George Guthrie, Susan S. Hubbard, Marianne Walck
Cosponsors: *Department of Energy; GSA Environmental & Engineering Geology Division; GSA Structural Geology and Tectonics Division; GSA Energy Geology Division; GSA Hydrogeology Division*

Subsurface energy sources satisfy more than 80% of total U.S. energy needs. The economic, sustainable, and environmentally sound utilization of our subsurface resources poses crosscutting research and technology challenges: Can we understand, monitor, image, and ultimately predict the behavior of subsurface injected fluids, the state of stress and seismicity in the subsurface, and the integrity of a well bore? Can we build the knowledge and tools needed to allow us adaptive control of subsurface fractures and fluid flow? Speakers will present geological challenges, state of the art, and research goals to meet the subsurface energy challenge. An open discussion will explore how research activities across federal labs, universities, and industry can be integrated to resolving these key challenges in subsurface science.

Monday, 26 Sept.

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

When/Where: 8 a.m.–5:30 p.m., CCC, Mile High Ballroom 2A/3A
Conveners: Daniel J. Soeder, Michael Focasio, Douglas B. Kent
Cosponsors: *GSA Hydrogeology Division; GSA Environmental and Engineering Geology Division; GSA Energy Geology Division; GSA Geology and Health Division*

Geoscientists have faced questions from the public for many years about the potential impacts of oil and gas production on the environment. This has been ratcheted up with the advent of shale gas development and high volume hydraulic fracturing. Sparse data and few studies initially caused a great deal of uncertainty, but an avalanche of investigations in recent years has been providing solid information. Researchers will present findings on the future development of oil and gas resources, advances in extraction, and improvements in understanding the potential human and environmental health impacts.

Tuesday, 27 Sept.

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

When/Where: 8 a.m.–noon, CCC, Mile High Ballroom 2A/3A
Conveners: Susan Stover, Rex C. Buchanan
Cosponsors: *GSA Geology and Society Division; GSA Geology and Public Policy Committee; GSA Hydrogeology Division; National Ground Water Association; GSA Sedimentary Geology Division; Society for Sedimentary Geology (SEPM); GSA Soils and Soil Processes Interdisciplinary Interest Group*

The High Plains aquifer provides water to portions of eight states, supporting irrigation, feedlots, dairies, ethanol plants, and communities. For decades, geoscientists have measured, modeled, and communicated the declines of this primary source of water to help society make informed decisions on its use and management. The documentary examines the conflicts, politics, economics, and scarcity that irrigators and residents of west Texas are facing. Are we making an impact?

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

When/Where: 1:30–5:30 p.m., CCC, Mile High Ballroom 2A/3A
Conveners: William B. McKinnon, S. Alan Stern, Jeffrey M. Moore
Cosponsors: *GSA Planetary Geology Division; AGU Planetary Sciences Section*

NASA's New Horizons mission has revealed surprisingly complex geology on the surfaces of Pluto and Charon. This symposium explores the geological diversity and ongoing activity on present members of the Kuiper belt (the Solar System's "Third

Zone"), such as Pluto, and former members, such as Triton, widely viewed as an icy dwarf planet captured by Neptune. Saturn's midsize satellite Phoebe and the largest asteroid, Ceres, have also been hypothesized to come from the Kuiper belt. This symposium will address, and a panel will discuss, the geological commonalities between these worlds and the future exploration of the Third Zone.

Wednesday, 28 Sept.

P4. Geologic Evolution of Cuba

When/Where: 8 a.m.–noon, CCC, Mile High Ballroom 2A/3A
Conveners: Robert Stern, Manuel Antonio Iturralde-Vinent, Antonio Garcia-Casco, Yamirka Rojas-Agramonte, J. Brendan Murphy, Darrel S. Cowan
Cosponsors: *GSA International/International Interdisciplinary Interest Group; Cuban Geological Society*

Cuba, the largest island in the Greater Antilles, has a complex geology that is key for understanding North American and Caribbean plate interactions, including Mesozoic passive margin sediments, Mesozoic ophiolites, volcanic-arc rocks, subduction/collision metamorphic complexes, and Cenozoic synorogenic basins related to collision with North America. This session will bring together geoscientists from Cuba, the U.S., and Europe to better constrain and understand the geologic evolution of Cuba and its surroundings. This is a joint event between the geological societies of the two nations, the first one in many years and a new start to what we hope will become a strong relationship.

Accommodations

	Downtown Denver Hotels	Distance to Colorado Convention Center	Single/Double Rate
1	Hyatt Regency Denver at CCC **(HQ Hotel)**	50 Steps	$223
2	Crowne Plaza Denver Downtown	2 Blocks	$179
3	Denver Marriott City Center	3 Blocks	$199
4	Grand Hyatt Denver **(Co-HQ Hotel)**	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

Critical Housing Dates

- **22 Aug.:** Last day to cancel rooms without a penalty.
- **31 Aug.:** Room rates are guaranteed as long as there are rooms available in the GSA room block.
- **After 31 Aug.,** hotel room rates and/or availability cannot be guaranteed.
- **15 Sept.:** All changes, cancellations, and name substitutions must be finalized through Orchid Event Solutions (OES) by this date.
- **16 Sept.:** Beginning on this date, you must contact the hotel directly for all changes, cancellations, and new reservations.

Once you receive your hotel acknowledgement and have booked your travel, please review your hotel arrival/departure dates 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, please contact the hotel directly to make them aware of your new arrival date.

Check the Geoscience Job Board at **www.geosociety.org/classiads/** for open positions, fellowships, and student opportunities.

Student Information and Activities

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** and then register for the meeting as a student volunteer.

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

- Sunday, 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. The museum is opening its doors for a fun-filled evening just for students and early career professionals. Explore the Prehistoric Journey, Space Odyssey, Extreme Mammals, and Gems and Minerals exhibits. Mingle in the Southeast Atrium area. Light hors d'oeuvres and a cash bar will available. Be sure to register for this event when completing your meeting registration online.

Student Downtown Deal Night

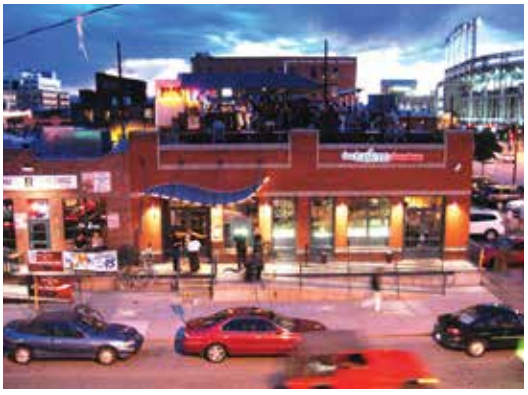
- Monday, 26 Sept., 7 p.m.

Join other students as they visit local pubs in the downtown Denver area. Some of the local area pubs have offered great deals for students wearing official wristbands. You can pick up maps and wristbands for this event just outside the Student Volunteer Office (room 206) on Monday beginning at noon and ending when all the wristbands are gone. Get there early and be prepared to show ID.

Best Student Geologic Map Competition

Please join us for in 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.

Neighborhood Spotlight



Photos courtesy of the Denver Metro Convention & Visitors Bureau.

Downtown Denver

From its early beginnings during the Gold Rush era, The Mile High City has always been a gathering place for diverse and creative people. Today, Denver is an outdoor city with a vibrant, walkable downtown offering urban adventures for all ages. Within a one-mile radius, you can kayak on the Platte River; explore some of the city's best museums; shop at art galleries and boutiques; see a Broadway touring show; enjoy live music; ride a rollercoaster or cool off in a water park; and experience exciting professional sports. Downtown is also home to many of Denver's top farm-to-table restaurants and innovative craft breweries, and the Denver Beer Trail is a great guide to sampling those local brews.

Downtown's free 16th Street Mall shuttle makes it even easier to get around. Visit Larimer Square and the newly renovated Denver Union Station in historic Lower Downtown (LoDo), where Victorian buildings now house restaurants, galleries, shops, bars, brewpubs, and coffee houses, or head to Denver Pavilions, where you'll find shops, restaurants, bars, and a movie theater.

You can also discover Denver's neighborhoods by bike, thanks to the B-Cycle bike-sharing program, and don't miss the chance for a photo with everyone's favorite Blue Bear public art sculpture at the Colorado Convention Center. (Text credit: Visit Denver.)

DENVER
The Mile High City

www.denver.org/about-denver/denver-neighborhoods/downtown/

Travel & Transportation

GSA's conference attendees will receive a discount and bonus Rapid Reward points from Southwest Airlines through our SWABIZ account. Southwest Airlines is offering **8% off Anytime & Business Select fares** for travel to and from the conference. Book your travel between 15 Apr. and 5 Sept. to take advantage of the discounted rates. (Discounts are available for travel 19 Sept. through 2 Oct.). Learn more at **www.swabiz.com/flight/search-flight.html?cid=99343650.**

Denver Light Rail

The A Line serves Denver International Airport to downtown Denver at a cost of US$9 each way. From Union Station, travelers can access local and regional transportation services, such as light rail, regional and local buses, Amtrak rail service, and taxis. The free 16th Street Mall Shuttle (MallRide) and free downtown MetroRide buses provide access to most downtown hotels. The new Denver airport rail has six stops along the way and takes about 37 minutes. Tickets can be purchased on rail-line platforms at ticket vending machines. Catch the train right by the Westin Denver International Airport Hotel.

More information: **community.geosociety.org/gsa2016/attendeeinfo/travel**

B-Cycle

Denver B-Cycle is an automated, bike-sharing system designed for use by many people for short trips around Denver. You can check out one of our 700 bikes from any one of the 82 stations and return it to any other station. Explore Denver by B-Cycle today at **www.denver.org/listings/Denver-B-Cycle/7581/7166/?mc=1.**

Photo courtesy of the Denver Metro Convention & Visitors Bureau.

International Attendees

Please print out GSA's personalized 2016 Annual Meeting Letter of Invitation at http://rock.geosociety.org/forms/visa_form.asp to include with your travel visa. If you require additional information on your invitation letter in order to obtain approval to travel or for your visa, please contact us at meetings@geosociety.org.

Please note: If you are a citizen of one of the 38 countries that are part of the visa-free entry program, you may still be required to obtain a visa to enter the U.S. if:

(1) You hold dual citizenship with Iran, Iraq, Sudan or Syria; and/or

(2) Have visited any of these countries on or after March 2011.

Room Sharing/Ride Sharing

Use the GSA Travel and Housing Bulletin Board at **community.geosociety.org/gsa2016/roommates** to share housing, airport shuttles, and/or carpool. You can also use this service to arrange to meet up with your colleagues at the meeting.

25-28 SEPTEMBER
GSA2016
Denver, Colorado, USA

Local Tours

The following local tours are open to all registered GSA Annual Meeting attendees and guests. For short visits and historical tours, it is valuable to have an experienced and knowledgeable tour guide to assist you as you tour the city. Our tour groups are small and provide guests with an opportunity to ask questions and get off the beaten path!

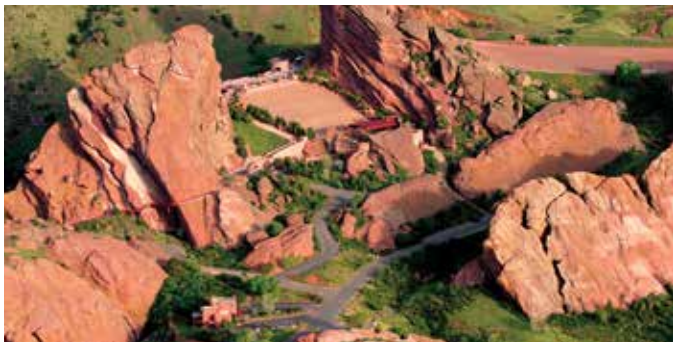


Photo courtesy of the Denver Metro Convention & Visitors Bureau.

101. **A Colorado Hike**

Sun., 25 Sept., 8 a.m.–noon. US$150; min. 20 participants.

Hike at Matthews/Winter Parks and Red Rocks Amphitheatre. A creek that winds past wild plum and willow trees greets visitors to Matthews/Winters Park, offering a bucolic setting for picnickers and a starting point for reaching the City of Denver's Red Rocks Park by trail. Across State Highway 93, the hogback offers a different recreation experience, with a steep climb up to the hulking ridge between plains and foothills. The group will start this beautiful trail together and then can split off into beginner and intermediate trail options. Snacks and water are included.

102. **Denver Bike Bar Microbrewery Tour**

Mon., 26 Sept., 2 p.m.–4 p.m. US$76; min. 15 participants.

The Denver Microbrew Tour is a two-hour guided tour through downtown Denver's historic LoDo (lower downtown), and Ballpark Neighborhood districts on a Bike Bar! Experience the city in a whole new way, pedaling to each brewery to discover why Denver has been dubbed the "Napa Valley of Beer." Taste multiple beers and learn more about the history of beer, how it's made, the different types and how they differ, as well as the history of Denver and how it became the city it is today. This tour is sure to be the most fun you've had in years!

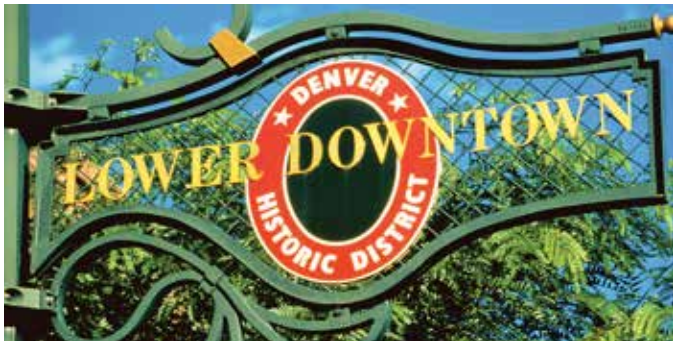


Photo courtesy of the Denver Metro Convention & Visitors Bureau.

103. **Denver "Foodie" Tour**

Tues., 27 Sept., 11 a.m.–2 p.m. US$99; min. 20 participants.

The Mile High City restaurant scene has exploded in recent years with celebrity chefs joining creative Denver chefs to create amazing culinary creations. Experience some of the best Denver "foodie" restaurants with a walking tour that takes you through the Theater District, Lower Downtown (LoDo), and historic Larimer Square, stopping at four restaurants to enjoy samples of their delicious fare and unique beverages. Our tour guide stops at interesting locations along the way to share the unique history of this fascinating part of the city.

Photo courtesy of the Denver Metro Convention & Visitors Bureau.

104. **Denver City Swing**

Wed., 28 Sept., 9 a.m.–noon. US$55; min. 20 participants.

The "Mile High City" has many unique and vibrant neighborhoods that guests will experience on a Denver City Swing. You'll tour the downtown finance and business district as well as the revitalized areas of "old" Denver that have been creatively combined with powerful skyscrapers. See the spectacular State Capitol building, one of the many "oohs and ahs" stops. Drive by the spectacular architecture of the Denver Art Museum and Civic Center Park. On the way to Denver's City Park, the city's gem that showcases over 370 lush acres of outdoor space, you'll enjoy driving through trendy Uptown Denver.

GUEST PROGRAM

Penrose Guest Hospitality Suite

Hours: Sun.–Wed., 25–28 Sept., 8 a.m.–5:30 p.m.

We warmly welcome all members of the GSA community to Denver! As part of that welcome, we offer registered guests and Penrose Circle invitees a comfortable Hospitality Suite for rest and relaxation while technical sessions are going on. As a registered guest, you are welcome to attend your companion's technical session(s), and you will have admission to the Exhibit Hall. Activities in the suite include complimentary refreshments, entertaining and educational seminars, and local experts ready to answer your questions about Denver. Local tours and activities will also be offered for an additional fee. We hope that you take advantage of the tours to learn about the area from one of the knowledgeable tour guides.

Seminars

Introduction to Smartphone Photography

Sun., 25 Sept., 10 a.m., Penrose Guest Hospitality Suite

In this workshop, a professional blogger and photographer will advise attendees on how to take pictures that are frame worthy using nothing more than a smartphone, a few simple accessories, and a mix of recommended apps. You'll learn the basics of photography composition, exposure, and lighting using a smartphone as a tool, as well as how to use some basic and inexpensive tools to improve your photos.

Cherry Creek Shuttle

Mon., 26 Sept., 10 a.m.–3 p.m., Penrose Guest Hospitality Suite

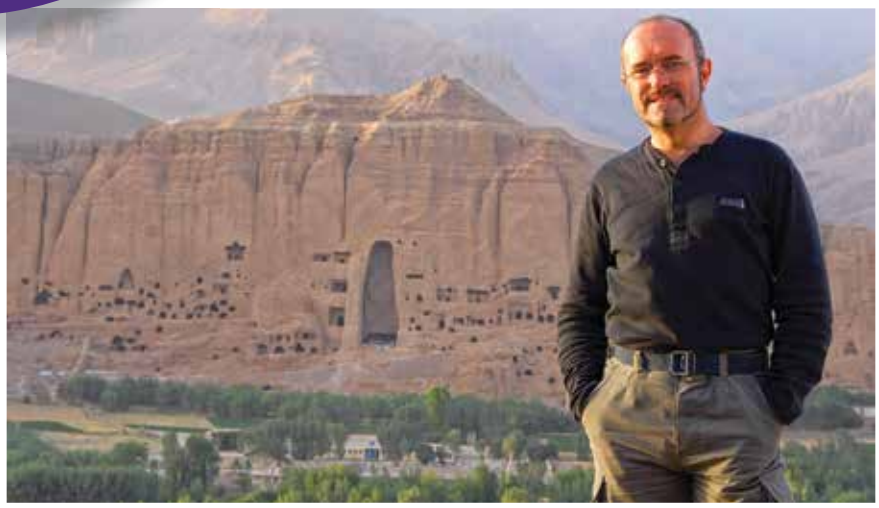
A fabulous day of shopping begins with a brief transfer to the Cherry Creek Shopping Center. After meeting in the hospitality suite, the tour will head to one of Colorado's most affluent and distinguished shopping areas. The shopping extravaganza begins with your Passport to Shopping, which offers discounts and savings to more than 60 shops and restaurants. Your group can browse through some of the world's most exclusive shops. Guests will then have the day to shop and enjoy lunch on their own in one of the many excellent restaurants.

Life Cleanse

Wed., 28 Sept., 10 a.m., Penrose Guest Hospitality Suite

This workshop is designed to help you grow and heal in a multitude of areas, including parenting, emotional well-being, balance and fulfillment, relationships, careers, and so much more. This workshop is both informative and interactive in a comfortable and non-judgmental setting.

LUNCHTIME ENLIGHTENMENT



Claudio Margottini
"Geosciences Save UNESCO Heritage"

▶ Wed., 28 Sept., 12:15–1:15 p.m.

Cultural heritage, both tangible and intangible, represents the legacy of humankind on Earth. It is evidence of millennia of adaptation of humans to the environment. The protection of this cultural heritage from geotechnical and geological hazards is at the intersection of conservation science and earth science. Claudio Margottini, trained as a geologist and engineering seismologist, uses examples from his experiences worldwide to demonstrate the relevance of geological sciences on the conservation of monuments destroyed or damaged by explosions (e.g., Bamiyan, Afghanistan), landslides and rock fall (e.g., Petra, Jordan), increasing pollution (e.g., Lumbini, Nepal), weathering (e.g., Rapa Nui, Chile), and structural degradation (e.g., Pompeii, Italy).

A focus will be on how investigation and monitoring using modern technology is a fundamental step in safeguarding and enhancing traditional knowledge and sustainable practices, primarily based on local conservation techniques. In the past 20 years, working as an engineering geologist, Margottini has supported UNESCO and local institutions on many international projects—from Afghanistan, Ethiopia, and Syria, to Peru, Bolivia, and Chile, to North Korea, South Korea, Mongolia, Nepal, and beyond—for the conservation of cultural heritage. He is currently responsible for the interpretation of remote sensing data (radar interferometry) at the site of Pompeii, Italy, and is scientific coordinator of a European Union project to investigate natural hazard and monitoring trends with radar interferometry in the European UNESCO sites.

Claudio Margottini is a Senior Scientist at the Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA), Geological Survey of Italy; Vice President of the International Consortium on Landslides; a UNESCO consultant; and an adjunct professor at Huangzou University, Wuhan, China.

KiddieCorp

Childcare by KiddieCorp

KiddieCorp will provide childcare services for GSA attendees on Sat.–Wed., 7 a.m.–6 p.m. The program is open to children six months to 12 years and the cost is only US$9 per hour per child (two-hour minimum). The advance registration deadline is **22 August.**

Register now at **community.geosociety.org/gsa2016/registration/needs** because availability is limited and handled on a first-come, first-served basis.

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—Grand Hyatt, 1750 Welton Street, Denver, Colorado 80202, USA. Rooms TBA.

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

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.

www.facebook.com/earthcache
www.earthcache.org

THE GEOLOGICAL SOCIETY OF AMERICA®

Let the Earth be your teacher!

Don't Forget to Sign up for a GSA Scientific Field Trip or Short Course!

These trips and courses fill up quickly—early registration is recommended.

To sign up, go to **community.geosociety.org/gsa2016/registration.**
If you register after 22 Aug., you will need to pay an additional US$30 for your short course.

Earn continuing education credits (CEUs): All trips and courses offer CEUs, and most are at low or no cost.

Full field trip descriptions:
community.geosociety.org/gsa2016/science-careers/fieldtrips

Field Trip Questions?
Contact Lindsey Henslee, lhenslee@geosociety.org.

Full short course descriptions:
community.geosociety.org/gsa2016/science-careers/courses

Short Course Questions?
Contact Jennifer Nocerino, jnocerino@geosociety.org.

The Geological Society of America®
GEOCAREERS

Especially for Students

GEOCAREERS DAY

Sun., 25 Sept., 8 a.m.–2 p.m. All-inclusive fee: $25—registration is required and space is limited. If you have already registered for the meeting, please call GSA Sales & Service at +1-888-443-4472 to add this to event.

8–9 a.m.	**Career Workshop** This workshop will be divided into 20-minute power sessions: reviewing résumés for industry and USA Jobs, and Q&A. US$10 if not registered for GeoCareers Day.
9–11 a.m.	**Career Information Session** This is your opportunity to ask questions and talk one-on-one with corporate and government representatives.
11 a.m.–2 p.m.	**Career Mentor Roundtables** Mentors from a variety of sectors will answer your career questions at table stations throughout the afternoon.
Noon–1 p.m.	**Career Pathways Panel** (includes lunch if registered for GeoCareers Day) Career Day attendees admitted first and then a few unregistered students will be accepted on a first-come, first-served basis.

THE PALEONTOLOGICAL SOCIETY MENTORS IN PALEONTOLOGY CAREERS LUNCHEON

Mon., 26 Sept., noon–1 p.m. This student luncheon features a panel of mentors representing a variety of colleges, universities, museums, and government agencies.

JOHN MANN MENTORS IN APPLIED HYDROGEOLOGY PROGRAM

Tues., 27 Sept., 11:30 a.m.–3:30 p.m. If you are a student member of GSA's Hydrogeology Division and you are attending the GSA Annual Meeting, keep an eye on your e-mail on 23 August for an invitation e-mail to receive a free ticket to the Hydrogeology Division Luncheon, Awards & Business Meeting.

PRE-MEETING WEBINAR

Impress for Success at GSA's Annual Meeting

Wed., 7 Sept., 11 a.m. MST
Presented by Patrick McAndless, P.Geo, FGC, this webinar is a guide to successfully navigating and getting the most out of your GSA Annual Meeting experience.
Register online at **https://attendee.gotowebinar.com/register/2937078506801961473.**

The Geological Society of America®

GEOCAREERS

Especially for Early Career Professionals

SCIENCE COMMUNICATION: "BE HEARD & BE INTERESTING"

Sat., 24 Sept., 8 a.m.–noon. Professionals: $35; students: $25; includes continental breakfast. Limited seating.
Sign up on your meeting registration form or call GSA Sales and Service at +1-888-443-4472.
Hone your public communication skills and practice in a safe and comfortable setting.
Learn to create clear and concise messages that are targeted to your audience, as well as how to prepare for a media interview. Develop strategies for using social media, identify opportunities for speaking in your community, and gain an understanding of how to approach policymakers on scientific issues.

PUBLISHING: "WHAT'S YOUR PROBLEM; WHAT'S YOUR POINT?"

Sun., 25 Sept., 11:30 a.m.–2 p.m. Experienced GSA science editors will explain the process of preparing your research for submission to scholarly journals. An application is required; you'll find complete information on a PDF flyer at **http://bit.ly/28IADvG.**

EARLY CAREER PROFESSIONALS COFFEE

Mon., 26 Sept. 9:30–10:30 a.m. No registration required.
This informal gathering will have remarks from several non-profits who have activities of interest to early career professionals. There will be time for networking and sharing ideas on how these organizations can best serve you.

For Everyone

WOMEN IN GEOLOGY CAREER PATHWAYS RECEPTION

Sun., 25 Sept., 5:30–7 p.m. This informal gathering begins with remarks from a few key women speakers who will address issues faced by women in geology. A roundtable mentoring session follows, providing time for networking, sharing ideas, and getting to know other women geoscientists.

▶ MENTORS NEEDED ◀

GSA is looking for mentors to help students understand the breadth of careers available to students and provide advice as they navigate their next steps, academically and professionally.
Mentoring opportunities range from one-on-one pairings to 30-minute consultations.
Learn more about becoming a mentor and the range of mentoring opportunities available at the GSA Annual Meeting at **https://goo.gl/LrpOCP.**

25-28 SEPTEMBER
GSA2016
Denver, Colorado, USA

2016 GSA/ExxonMobil Field Camp Award Winners

GSA/EXXONMOBIL FIELD CAMP EXCELLENCE AWARD

This US$10,000 award is given each year to a geology field camp to assist with the summer field season. It is based on safety awareness, diversity, and technical excellence.

Jeff Meyer, Santa Barbara City College Summer Field Camp

GSA/EXXONMOBIL FIELD CAMP SCHOLARS AWARD

This award is for undergraduate students to attend summer field camp. Twenty students will be awarded US$2,000 each to attend the field camp of their choice based on diversity, economic/financial need, and merit.

Alexandra Busk, University of Alaska Anchorage

Victor Cabrera, Dartmouth College

Hector Flores, Humboldt State University

Sade Haake, California State University Bakersfield

Eric Hanna, Austin Peay State University

Joseph Humphrey, Austin Peay State University

Brandon Keough, State University of New York at Potsdam

Kelsy Konkright, University of Alaska Anchorage

Corinne Kuebler, University of Pittsburgh

Baylee Kushner, Slippery Rock University

Jessica McGuire, Clarion University

Brian Minkin, University of Nevada–Reno

Brittany O'Brien, State University of New York at Fredonia

Molly Peek, Smith College

Jacqueline Snow, Central Michigan University

Noor Soboh, Wayne State University

Jasmine Stefansky, Central Michigan University

Jordan Vega, Sam Houston State University

Christopher Vito, Drexel University

Shannon Wang, Rice University

THE GEOLOGICAL SOCIETY OF AMERICA®

ExxonMobil

The Geological Society of America®

GEOCAREERS Mentoring Tomorrow's Geoscience Leaders at the 2016 Section Meetings

GSA is proud to provide mentoring and career pathway events at all its meetings. At Section Meetings, students are invited to participate in the Roy J. Shlemon Mentor Program in Applied Geology and the John Mann Mentors in Applied Hydrogeology Program. These popular events, supported by the GSA Foundation through gifts from Roy J. Shlemon and John Mann, with additional financial assistance from GSA's Northeastern Section, are designed to extend the mentoring reach of individual professionals. Together, mentor volunteers and students meet in a relaxing, informal setting, to discuss careers in geology over lunch.

This past spring, 444 students and 56 mentors participated in the Shlemon Program and 195 students and 25 mentors attended the Mann Program. Mentors and students left the events expressing feelings of personal and professional growth. As a result of the events, new friendships were made and professional contacts were established that will last well into the future.

In addition to mentoring, GSA also provided three career workshops for students designed to help them plan and prepare for their job search. The workshops covered career planning and informational interviewing, career exploration, and cover letters, résumés, and CVs. Working professionals from academia, government, and industry were invited to answer questions and help students maneuver the career exploration process.

GSA gratefully acknowledges the following mentors for their individual gifts of time and for sharing their insight with students. To learn more about these programs, or to be a mentor at a future Section Meeting, please contact Jennifer Nocerino, jnocerino@geosociety.org.

The John Mann Mentors in Applied Hydrogeology Program

Helping Mentor Students Since 2004

SOUTH-CENTRAL SECTION

Cas Bridge, Chevron Environmental Management Company

Katherine Knierim, U.S. Geological Survey

NORTHEASTERN SECTION

Elizabeth Blaise, Griggs-Lang Consulting Geologists Inc.

Doug Burns, U.S. Geological Survey

Susan Hagar, ARCADIS U.S. Inc. Corporate

Richard Hisert, H2H Associates LLC

Jean Neubeck, Alpha Geoscience

Doug Reed, Hudson Basin River Watch

SOUTHEASTERN SECTION

Devendra Amatya, Center for Forested Wetlands Research

Charlie Kaufman, South Carolina Emergency Management Division

C. Alex Pellett, South Carolina Department of Natural Resources

Ronald Wallace, Georgia Environmental Protection Division

CORDILLERAN SECTION

Kerry Cato, Cato Geoscience Inc.

Elizabeth Goldbaum, Geological Society of America

Joe Kingsbury, GEOSCIENCE Support Services Inc.

Lindsay Swain, GEOSCIENCE Support Services Inc.

NORTH-CENTRAL SECTION

Kenneth Bradbury, Wisconsin Geological and Natural History Survey

David Kulczycki, Geosyntec Consultants

Diane Lamb, Independent Contractor

Eric Plankell, Illinois State Geological Survey Prairie Research Institute

Erica Toledo, Fehr Graham – Engineering & Environmental

ROCKY MOUNTAIN SECTION

Kevin Brackney, Nez Perce Tribe

David Kelley, Kelley & Associates Environmental Sciences

John Welhan, Idaho Geological Survey

Jen Woody, Oregon Water Resources Department

continued on p. 28

continued from p 27

The Roy J. Shlemon Mentor Program in Applied Geology

Helping Mentor Students Since 2000

SOUTH-CENTRAL SECTION

Bill Boshart, Coastal Protection and Restoration Authority of Louisiana

Thomas Ewing, Frontera Exploration Consultants

Bill Haworth, Geologist (Retired, Chevron)

Claire Renault, Leaaf Environmental LLC

Kasey White, Geological Society of America

Kevin Woller, Pioneer Natural Resources

NORTHEASTERN SECTION

Noel Elizabeth Anderson, NYC Mayor's Office of Environmental Remediation

Elizabeth Blaise, Griggs-Lang Consulting Geologists

Aaron Bobar, Arcadis

Paul D'Annibale, O'Brien & Gere

William deLorraine, St. Lawrence Zinc

Bill Devlin, Rock Bottom Geological Research

Harry Edenborn, U.S. Department of Energy

Eric Eslinger, e*GAMLS* Inc.

Robert Fakundiny, Consultant

Robert Feranec, New York State Museum

Andrew Fetterman, Liberty Environmental Inc.

Mike Flanagan, Fancamp Exploration Ltd.

Mark Flusche, Arcadis

Victor Gabriel, Callanan Industries Inc.

Susan Hagar, Arcadis U.S. Inc. Corporate

Mark Hempton, Aksu Resources

Jinesh Jain, AECOM

Bill Kelly, New York Geological Survey (Retired)

Andrew Kozlowski, New York State Museum

Greg Lesniak, Barton & Loguidice

Isabel McRae, NYC Mayor's Office of Environmental Remediation

Arthur Merschat, U.S. Geological Survey

Peter Muller, Muller Geological Consulting LLC

Doug Reed, Hudson Basin River Watch

Becky Remis, Schalmont High School

Joshua Smith, American Institutes for Research

SOUTHEASTERN SECTION

George Edwards, G.H. Edwards & Associates Inc.

Randy Kath, National Association of State Boards of Geology

Gerry Stirewalt, U.S. Nuclear Regulatory Commission

Sean Sullivan, Fugro Consultants Inc.

Ronald Wallace, Georgia EPD

CORDILLERAN SECTION

Alton Dooley, Jr., Western Science Center

Will Gaston, Gaston and Associates

Margaret Gooding, LSA

Janis Hernandez, California Geological Survey

Shannon Mahan, U.S. Geological Survey

Lindsay Swain, Geoscience Support Services Inc.

NORTH-CENTRAL SECTION

Neal Farrar, Sunbelt Environmental Services Inc.

Leo Giannetta, Illinois State Geological Survey

Ann Hagni, Brewer Science, Inc.

Jeffrey McDonald, U.S. Environmental Protection Agency

Claudia Mora, Los Alamos National Laboratory

John Popp, Natural Resource Partners L.P.

ROCKY MOUNTAIN SECTION

David Coles, Coles Environmental Consulting Inc.

Barry Devlin, Gold Resource Corporation

Nicholas Furlin, Lucky Friday Unit, Hecla Limited

Virginia Gulick, NASA Ames Research Center

Robin Nimmer, TerraGraphics Environmental Engineering Inc.

Jim O'Connor, U.S. Geological Survey

Kelsay Stanton, Stanton Geological Services

Geoscience Career Exploration Workshops

Helping Mentor Students Since 2014

SOUTH-CENTRAL SECTION

Bill Boshart, Coastal Protection and Restoration Authority of Louisiana

Peter Clift, Louisiana State University

Claire Renault, Leaaf Environmental LLC

NORTHEASTERN SECTION

Robert Feranec, New York State Museum

Laura Guertin, Penn State Brandywine

Susan Hagar, ARCADIS U.S. Inc. Corporate

SOUTHEASTERN SECTION

Cole Bates, OceanaGold Exploration

Amy Brock-Hon, The University of Tennessee at Chattanooga

Gerry Stirewalt, U.S. Nuclear Regulatory Commission

CORDILLERAN SECTION

Will Gaston, Gaston and Associates

Elizabeth Goldbaum, Geological Society of America

Brian Olson, California Geological Survey

Eric Scott, Dr. John D. Cooper Archaeological and Paleontological Center

NORTH-CENTRAL SECTION

Dick Berg, Illinois State Geological Survey

Paul Doss, University of Southern Indiana

Tim Drexler, U.S. Environmental Protection Agency

Jennifer Druhan, University of Illinois Urbana–Champaign

Douglas Mateas, Geosyntec Consultants, Inc.

ROCKY MOUNTAIN SECTION

Renee Breedlovestrout, Idaho Geological Survey

Katie Cooper, Washington State University

Nicholas Furlin, Hecla Limited

Recommendations from the GSA Diversity Task Force

The Geological Society of America (GSA) embraces and values diversity and actively works toward creating an inclusive and safe environment for all participants engaged in events, meetings, and throughout the organization. Last year GSA leadership authorized a Diversity Task Force to review the organization's internal non-discrimination and diversity directives.

Over the course of six months, the Diversity in the Geosciences Committee, four Councilors, and the Executive Director reviewed policies and practices regarding diversity and equity to ensure that they were consistent and effective across the organization. The recommendations from the Diversity Task Force, which were subsequently approved by Council at its spring 2016 meeting, include:

- Revisions to the GSA Position Statement on diversity (http://www.geosociety.org/positions/pos15_Diversity.pdf) that expand upon the list of protected classes;
- Acknowledgment of GSA's Position Statement on diversity in future contracts with vendors and contractors with whom GSA conducts business;
- Creation of an ad hoc committee charged with developing a Code of Conduct for Meetings and set of procedures applicable to all GSA-sponsored events and meetings with the aim of ensuring a safe and respectful environment for all participants;
- Adoption of protocols to assist leadership in assessing and responding to situations which may be regarded as inconsistent with GSA's policies on diversity and inclusiveness; and
- Commissioning the Executive Committee to conduct a review of the responsive protocols to help further improve the process after such time as an incident may occur.

Through these actions, GSA aims to demonstrate its commitment to the values of diversity and inclusivity more effectively, fostering an environment in which all participants can thrive. These recommendations are intended to encourage and promote insightful and respectful professional conduct in the geoscience community.

Why GSA Membership Is Important to Me

Tiffany Rivera on the island of Bornholm, Denmark.

My membership with GSA has offered me numerous "firsts," including my first presentation at a conference, my first grant, my first time working on public lands, and first experiences serving on guiding committees. Throughout my career, I have found myself looking for opportunities to serve GSA. After a summer as a GeoCorps™ America intern, I realized that GSA is more than just a membership. It is a community of learners and scientists. It is a way to be involved with geoscience beyond my institution, and a way to give back to an organization that has given me so many opportunities.

Last week, I had another first experience with GSA. Thanks to funding available through my institution, three of my undergraduate research students were able to attend the GSA Rocky Mountain Section Meeting. I was proud to watch them present research, participate in student mentoring activities, and meet other geoscience students. But mostly, I was excited to provide them with their first conference experience.

My GSA membership has evolved from a passive one into a way for me to be a leader. My membership has also given me a place to advance, and it will be a place for students to flourish for generations to come.

Dr. Tiffany Rivera
Assistant Professor of Geology
Westminster College
GSA Member Since 2006

Geoscience Jobs & Opportunities

Positions Open

INSTRUCTIONAL SUPPORT SPECIALIST
DEPARTMENT OF GEOLOGICAL SCIENCES
SUNY GENESEO

The SUNY Geneseo Department of Geological Sciences invites applicants for a staff position as an Instructional Support Specialist. Responsibilities of the position include operation and maintenance of departmental equipment (e.g. rock prep. facilities, XRF, XRD, SEM, ICP-OES, etc.), training of undergraduate students on use of equipment, assisting with development and organization of weekly lab exercises, assisting with field trip logistics, and curating departmental collections (rocks, maps, fossils). The successful applicant must have at least a MS degree in Geosciences or a related area at the time of appointment. Required qualifications include demonstrated interest in and aptitude for teaching, demonstrated ability to develop laboratory exercises using current pedagogy, interest in outreach and superior organizational, written and oral communication abilities. Position opportunities include mentoring undergraduate students in research and club activities, teaching summer courses, and collaborating with faculty on research grants. Must also be able to bend and lift up to 40 pounds.

To apply, complete a professional application at https://jobs.geneseo.edu. Applicants should be prepared to upload a cover letter that addresses teaching and technical qualifications and a CV. In addition, applicants should be prepared to supply contact email address for three references. References will be contacted and invited to submit letters of recommendation at the time of application.

Review of completed applications will begin upon receipt. To be guaranteed consideration, applications must be completed by August 15, 2016. The anticipated appointment for this position is as early as December 2016.

SUNY Geneseo is an Equal Opportunity/Affirmative Action employer, committed to recruiting, supporting and fostering a diverse community of outstanding faculty, staff and students. All qualified applicants will receive consideration for employment without regard to race, color, religion, national origin, disability or protected veteran status. For our full non-discrimination statement, see http://www.geneseo.edu/affirmativeaction.

FACULTY POSITIONS AT
THE UNIVERSITY OF MICHIGAN

The Department of Earth and Environmental Sciences and the Program in the Environment at the University of Michigan anticipate two openings for joint tenure-track assistant professors for university-year appointments starting September 1, 2017. We are particularly interested in candidates whose strengths complement existing research programs within the Department and the Program.

Biological Oceanography: We encourage applications from candidates whose research interests encompass the role of biology in ocean chemistry, marine geology, or physical oceanography. Specific areas of interest include (but are not limited to) carbon and nitrogen cycling in the ocean, physical-biological interactions, biomineralization of marine organisms, sediment biogeochemistry, and the impact of global change on marine life and biogeochemistry. The position is open to candidates who use field, lab, and/or modeling approaches at scales ranging from molecular to global.

Geobiology: We encourage applications from candidates whose research interests encompass interactions between biology and geology, geochemistry, or hydrology. Specific areas of interest include (but are not limited to) soils, biomineralization, microbe-mediated water-rock interactions, nanoparticles, microbe-metal interactions, and organic geochemistry. The position is open to candidates who study any organism (e.g., microbes, fungi, plants, and animals), at all scales (molecular to global, individual to community), and with various approaches (e.g., isotopic, molecular, spectroscopic).

The successful candidate is expected to establish an independent research program and contribute to both undergraduate and graduate teaching. Applicants must have a Ph.D. at the time of appointment, and should submit a CV, statement of current and future research plans, a statement of teaching philosophy and experience, and evidence of teaching excellence, if available. Letters of recommendation from three to five references should be submitted directly by the recommender, before the application deadline, using a link that will be provided once the application is submitted.

Information about the Department can be found at www.lsa.umich.edu/earth and information about the Program can be found at www.lsa.umich.edu/pite.

To apply please go to http://apps-prod.earth.lsa.umich.edu/search16/index.php, complete the online form, and upload the required application documents as a single PDF file. If you have any questions or comments, please send an email message to Michigan-Earth-Search@umich.edu.

The application deadline is September 8, 2016, for full consideration, but applications will continue to be reviewed until the position is filled. Women and minorities are encouraged to apply. The University of Michigan is supportive of the needs of dual career couples and is an equal opportunity/affirmative action employer.

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Department of Natural Sciences: 1.5 year, full-time, temporary position beginning spring of 2017 teaching Sedimentology and Stratigraphy. Introduction to GIS, Geomorphology, various introductory level courses and/or courses in the candidate's area of interest. Requirements: Minimum master's degree. ABD or Ph.D. preferred. Castleton places a special value on the teaching role of its faculty so candidates for this position will be evaluated on their potential to be outstanding teachers. Application review will begin on August 15th. For a full position description, including application procedures, visit http://www.castleton.edu/about-castleton/faculty-jobs. AA/EEO Employer.

Check out the Job Board for the latest recruitment postings.

www.geosociety.org/classiads

GROUNDWORK
Furthering the Influence of Earth Science

Geologic training for America's astronauts

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ABSTRACT

NASA astronauts are smart, highly motivated, intensely curious, and intellectually fearless. As pilots, scientists, and engineers, they have outstanding observational and reasoning skills. Very few, however, have any prior background in geology. The purpose of this article is to inform the geologic community about what we are doing to provide useful geologic training for current and future NASA astronauts who will spend many months observing Earth from orbit on the International Space Station and who will be involved in such activities as suit and tool testing, field operations, mission planning, and future off-planet exploration.

THE CONTEXT

NASA currently selects a new astronaut candidate class every four years, and each astronaut class undergoes 18 months of training before graduating to join the Astronaut Corps. The training is intense and focuses primarily on the International Space Station (ISS)—basic spaceflight operations, ISS systems, spacewalks, robotic arm operations, Russian language, human life sciences, and flight certification in T-38 jets. Geologic training is currently limited to four weeks. In that short amount of time, astronaut candidates must have an effective initial training experience in Earth observations, as well as learn about past, present, and future planetary missions to prepare them for public outreach obligations and future lunar and planetary exploration destinations.

In 2008, the authors introduced a new geologic training program built on geologic training that began with the *Apollo* missions. Each crewmember of *Apollo* 15, 16, and 17 received over 550 hours of geologic training in mission-relevant field locations (Amsbury, 1989; Evans et al., 2011; Lofgren et al., 2011; Phinney, 2015), and the success of a mentored approach to field training has shaped our current curriculum. After *Apollo*, classroom training focused on Earth observations from orbit (Amsbury, 1989; Evans et al., 2011). Field training remained an important, though much more limited, part of astronaut training (Bauer et al., 2000; Muehlberger, 2004; Dickerson, 2004), and Shuttle-era field training provided important background and context for our curriculum. The integrated approach to astronaut geologic training currently involves two weeks of classroom training followed by five days in the field. In addition, astronauts also receive a week of classroom training focused on NASA planetary missions, including the successes of *Apollo* and the motivation for human exploration of the Moon, Mars, and asteroids.

DESIGNING EFFECTIVE GEOLOGIC TRAINING

NASA's current mission is ISS-focused, and Earth is the first planet that current astronauts will see from a spacecraft. Geologic training must prepare astronauts to recognize geologic features and events, and to interpret, document, and report what they see from orbit to geologists on the ground. They also need to understand how remotely sensed data augment visual observations and relate to features that can be observed in the field.

In order to meet a NASA requirement to make the training ISS-focused, we have taken an "orbit to outcrop" approach. Astronauts gain first-hand experience both in interpreting what can be seen from orbit and in making field observations and interpretations that provide critical constraints on what can be interpreted from orbital images alone. ISS crewmembers have responded enthusiastically to requests to photograph specific targets for use in training their fellow astronauts. Consequently, we can base our training around recently acquired images from the ISS of rock units, structures, and surface features that astronauts will interpret in the field.

Our biggest challenge was how to provide effective training for geological novices in a period of time that is presently constrained by astronaut schedules to two weeks in the classroom followed by one week in the field. Our approach is to focus the entire training on a narrowly defined field problem, use the classroom training to prepare astronauts effectively for tackling that field problem, and challenge them with a field experience that gives them personal practice in making informed observations, collecting data, and interpreting geologic processes and histories at a field site with geologic features that are important in both a terrestrial and planetary context.

The field site around which we have based the training is located in the northern Rio Grande Rift in New Mexico, USA. We chose the site in part for the variety of features that can be interpreted both in the field and in orbital imagery and in part for analogs of basaltic volcanism and faulting on other planets. During the pre-field classroom sessions, astronauts use a variety of remotely sensed data, including ISS photos, to construct a

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Figure 1. Astronauts Andrew Morgan and Christina Hammock Koch working a field geologic mapping problem along the Rio Grande Gorge in the Rio Grande del Norte National Monument, Questa, New Mexico, USA. NASA photograph jsc2014e069405 by Lauren Harnett.

preliminary geologic map of the field area, adding new observations and interpretations as they learn about topics in the classroom. Fieldwork includes three days of geologic mapping and one day of geophysical surveys to add subsurface data. We group the astronauts into small groups (in 2013, four per group, with two geologist instructor-mentors), and each group combines their individual preliminary maps into a consensus solution to the geology of the field area. On the final day in the field, each astronaut team presents a geologic map, cross section, and geologic interpretation.

Throughout the training, we underscore that the purpose is to develop astronauts' abilities to infer processes from products, to recognize significant relationships and events on Earth's surface, and to document and describe those events in a way that allows Earth-bound scientists to understand and visualize them. Both in the classroom and in the field, we emphasize the relationships among outcrop, local, regional, and global patterns. In short, the training is designed to give them an effective experience in doing what geologists do and tying that to what they will see from the ISS.

FIELD TRAINING—INTEGRATING GEOLOGY AND FLIGHT OPERATIONS

Life on the ISS involves both management of daily operations and integration of new crewmembers into an experienced crew that has been aboard ISS for several months. In order to improve crew integration skills, NASA emphasizes crew resource-management training. We conduct our fieldwork from a semi-primitive camp on the edge of the Rio Grande Gorge, and teams of astronauts assist in cooking duties as well as engage in camp activities, managed by a senior astronaut, to focus on the crew management skills needed for ISS. This part of the training purposely stresses the astronauts—long days are common during spaceflight, with multiple priorities demanding attention and challenging each crewmember's time management as well as interpersonal skills. Conducting a field geologic investigation while managing camp activities has proven valuable for teaching both geology and spaceflight management skills.

THE FUTURE

Our team is currently looking forward to training the 2017 astronaut candidate class. We will also continue to offer short geologic field experiences for NASA engineers and managers and provide additional preflight training as requested by astronauts who have been selected for ISS missions and want a deeper understanding of the geology they will see on orbit. We are also expanding "post-graduate" training opportunities to accommodate a strong crew interest in geology, which we have seen continue after their basic geology training. We feel that this is a good indicator that Earth and planetary science is alive and well in NASA's Astronaut Corps. That interest and experience will be critical for developing crew operations for future planetary exploration missions.

ACKNOWLEDGMENTS

The authors would like to acknowledge the contributions and participation of all the instructors who have helped make this training successful, including Paul Abell, Waleed Abdalati, Paul Bauer, Don Bogard, Paula Bontempi, John Callas, David Carrier, Roy Christoffersen, Chris Condit, Pat Dickerson, Jay Dixon, Allen Glazner, Tien Grauch, Jim Hansen, Jim Head, Kip Hodges, Fred Hörz, José Hurtado, David Kring, Gary Lofgren, Jeff Plescia, Harrison Schmitt, David R. Scott, Will Stefanov, Robert Stern, Rob Stewart, Dawn Sumner, Phil Townsend, Jim Tucker, Woody Turner, Justin Wilkinson, and Michael Zolensky.

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Changes Coming to GEOLOGY

Beginning in January 2017, GSA members will have free online access to *Geology* at **www.gsapubs.org.** If you aren't already a subscriber, you'll receive instructions on how to activate your account when you renew your membership. Paid print subscriptions will continue to be available.

GSA Council's original plan was to transition *Geology* to 100% open access online for all beginning in 2017, but it has now voted to delay that change. (See "Open Access," p. 50, July 2016 *GSA Today*). GSA Council remains committed to making all GSA journals 100% open access in the future.

Geology's publication fee structure is changing as well. For papers submitted to *Geology* on or after 1 Sept. 2016, per-figure color charges will be replaced with a flat publication fee of US$1,750, and all figures can be in color at no extra charge. However, no article will be rejected for an inability to pay.

If authors want their papers to be open access to the public and the worldwide geologic community immediately upon publication, the article processing charge (APC) remains at US$2,500 for non-members. GSA members will now receive a US$100 discount on this APC. No additional color charges will be assessed to *Geology* authors paying the open access APC.

Geology's impact factor is among the highest in the geosciences (see p. 38, this issue), and no changes will be made to the rigorous peer review and editing processes that uphold the quality of *Geology* or any of the GSA journals.

As part of GSA's transition to open access, the GSA Foundation is seeking endowment funds to cover publications fees for those who cannot afford to pay (e.g., authors from countries and institutions with little funding). If you are interested in supporting GSA's transition to open access, please contact the GSA Foundation at **www.gsafweb.org.**

Foundation Booth Schedule of Events Annual Meeting GSA 2016

The GSA Foundation invites you to a new experience at our booth. Talk with representatives and hear inspiring presentations and research by program participants fulfilling GSA's mission of science, service and stewardship.

MONDAY

11 a.m.–noon: Rocky Mountain and Acadia Field Camps

1:30–2 p.m.: Ask A Geoscientist™2–3 p.m.: Mammoth Cave and Mount Saint Helens Field Camps

3–4 p.m.: GeoTeachers

5:30–7:30 p.m.: Penrose Circle Reception and Student Awards

TUESDAY

1–2 p.m.: Ask A Geoscientist

2–3 p.m.: Graduate Student Research Grants

4–5 p.m.: Ask A Geoscientist

5–6 p.m.: GeoCorps™ America Beer Reception

Drop by any time to meet with GSA Foundation and program staff. We look forward to seeing you!

www.gsafweb.org

John W. (Jack) Hess, *GSA Foundation President*

Do You Want to Learn Firsthand How Gifts Impact Programs and Recipients?

Visit Our Booth and Our Website

The GSA Foundation is pleased to expand a new theme in its booth during GSA 2016 in Denver: showcasing GSA programs that you have generously supported through the Foundation.

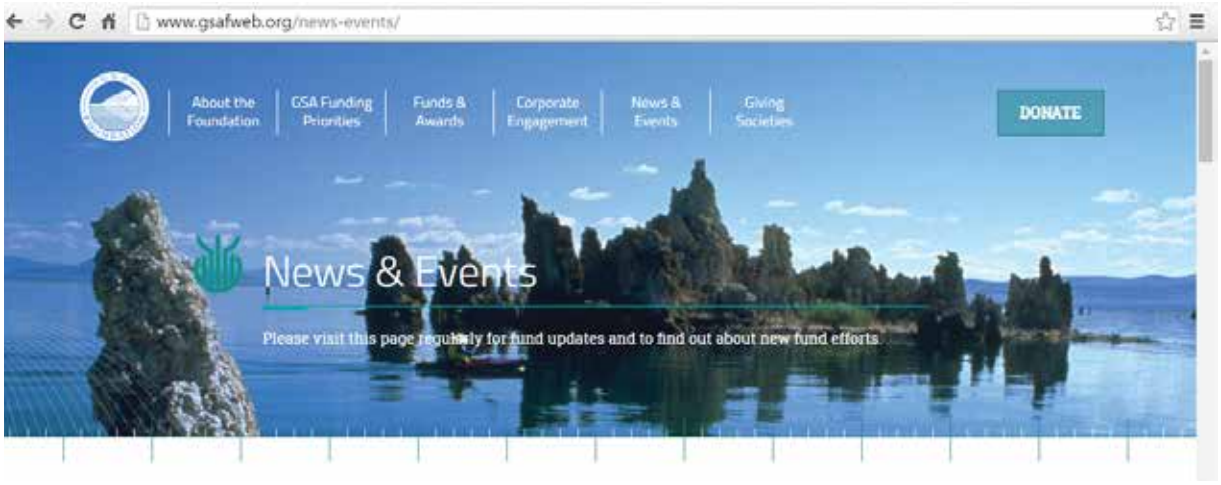
Stop by the booth to hear about the **GeoTeachers** program and **"Ask a Geoscientist"** at the **GeoCareers** table, hot topics in **geoscience policy**, and updates on GSA **meetings** and **publications**. We hope you will enjoy talking with some of GSA's program recipients while you visit: **On To the Future** students attending their first GSA Annual Meeting, students who took part in various **field opportunities**, **research grant** awardees bringing science into the booth as they share their posters, and **GeoCorps** participants highlighting their assignments on federal lands.

Representatives from a number of these programs will be giving presentations in the booth at scheduled times throughout the meeting.

Be sure to take a look at the past and current **Geologic Mapping Awards** display, including an original map by Florence Bascom, whom the award honors. Look through a small **selection of items** available for purchase to treat yourself or find a gift, and learn more about **EarthCache** while at that table.

I would also like to remind you of the Foundation's recently recreated website. Check **www.gsafweb.org** for current news and events, stories about donors and recipients, and information relevant to our family of donors leading up to the Annual Meeting.

We look forward to seeing you in Denver and offering you engaging opportunities to learn more about GSA programs supported by the GSA Foundation and the contributions of our committed, active membership.



Publications Highlights

New Impact Factors Released, *Geology* Still #1

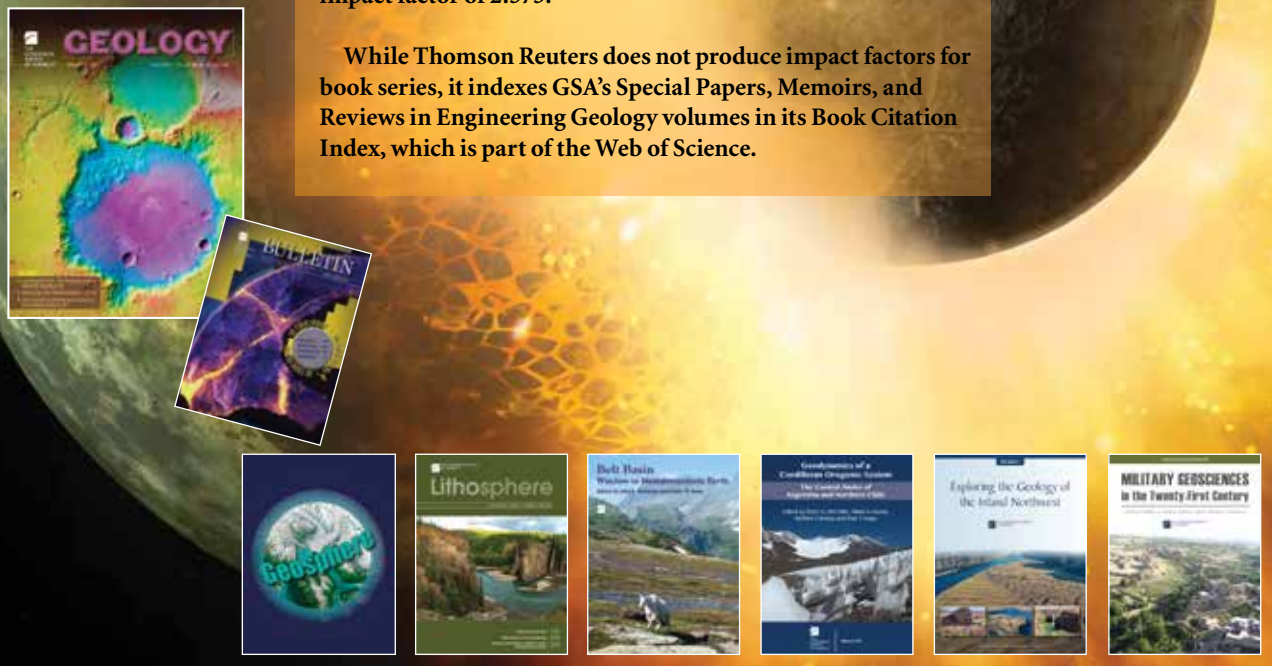
Geology **has continued its reign as the Journal Citation Reports' #1 ranked geology journal for the tenth year in a row. According to Thomson Reuters, it had a 2015 impact factor of 4.548 and a five-year impact factor of 4.813.**

Both the impact factor and five-year impact factor rose for *The Geological Society of America Bulletin*, reaching 4.332 and 4.730, respectively. *Bulletin* remains the #12 ranked multidisciplinary geosciences journal.

Lithosphere **has also held steady as the #5 ranked geology journal. Its 2015 impact factor was 2.618, and its five-year impact factor rose to 2.858.**

Geosphere's **impact factor increased to 2.262, with a five-year impact factor of 2.573.**

While Thomson Reuters does not produce impact factors for book series, it indexes GSA's Special Papers, Memoirs, and Reviews in Engineering Geology volumes in its Book Citation Index, which is part of the Web of Science.



This artist's concept shows a celestial body about the size of our moon slamming at great speed into a body the size of Mercury. NASA's Spitzer Space Telescope found evidence that a high-speed collision of this sort occurred a few thousand years ago around a young star, called HD 172555, still in the early stages of planet formation. The star is about 100 light-years from Earth. 26 August 2009. www.nasa.gov/multimedia/imagegallery/image_feature_1454.html. Credit: NASA/JPL-Caltech.

Browse GSA's journals and books at www.gsapubs.org/.

THE GEOLOGICAL SOCIETY OF AMERICA®

2017 GSA Section Meetings

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

South-Central Section
Location: San Antonio, Texas, USA
Dates: 13–14 March
Meeting Chair: Benjamin Surpless, bsurples@trinity.edu
www.geosociety.org/Sections/sc/2017mtg/

Pittsburgh skyline panorama at night.

Northeastern Section
(Joint with North-Central Section)
Location: Pittsburgh, Pennsylvania, USA
Dates: 19–21 March
Meeting Chair: Patrick Burkhart, patrick.burkhart@sru.edu
www.geosociety.org/Sections/ne/2017mtg/

North-Central Section
(Joint with Northeastern Section)
Location: Pittsburgh, Pennsylvania, USA
Dates: 19–21 March
Meeting Chair: Timothy G. Fisher, timothy.fisher@utoledo.edu
www.geosociety.org/Sections/ne/2017mtg/

Midlothian Mines. Photo used with permission from Richmond Region Tourism.

Southeastern Section
Location: Richmond, Virginia, USA
Dates: 30–31 March
Meeting Co-Chairs: David Spears, david.spears@dmme.virginia.gov; Karen Layou, klayou@reynolds.edu
www.geosociety.org/Sections/se/2017mtg/

Waikiki view from Diamond Head.

Cordilleran Section
Location: Honolulu, Hawaii, USA
Dates: 23–25 May
Meeting Chair: Craig R. Glenn, glenn@soest.hawaii.edu
www.geosociety.org/Sections/cord/2017mtg/

Dinosaur Provincial Park. Photo by Jenni Scott.

Rocky Mountain Section
Location: Calgary, Alberta, Canada
Dates: 9–10 June
Meeting Chair: Katherine Boggs, kboggs@mtroyal.ca
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