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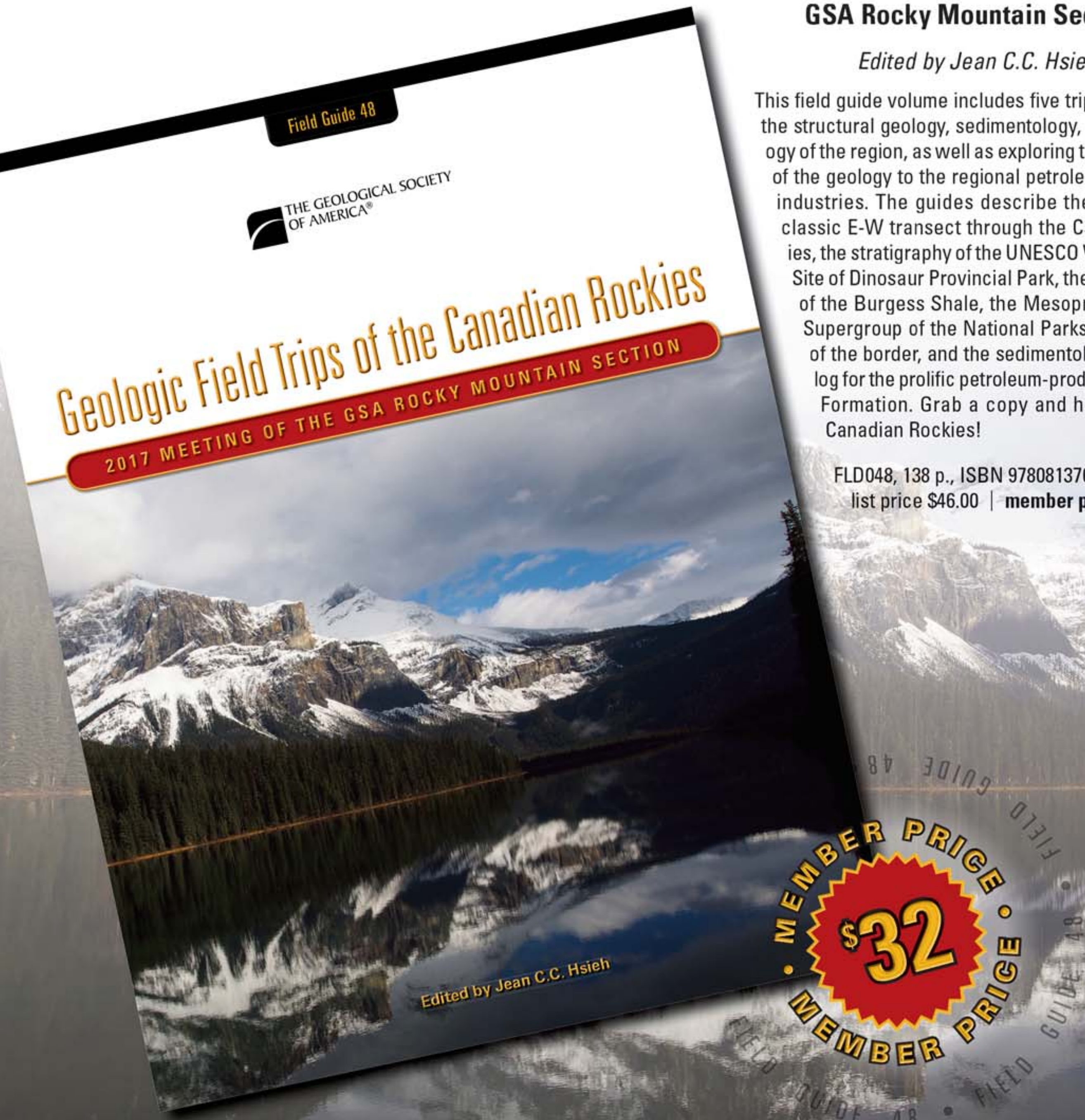

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Edited by Jean C.C. Hsieh

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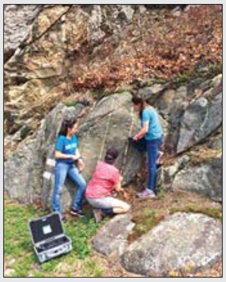
SCIENCE



Cover: Mount Holyoke College astronomy students field-testing a Raman BRAVO spectrometer for field mineral identification, examining pegmatite minerals crosscutting a slightly foliated hornblende quartz monzodiorite and narrow aplite dikes exposed in the spillway of the Quabbin Reservoir. All three units are part of the Devonian Belchertown igneous complex in central Massachusetts, USA. See related article, p. 4–9.

GSA 2017 Annual Meeting & Exposition

GSA News

Cover inset image: 18 May 1980, a major volcanic eruption occurred at Mount St. Helens, a volcano located in Skamania County, Washington, USA. Photo courtesy of USGS.

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Extracting Bulk Rock Properties from Microscale Measurements: Subsampling and Analytical Guidelines

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ABSTRACT

Geologists are commonly faced with questions relating to representative sampling at all scales: outcrop to formation, hand sample to bulk rock, microanalysis to overall chemistry. A new computer model allows quantitative answers to the question of how many different microanalysis spots are needed to determine different bulk properties of a rock for any type and scale of measurement, including whole rock composition and oxidation state. The relationships among grain size, glass ordering, and microbeam size, the composition and heterogeneity of the rocks studied, and the location of the analyses relative to textural features are all important. These variables can be grouped into those that affect the heterogeneity (H) of the material versus the scale of measurements (M) being used. For rocks where H (grain size, glass long- or short-range ordering, or composition) <<M (beam size), an average of fewer than ten analyses will yield a representative bulk rock composition no matter how heterogeneous the phase assemblage. For rocks where H ≥ M, hundreds of analyses may be needed to result in acceptable analytical precision. Guidelines for how many samples/analyses are needed to represent geologic materials at any scale are presented.

INTRODUCTION

For more than a century, geologists have used bulk analyses (e.g., Bowen, 1928; Daly, 1933; Yoder and Tilley, 1962; BVSP, 1981) to develop frameworks and classifications for understanding rock paragenesis and properties. This practice has its origins in the tradition of wet chemistry, which required grams of material for analyses. Despite the now-widespread availability of modern microanalytical techniques, use of terminology based on bulk rock characteristics persists even in the twenty-first century. Thus an ironic modern conundrum is this: how many microanalyses of a rock are needed to accurately represent its bulk composition?

The problematic issue is that of scale, i.e., the ratio of sampling size to that of the feature being measured. Field geologists encounter this problem when they set out to sample an outcrop: how many hand samples will represent the bulk characteristics of the outcrop, or even the entire formation? For geochemists, the scale of interest is that of mineral grain size relative to analytical beam size. As microbeam techniques continue to sample smaller volumes, the scale may be that of individual atoms. Increasing resolution only exacerbates the understanding of bulk geological properties.

Why are bulk rock analyses important? Because magma composition is rarely, if ever, measured in its liquid state, data from the resulting solidified materials must be used to back-calculate original compositions and conditions. In an era when microanalysis is routine, bulk rock composition is still an important parameter because it permits correlations with other rocks and geologically related regions (e.g., Philpotts and Ague, 2009). On an even broader scale, knowledge of magma source region conditions and compositions helps define the state of the mantle, provides insight into the geochemistry of crystallization and ascent, and characterizes processes affecting composition and redox, such as assimilation or injection of a new melt (e.g., Cox et al., 1979; BVSP, 1981; Asimow, 2000). Bulk rock compositions and properties may also be important in sedimentary and metamorphic rock studies to provide information on protoliths and formation conditions, as well as pseudosection analysis (e.g., Nutman et al., 1997; Powell et al., 1998; Bucher and Frey, 2002).

Despite the importance of bulk rock data, they are surprisingly complicated to measure. For glassy or fine-grained rocks (e.g., pumice or shale), direct microanalyses and bulk techniques easily yield comparable results. Complications arise when a rock contains xenocrysts or rock fragments that are not in equilibrium, or when mineral chemical zonation is present. It should be obvious why bulk composition calculations are rarely attempted on coarse-grained samples. For porphyritic or most metamorphosed rocks, determining a bulk composition is possible but tedious. Igneous rocks can be crushed and handpicked to separate the glass for melt composition analysis, or mass balance calculations can be run using glass and crystalline compositions from electron probe microanalysis (EPMA). Alternatively, material can be ground and fused experimentally prior to bulk or microanalysis. These are time-consuming tasks, and the accuracy of these estimation methods is difficult to quantify. In addition, the total sample volume may be prohibitively small to apply these methods to, as is often the case for extraterrestrial materials, thereby requiring a microanalytical technique.

Moreover, "bulk analysis" means different things for varying scales of geologic processes and analytical instruments; a "bulk" analysis for one application may not be useful for another (e.g., Potts et al., 1995; Martin, 2003). EPMA routinely measures sample sizes of 1 × 1 µm; handheld Raman or laser-induced breakdown spectroscopy (LIBS) beam sizes can be nanometers up to centimeters; an atom probe may have sub-nanometer spatial resolution (Fig. 1). When beam size shrinks to the

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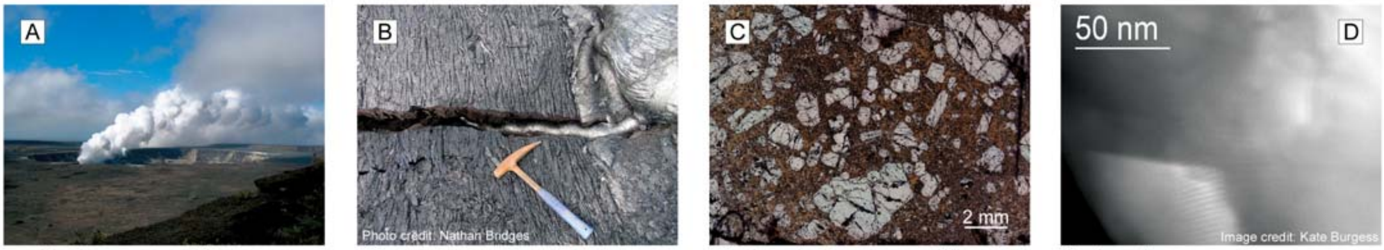

Figure 1. Comparison of geoanalytical scale. (A) Halemaumau crater, Kilauea, Hawaii. Photo by Molly McCanta. (B) Lava flow features, Kilauea. Photo by Nathan Bridges. (C) Photomicrograph of basaltic magma from Kilauea Iki lava lake. Photo by Molly McCanta. (D) Scanning transmission electron microscopy–electron energy loss spectroscopy (STEM-EELS) large grayscale high-angle dark field image of basaltic glass. Brighter areas show where iron is concentrated; bottom left corner shows the sample edge. LIBS—laser-induced breakdown spectroscopy; XAS—X-ray absorption spectroscopy.

scale of single atoms, as is the case with scanning transmission electron microscopy–electron energy loss spectroscopy (STEM-EELS; e.g., Garvie and Buseck, 1998; van Aken and Liebscher, 2002) and the atom probe (e.g., Kelly and Larson, 2012; Valley et al., 2015), additional considerations arise. Do the compositions of single atoms or even tens of atoms record anything about properties of the whole sample? Any misunderstanding of how to reconcile sample size and measurement technique size runs the risk of leading to difficulties in interpretation.

This paper thus explores sampling strategies that result in the most accurate returned bulk rock properties from varying scales of measurements, rock types, textures, and analytical instruments. Rock characteristics (mineral and melt constituents, grain size) and analytical conditions (beam size, analysis location, number of analyses) are varied to study errors propagated onto bulk rock compositions. The results define the number of analyses required to get reproducible bulk rock compositions in lab and field applications. These are broadly relevant to any type of microanalysis, and also to sampling at field scales, where the ratio of hand sampling size to outcrop/formation scale heterogeneities is relevant.

METHODOLOGY

Grain size, beam size, phase assemblage, and phase composition are varied using a computer model to determine potential effects on the accuracy of bulk rock measurements. The modeling program returns mineral and oxide percentages along with standard deviations of the bulk composition represented by the average of the chosen analyses, which are randomly located. The model is built around a 2-D 1000 × 1000 pixel image. Applications to Mars exploration along with user input parameters are given in McCanta et al. (2013), and the model itself is available at www.mtholyoke.edu/~pdobosh/libssim/lasersimR5.html.

RESULTS

Accuracies of bulk compositions for multiple rock types, melt compositions, and beam conditions were calculated as a function of grain size, beam size, and sampling density. Grain size here refers to either mineral size in a crystalline rock or ionic radius of an atom within either a crystallographic matrix (mineral) or a randomly distributed amorphous matrix (melt).

Crystalline Rocks

To evaluate size ratio effects in crystalline rocks, basalt and dacite compositions from Mt. Shasta, California, USA, were used as program inputs. These natural island arc samples are fully crystallized, making it difficult to obtain a bulk composition as discussed above. Experimental work (Baker et al., 1994; McCanta et al., 2007) reproduced the melt-crystal assemblages, allowing bulk rock composition to be estimated and compared with model results. Variable grain sizes (Figs. 2A–2C), beam sizes, and sampling densities were studied (see GSA Data Repository[1] Table S1). For each sampling density (10, 50, or 100 locations), three data sets are shown: grain size << beam size (ratio = 0.25), grain size = beam size (ratio = 1.0), and grain size >> beam size (ratio = 2.5). Precision values, represented by relative standard deviation (RSD), are given in Table 1.

Single Phase Systems

If only a single phase is present, then a reliable bulk composition requires few analyses, given the reasonable expectation that analytical precision is as good or better than accuracy. In our model results, six spot analyses are generally enough to generate a statistically significant bulk composition and account for minor heterogeneities; this number varies slightly with the relative precision and accuracy of each analytical method. These results apply to chemical measurements in glasses or homogeneous single crystals with sizes larger than the beam.

Grain Size

The presence of multiple phases introduces complications to sampling protocols and forces consideration of the grain-size to beam-size ratio. When grain size is small relative to the beam (ratio = 0.25; Fig. 2A), a single analysis likely samples a nearly representative portion of the assemblage, and may include all phases in the rock in their true proportions. Therefore, archetypal bulk compositions are returned when the sample grain size << beam size (Supplementary Table [see footnote 1]). As grain and beam size converge (grain size = beam size), calculated bulk compositions decrease in precision (Table 1). When grain size >> beam size (ratio = 2.5), it becomes unlikely that any microanalysis

[1]GSA Data Repository Item 2017081, Table S1 (measured vs. calculated bulk compositions), is online at http://www.geosociety.org/datarepository/2017/. Questions? Please email gsatoday@geosociety.org.

Table 1. Precision of bulk composition data

	Sampling density = 10			Sampling density = 50			Sampling density = 100		
Basalt	0.25	1.0	2.5	0.25	1.0	2.5	0.25	1.0	2.5
SiO_2	0.01*	0.02	0.03	0.00	0.01	0.02	0.00	0.01	0.02
Al_2O_3	0.05	0.05	0.20	0.02	0.07	0.11	0.01	0.05	0.05
TiO_2	0.06	0.11	0.19	0.01	0.07	0.15	0.03	0.07	0.15
FeO	0.06	0.09	0.19	0.01	0.06	0.10	0.01	0.04	0.07
MgO	0.10	0.22	0.42	0.03	0.13	0.26	0.03	0.12	0.13
MnO	0.07	0.07	0.20	0.00	0.07	0.06	0.00	0.07	0.07
CaO	0.04	0.12	0.12	0.01	0.05	0.09	0.01	0.03	0.06
Na_2O	0.04	0.07	0.16	0.01	0.06	0.12	0.01	0.05	0.05
K_2O	0.04	0.11	0.20	0.02	0.08	0.15	0.02	0.06	0.14
Dacite	Sampling density = 10			Sampling density = 50			Sampling density = 100		
	0.25	1.0	2.5	0.25	1.0	2.5	0.25	1.0	2.5
SiO_2	0.01	0.03	0.05	0.01	0.02	0.03	0.00	0.01	0.02
Al_2O_3	0.02	0.07	0.08	0.01	0.05	0.04	0.01	0.03	0.05
TiO_2	0.06	0.24	0.25	0.03	0.12	0.23	0.03	0.06	0.15
FeO	0.06	0.18	0.18	0.02	0.08	0.16	0.02	0.05	0.12
MgO	0.13	0.38	0.47	0.06	0.15	0.39	0.05	0.13	0.25
MnO	0.00	1.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
CaO	0.07	0.15	0.22	0.03	0.08	0.11	0.02	0.07	0.12
Na_2O	0.03	0.05	0.09	0.01	0.03	0.05	0.01	0.02	0.04
K_2O	0.05	0.11	0.20	0.02	0.06	0.08	0.01	0.05	0.09

*Relative standard deviation (standard deviation/measured value).

will sample all phases in a rock in correct proportions. In such cases, returned wt% oxide values do not accurately represent the bulk rock (Supplementary Table; Figs. 2D–2F), and the RSDs associated with such analyses are so large as to render them meaningless (Table 1).

Phase Assemblage

Although grain size is a significant determining factor in producing accurate bulk compositions, the chemistry of constituent minerals and glasses in the phase assemblage may also play roles. If a single phase contains the majority of an element in a system, it will have a disproportionate effect on bulk composition if the size of that mineral is close to the beam size. In the Shasta basalt experiments, olivine is the major MgO host and therefore controls the bulk MgO content. As grain size increases relative to beam size, errors associated with predicted MgO content get larger at a much faster rate than those of the other oxides (Fig. 3) due to disproportionate undersampling of the coarse-grained olivine. Other oxides in this basalt (CaO, Al_2O_3, SiO_2) do not show similar behavior (Fig. 3). They occur in comparable amounts among all mineral phases (plagioclase, augite, glass), so representative sampling of them is not as critical to returning the true bulk rock composition.

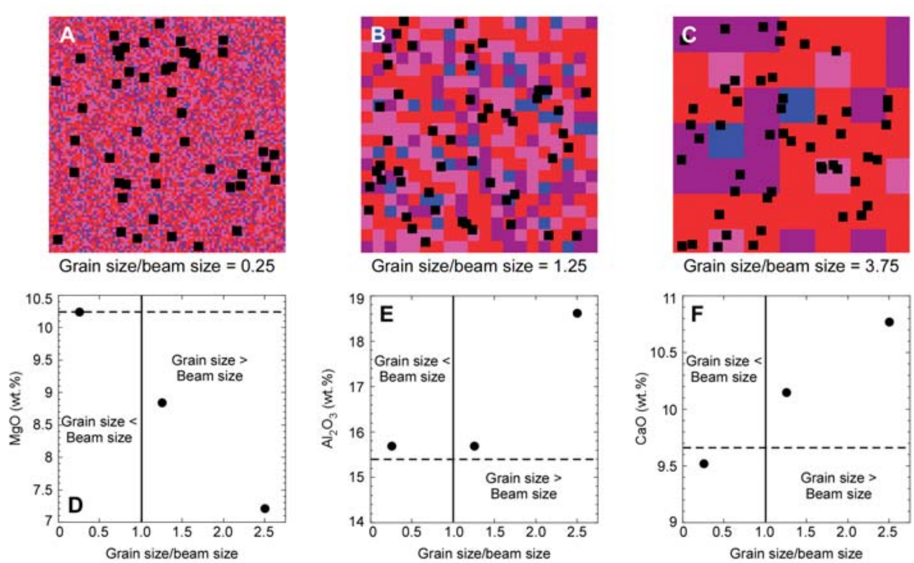

Figure 2. (A–C): Modeled basaltic "rocks" of varying grain size: red—glass, blue—olivine, purple—plagioclase, and pink—augite. Black squares are the sampling areas (50). Grain size relative to beam size increases to the right; beam size remains constant at 40 pixels. (A) Grain size = 10 pixels. (B) Grain size = 50 pixels. (C) Grain size = 150 pixels. (D–F): Comparison of true versus calculated bulk composition as grain size increases relative to beam size, with grain size < beam size (0.25), grain size ≈ beam size (1.25), and grain size > beam size (2.5). The solid line denotes where grain size and beam size are of equal size. Dashed lines represent the true electron probe microanalysis–determined bulk composition. Circles are the calculated values. (D) MgO. (E) Al_2O_3. (F) CaO.

Number and Placement of Analysis Spots

From a statistical viewpoint, minerals in rocks can be viewed as randomly distributed unless there is textural evidence to the contrary (Figs. 2A–2C). As the number of analyses increases, calculated bulk composition gets closer to the true bulk value (Figs. 4A–4C; Supplementary Table). Analytical precision increases with sampling density as well, especially for minor elements or those concentrated in a single phase (i.e., MgO as noted above) (Table 1). In our modeled rocks, ~6–10 analyses are necessary for calculated bulk composition to fall within a 1σ error envelope of the real composition for most fine-grained samples (grain size < beam size) (Figs. 4A–4C). This is definitely *not* the case for coarse-grained samples (beam size > grain size; Fig. 4D), where sampling of even 100 locations does not reproduce calculated bulk compositions within the 1σ error envelope (Table 1).

Melt Properties

Geologists are increasingly investigating chemical phenomena that occur at smaller scales than the routine 1 μm EPMA measurement, such as measurement of iron redox state by X-ray absorption spectroscopy (XAS: spot size = 1000–5000 nm) and STEM-EELS (spot size = 0.1–0.2 nm). To illustrate the resulting issues of scale, we calculated Fe^{3+}/Fe^{2+} ratios for a basaltic melt (BAS-2; Dyar et al., 2016) homogenized under oxidizing conditions. To simulate STEM-EELS measurements, a beam/sample order size ratio of 0.1 was used (beam size = 10 pixels; order size = 100 pixels;

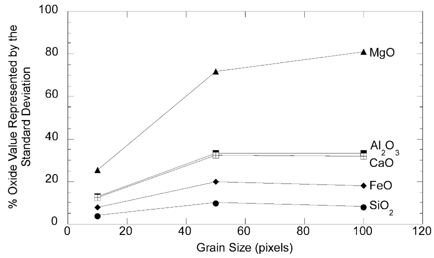

Figure 3. Comparison of influence of phase assemblage on the precision of the bulk analysis. Precision = percentage of the oxide value represented by the relative standard deviation (RSD*100). Elements that occur dominantly in one phase are more affected as grain size increases relative to beam size because they are more likely to be undersampled.

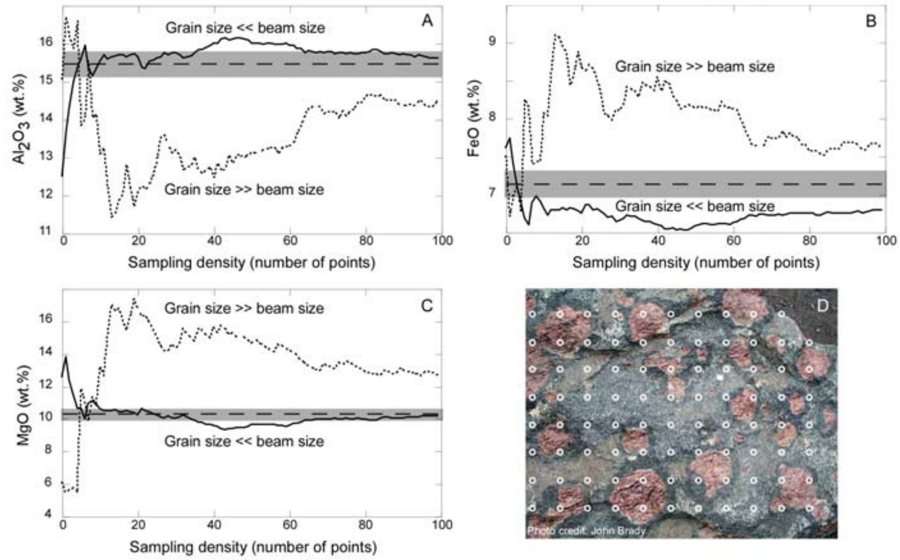

Figure 4. Comparison of sampling number with modeled bulk compositions. Solid line represents grain size << beam size; dotted line represents grain size >> beam size; dashed line is the true electron probe microanalysis oxide value. Modeled and true bulk values are approached within ~10 analyses for fine-grained samples (solid line) with larger beam spot sizes. Significantly more analyses are needed when the sample is coarse-grained (dotted line). (A) Al_2O_3. (B) FeO. (C) MgO. (D) Gore Mountain garnet outcrop. Circles represent the 1.5 cm diameter of possible Raman or laser-induced breakdown spectroscopy analytical dimensions. Note the difficulty in sampling a representative bulk composition even at these relatively large analytical sizes in a coarse-grained material. For comparison, with a 2 µm diameter beam size, 7,500 electron probe microanalysis or X-ray absorption spectroscopy spots would fit the diameter of each individual circle; for a 0.2 nm diameter beam size, 75,000,000 electron energy loss spectroscopy spots would fit the diameter of each individual circle.

Fig. 5A). Here "order" reflects the extent of short- or long-range ordering in the glass/melt, which is unknown. For XAS measurements a beam/order size ratio of 950 was used (beam size = 950 pixels; ordering size = 1 pixel; Fig. 5B) because our model has maximum beam size of 1000 that results in full sample coverage.

Beam Dimensions

Even when grain size is small, as in either crystallographic dimensions of a mineral or short range order in melts, variations in analytical spot size also result in sampling challenges. For example, the redox state of a melt (glass) can be calculated from its $Fe^{3+}/\Sigma Fe$ ratio (e.g., Kilinc et al., 1983; Kress and Carmichael, 1991). Measured Fe^{3+} concentration must be representative of the bulk system to be interpretable. Our model simulates truly random melts (Figs. 5A and 5B), but natural silicate glasses may exhibit short range ordering on ~1–2 nm scales (e.g., Mysen and Richet, 2005). If beam size is much smaller than the short range ordering in the melt (e.g., STEM-EELS), a single analysis may sample only one atom (Fig. 5A), generating no representative information on the redox state of the bulk system (Table 2). Multiple analyses with this 0.1 beam/order ratio may never actually sample all of the elements present (Fig. 5A). Even with an impractically large number of analyses per single sample ($n = 50$), true bulk glass redox ratio is elusive (Table 2). Oxidation state of the sample cannot be quantified accurately without excessively large numbers of analyses.

When analytical beam size is several orders of magnitude greater than the short range order in the melt (e.g., XAS), a single analysis will sample a large, nearly representative number of atoms (Fig. 5B), and the calculated redox value approaches that of the true value (Table 2). Multiple analyses are still required to adequately cover the sample area and reduce standard deviations, but they do not significantly improve the match to the actual data (Table 2). The apparent decrease in the precision of the Fe_2O_3/FeO ratio with more analyses observed in Table 2 is an artifact of the model dimensions; when a single analysis covers nearly the whole sampling area, multiple analyses lead to increased analytical overlap, resulting in oversampling of the minor elements. This would not occur in a natural sample of near "infinite" dimension.

DISCUSSION

Using spot analyses to return representative data on a bulk sample thus requires consideration of several issues: the mineralogy or scale of ordering in a glass,

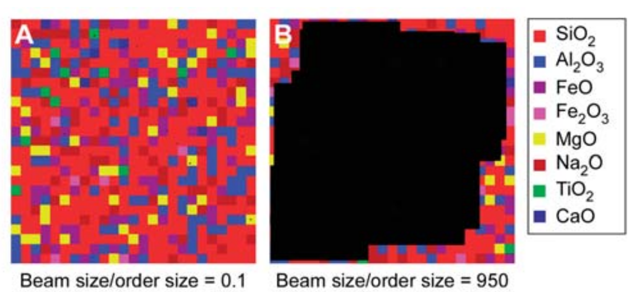

Figure 5. Modeled basaltic "melts." Black squares are the sampling areas (20). (A) Electron energy loss spectroscopy measurements: beam/order size ratio = 0.1 (beam size = 10 pixels; order size = 100 pixels). (B) X-ray absorption spectroscopy measurements: beam/order size ratio = 950 (beam size = 950 pixels; order size = 1 pixel).

Table 2. Accuracy of melt redox compositions.

	BAS-2		$n = 1$	$n = 10$	$n = 50$	$n = 1$	$n = 10$	$n = 50$
Beam/order size ratio*	n/a		0.1	0.1	0.1	950	950	950
SiO_2	49.73	(0.35)	100.00	20.00	45.00	50.88	49.95	49.96
Al_2O_3	15.51	(0.19)	0.00	28.00	13.00	14.56	16.00	16.00
TiO_2	1.55	(0.03)	0.00	0.00	0.00	1.92	2.03	2.03
FeO	8.51	(0.43)	0.00	10.00	15.60	8.00	9.00	8.97
Fe_2O_3	1.29	(0.03)	0.00	0.00	0.00	1.44	2.02	2.00
MgO	7.10	(0.08)	0.00	32.00	15.00	9.60	8.00	8.02
CaO	11.48	(0.07)	0.00	10.00	6.00	10.40	10.01	10.00
Na_2O	2.66	(0.07)	0.00	0.00	5.40	3.20	2.99	3.02
Total	97.83		100.00	100.00	100.00	100.00	100.00	100.00
Fe_2O_3/FeO	0.152			0.000	0.000	0.180	0.224	0.223

*Here order means the scale of the composition variation, which for a glass would be the scale of long- or short-range ordering.

texture (phase heterogeneity) of the target rock, distribution of textural features within each target, sampling size of the analytical instrument used, and sampling strategy employed (Fig. 6).

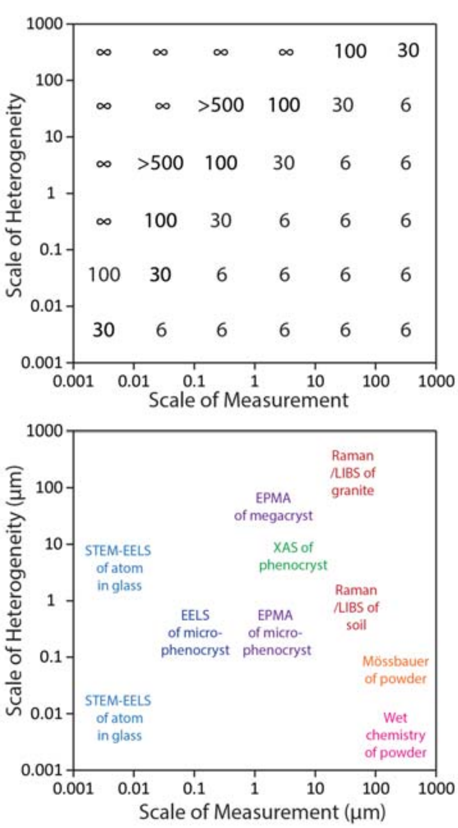

Figure 6. Comparison of the number of analyses required for reproducible bulk compositional data as a function of the scale of sample to measurement heterogeneity (upper). The same plot is used to indicate where various analytical techniques and common geological samples might intersect (lower). STEM-EELS—scanning transmission electron microscopy–electron energy loss spectroscopy; XAS—X-ray absorption spectroscopy; LIBS—laser-induced breakdown spectroscopy; EPMA—electron probe microanalysis.

Target Rock Type

It is intuitive to understand how a beam that samples the maximum number of grains in proportions representative of the entire rock will yield optimal results. In coarser-grained rocks with varying abundances of minerals in their modes, sampling strategy becomes critical; it is *very important* that the phase assemblage be sampled proportionately. This may require plotting out sampling grids prior to analysis or point-counting phases on an outcrop to determine the major phenocryst concentration. In truly coarse-grained rocks (i.e., Fig. 4D), obtaining bulk compositions from smaller scale analyses is simply not feasible. However, in such samples individual mineral compositions may be representatively sampled, although fine-scale zonation might be obscured.

Sampling strategy is also critically important when the analytical instrument has a sampling size much smaller than the crystallinity or long-range ordering of the phase. As modern instrument resolution continues to increase, understanding of sampling strategy will become even more critically important.

It is less obvious that relative chemistries of the individual phases being studied are important; if even one phase has dramatically different elemental abundances over the other(s), then a larger number of analyses will be needed to represent the bulk. On the other hand, an ultramafic rock composed solely of olivine and pyroxenes might have much less elemental variability among phases, and thus require fewer analyses to be representative.

Distribution of Analysis Spots

Our model assigns sample locations randomly to prevent systematic sampling bias. In the field or in most microanalyses, analytical spots are chosen by the operator. Therefore, the distribution of sampling points must be strategically selected to minimize both the number needed and the sampling bias (Fig. 6). This can be accomplished in one of two ways: analyze a large number of truly randomly selected points, or estimate the mineral mode and apportion analysis locations to represent each one appropriately (i.e., Chayes, 1956). The former is generally far easier than the latter, with the modal analysis method presenting the additional potential issue of assuming a 2D surface mode characterization represents a 3D rock sample. New software for quantitative EPMA mapping, which can provide full compositional quantification of each image pixel (e.g., Carpenter et al., 2013; Carpenter, 2016), may reduce sampling bias and better account for geochemical heterogeneity.

For rocks with distinct foliation, lineation, grain preferred orientation, or layering, sampling strategy becomes even more important; in these samples, an accurate bulk rock composition may not be meaningful. For example, if a rock is layered, sampling traverses should crosscut bedding planes with a sampling interval smaller than the layering interval to ensure proportional representation of each layer. Alternatively, traverses that probe a single layer laterally may be extremely useful, especially if multiple layers are similarly studied for contrast.

Number of Analyses Needed

Several sampling strategies can ensure quality analyses with reproducible results (Fig. 6). First, the larger the ratio between grain and beam size, the more analyses are required. For grain sizes << beam size, 6–10 analyses produce a statistically meaningful result as long as the phases present are sampled proportionally (Figs. 4A–4C) and measurement accuracy is appropriate. When the scale of grain size or the extent of ordering is close to or exceeds beam size (Fig. 4D), significantly more analyses are needed (up to 1000) to generate reproducible bulk compositional data. When more than one phase is present, analysis locations must be designed to represent all phases in the rock proportionately if a true bulk rock analysis is desired.

CONCLUSIONS

Our models show quantitatively what is intuitively obvious: heterogeneous rocks with coarse grain sizes present great challenges when obtaining bulk analyses. Care must be taken both when choosing randomly distributed analytical points and when interpreting data from instruments with different sampling volumes (Fig. 6). Moreover, rocks with visible texture (layering, phenocrysts, etc.) must be carefully sampled (if bulk compositions are needed) to ensure that analysis locations are proportionally representative of all textures present (Fig. 6). Additionally, the ratio of sample size to analytical size needs to be considered, especially as modern instruments resolve increasingly small analytical volumes. The concept of a "bulk analysis" likely needs to be revised for each system, following the methods provided in this study (Fig. 6).

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Education, Careers, and Mentoring

SHORT COURSES

Don't forget to sign up for a Short Course. Course prices go up US$30 after 18 Sept., **community.geosociety.org/gsa2017/science-careers/courses.**

JUMPSTART YOUR CAREER AT GSA's ANNUAL MEETING

If you are interested in a career in government or industry, you won't want to miss the GeoCareers Day on Sun., 22 Oct. You can interact with professionals from government and industry sectors and ask them career-related questions. This program includes a career workshop, booths highlighting careers and career opportunities, a lunch panel of professional representatives, and 30 mentors with varying careers to speak with in a small group setting. **community.geosociety.org/gsa2017/careers.**

MAKE AN IMPACT—BE A MENTOR

GSA is recruiting mentors to provide real-world information and insight to students and early career professionals at GSA's Annual Meeting. Mentoring can range from one-on-one mentor pairs for the duration of the meeting to short-term mentoring opportunities. Learn more about becoming a mentor and sign up at **http://bit.ly/2r3mW7Z.**

BE A PART OF THE MOVEMENT—ON TO THE FUTURE (OTF)

Since 2013, GSA has supported 435 students from underrepresented groups to attend their first GSA Annual Meeting. Support from members is instrumental in shaping careers and changing lives. Join us as we look forward to another successful year by mentoring an OTF student at the meeting and/or donating to support a student at **https://www.gsafweb.org/fund/on-to-the-future-fund/.** Learn more about this program or how you can get involved at **http://bit.ly/2r1EwZ1.**

In the Loupe

- Did you know, GSA and the housing bureau ask for the names of all people in a room in case of emergency? For your safety, you will be accounted for if an emergency situation should arise. Now you are *In the Loupe*!
- Did you know, GSA provides a self-care room at the annual meeting for a wide variety of needs: mother's room, prayer room, meditation room. Simply go to the registration desk and a GSA representative can assist you. Now you are *In the Loupe*!

FEED YOUR BRAIN
THE GEOLOGICAL SOCIETY OF AMERICA®

LUNCHTIME ENLIGHTENMENT

David B. Williams

The Protean City: Reshaping the Seattle Landscape

▶ Monday, 23 Oct., 12:15–1:15 p.m.

Since settlers first arrived in Seattle, the city's citizens have altered the landscape with an unrivaled zeal. We have regraded hills, which required moving more than 11 million cubic yards of sediment; reengineered tide flats, which led to the making of more than 2,200 acres of new land; and re-plumbed the second largest lake in the state, which completely altered its drainage. The goal of these projects was to provide better locations for business and easier ways to move through the challenging topography.

Seattleites are still at it, though now we also understand that earthquakes and rising sea levels have the potential to change us as much as we have changed the land.

Based on his book, *Too High and Too Steep: Reshaping Seattle's Topography*, David B. Williams' talk will explore the myriad ways that Seattle has reimagined and reengineered its landscape.

Williams is a naturalist, author, and educator whose award-winning book explores the unprecedented engineering projects that shaped Seattle during the early part of the twentieth century. Previous books include *The Seattle Street-Smart Naturalist: Field Notes from the City* and *Stories in Stone: Travels through Urban Geology*, which was nominated for a Washington State Book Award in 2010. He has written for *EARTH*, *Smithsonian*, and *National Wildlife* and maintains the website GeologyWriter.com.

The Denny Regrade neighborhood in Seattle. Photo by Asahel Curtis, ca. 1910.

Neighborhood Spotlight: South Lake Union

A rapidly evolving waterside neighborhood and home to e-commerce giant Amazon, South Lake Union is known for the latest in both technology and culture. The lake itself lends a nautical flavor to the area, while a bevy of shops, bars, and restaurants make this a busy destination for locals and visitors alike*.

Portage Bay Cafe. Photo: Nelle Clark.

▶ Eat

Variety is the name of the game when it comes to dining in South Lake Union. **Portage Bay Cafe** offers sustainable food for brunch and lunch, such as Dungeness crab cake benedicts and vegan banana pancakes. Stop by **Re:public Restaurant & Bar** for traditional Northwest fare, as well as exotic dishes like wild boar Bolognese. For seafood lovers, **The 100-Pound Clam** does such waterfront-friendly fare as salmon BLTs, cornmeal-crusted rockfish, and steamed clams. And Southwest favorite **Cactus** welcomes all, with choices ranging from braised brisket tacos to made-from-scratch margaritas.

REI. Photo: REI.

▶ Shop

Find a vibrant mix of treasures, from vintage Swiss Army blankets to traditional wooden toys, at **Eurostyle Your Life.** Celebrities like Jennifer Garner have praised the elegant home fragrances crafted by **Anthousa,** which opened its flagship store in South Lake Union a few years ago.

Lake Union Park. Photo: Stuart Mullenberg.

▶ Play

The **Museum of History & Industry (MOHAI)** displays hundreds of historic artifacts from the Puget Sound to delve into the city's maritime history and entrepreneurial spirit. At the nearby **Historic Ships Wharf,** find four classic seagoing vessels, including *Arthur Foss*, a tugboat that served in World War II and starred in the 1933 film *Tugboat Annie*. For those looking to unwind after a long day spent exploring, the traditional German pub **Feierabend** supplies imported beer and a jovial atmosphere.

*Text copy credit Visit Seattle, www.visitseattle.org/neighborhoods/south-lake-union/.

2017 GSA Medal & Award Recipients

PENROSE MEDAL
George Plafker, U.S. Geological Survey, Menlo Park

ARTHUR L. DAY MEDAL
Neal R. Iverson, Iowa State University

YOUNG SCIENTIST AWARD (DONATH MEDAL)
Sterling J. Nesbitt, Virginia Tech

PRESIDENT'S MEDAL OF THE GEOLOGICAL SOCIETY OF AMERICA
Thure E. Cerling, University of Utah

GSA PUBLIC SERVICE AWARD
Alexander E. Gates, Rutgers University–Newark

RANDOLPH W. "BILL" AND CECILE T. BROMERY AWARD FOR MINORITIES
Aradhna Tripati, University of California, Los Angeles

DORIS M. CURTIS OUTSTANDING WOMAN IN SCIENCE AWARD
Sonia M. Tikoo, Rutgers University

GEOLOGIC MAPPING AWARD IN HONOR OF FLORENCE BASCOM
Ray E. Wells, U.S. Geological Survey, Portland

GSA DISTINGUISHED SERVICE AWARD
Jean M. Bahr, University of Wisconsin–Madison

HONORARY FELLOWS
Augusto Neri, Istituto Nazionale di Geofisica e Vulcanologia
Zvi Garfunkel, Hebrew University of Jerusalem

JOHN C. FRYE AWARD
The West Salt Creek Landslide: A Catastrophic Rockslide and Rock/Debris Avalanche in Mesa County, Colorado, 2015, by Jonathan L. White, Matthew L. Morgan, and Karen A. Berry: Colorado Geological Survey Bulletin 55, 57 p.

Isabel P. Montañez

Show your support for our 2017 Awardees by attending the GSA Presidential Address & Awards Ceremony on 22 Oct. at the 2017 GSA Annual Meeting & Exposition in Seattle, Washington, USA. You will also have the privilege of hearing **Isabel P. Montañez'** Presidential Address.

2017 GSA Division Primary Awards

RIP RAPP ARCHAEOLOGICAL GEOLOGY AWARD
Archaeological Geology Division
(award winner pending)

GILBERT H. CADY AWARD
Energy Geology Division
Cortland F. Eble, University of Kentucky, Kentucky Geological Survey

E.B. BURWELL, JR. AWARD
Environmental & Engineering Geology Division
Johnson, P.L., Shires, P.O., and Sneddon, T.P., 2016, Geologic and Geotechnical Factors Controlling Incipient Slope Instability at a Gravel Quarry, Livermore Basin, California: Environmental & Engineering Geoscience, v. 22, p. 141–155, doi:10.2113/gseegeosci.22.2.141.

OUTSTANDING CONTRIBUTIONS AWARD
Geoinformatics Division
Kerstin Lehnert, Lamont-Doherty Earth Observatory, Columbia University

GEORGE P. WOOLLARD AWARD
Geophysics Division
Susan Beck, University of Arizona

BIGGS AWARD FOR EXCELLENCE IN EARTH SCIENCE TEACHING
Geoscience Education Division
Laura Lukes, George Mason University

MARY C. RABBITT HISTORY OF GEOLOGY AWARD
History and Philosophy of Geology Division
A.M. Celâl Şengör, Istanbul Technical University

O.E. MEINZER AWARD
Hydrogeology Division
Donald O. Rosenberry, U.S. Geological Survey, Denver

ISRAEL C. RUSSELL AWARD
Limnogeology Division
(award winner pending)

DISTINGUISHED GEOLOGIC CAREER AWARD
Minerology, Geochemistry, Petrology, and Volcanology Division
Jon P. Davidson, Durham University (deceased)

G.K. GILBERT AWARD
Planetary Geology Division
(award winner pending)

KIRK BRYAN AWARD FOR RESEARCH EXCELLENCE
Quaternary Geology and Geomorphology Division
Leslie D. McFadden, University of New Mexico

LAURENCE L. SLOSS AWARD
Sedimentary Geology Division
Isabel P. Montañez, University of California at Davis

CAREER CONTRIBUTION AWARD
Structural Geology and Tectonics Division
(award winner pending)

2017 GSA Fellows

Nominate a deserving colleague with the honor of GSA Fellowship. GSA Fellows are among the best and the brightest geoscientists who have made significant contributions to our science. Visit **www.geosociety.org/fellowship** to make a nomination for 2018.

Fellowship nominations are submitted in the following categories:

- Publication of the results of geologic research;
- Applied research;
- Training of geologists;
- Administration of geological programs;
- Public awareness of geology;
- Professional organizations;
- Editorial, bibliographic, and library responsibilities; and
- Other.

Society Fellowship is an honor bestowed on the best of our profession by election at the spring GSA Council meeting. GSA members are nominated by existing GSA Fellows in recognition of their distinguished contributions to the geosciences. Learn more at www.geosociety.org/fellowship.

GSA's newly elected Fellows will be recognized at the 2017 GSA Annual Meeting Presidential Address & Awards Ceremony on 22 October in Seattle, Washington, USA. We invite you to read some of what their nominators had to say:

Mark H. Anders (George Mason University): Mark Anders has published important papers on diverse topics in structural geology and tectonics, from the evolution of normal fault systems and the paradox of low-angle normal faulting to landslides and the Yellowstone hotspot. —Nicholas Christie-Blick

Robert Charles Anderson (NASA Jet Propulsion Laboratory): For outstanding service to planetary science and its community, for outstanding research in Mars tectonics, and for excellence in communicating planetary science to the public. —David Allen Williams

Donald F. Argus (Jet Propulsion Laboratory): In recognition of many high-impact and pioneering investigations, including applications of marine geophysics and tectonic space geodesy, that have greatly advanced our understanding of global plate motions and our understanding of the active kinematics and tectonics of the western United States. —Richard G. Gordon

John C. Ayers (Vanderbilt University): As an experimentalist and analytical geochemist, John Ayers has made critical contributions to the understanding of high temperature among fluids, minerals, and melts, especially with respect to accessory minerals that underpin modern studies of crustal and upper mantle evolution. His work has served to illuminate subduction zone processes and ultra-high pressure metamorphism. —Calvin F. Miller

Rachel J. Beane (Bowdoin College): Rachel is one of the most effective and progressive national leaders in geoscience education, notably as co-principal investigator of *On the Cutting Edge* and convener of many of its workshops and webinars. She and her undergraduate students have also made significant contributions to the study of silicic magma systems. —Reinhard A. Wobus

Callan Bentley (Northern Virginia Community College): Through his GigaPan development, online teaching, and public outreach talks and field trips, Callan has made outstanding contributions to geology nationally and internationally. He has demonstrated all of the qualities and quantities of work that we expect of a GSA Fellow. —Declan G. De Paor

Andrew T. Calvert (U.S. Geological Survey): For determining the eruptive histories of Quaternary volcanoes through precise argon geochronology integrated with geologic mapping. —Charles R. Bacon

Barbara Carrapa (University of Arizona): Dr. Barbara Carrapa is nominated for her impressive publication record and her major contributions on understanding rock uplift and her integrative regional tectonics approach to understanding mountain belts. —Susan L. Beck

Cinzia Cervato (Iowa State University): Cinzia Cervato is a tireless educator and education researcher whose passion for geoscience has inspired students and teachers for decades. —Suzanne O'Connell

Matthew Clapham (University of California Santa Cruz): For his seminal contributions on the evolution of invertebrates during the Paleozoic. —James C. Zachos

Drew Steven Coleman (University of North Carolina): For outstanding contributions to the field of geochronology, and for outstanding training of students in the lab and in the field. —Allen F. Glazner

"She is a tireless educator and education researcher whose passion for geoscience has inspired students and teachers for decades."

John A. Diemer (University of North Carolina at Charlotte): A sedimentary geologist who has studied and published on alluvial channel deposits, John A. Diemer has also contributed to knowledge of the history of the earth sciences, having written major works on Roderick Murchison, served as editor of *Earth Sciences History*, and chaired the History and Philosophy Division of GSA. —Sandra Herbert

Mark A. Evans (Central Connecticut State University): Mark Evans is a leading authority on the nature and evolution of paleofluids in foreland fold-thrust belts and the interrelationships between fluid flow, diagenesis, paleomagnetism, and both brittle and ductile deformation. He has also excelled in the training of young geologists through classroom experiences and involvement in geological research. —Charles M. Onasch

Russell C. Evarts (U.S. Geological Survey): Russ Evarts has published 27 geologic maps, most of them 7.5′ quadrangle maps in Washington and Oregon, as well as numerous interpretive offshoot journal articles and reports. His rigorous geologic mapping has been foundational for our evolving understanding of the tectonics and volcanism of the Pacific Northwest. —Thomas C. Pierson

Ralph Owen Ewers (Eastern Kentucky University): Ralph Ewers is nominated for his lifelong leadership in applied research in groundwater flow in karst terrains, innovative techniques, teaching geologists, and serving academia and society in a remarkable way. —Gareth James Davies

Jack D. Farmer (Arizona State University): Jack Farmer is nominated in recognition of his rich and seminal research in biogeosciences and astrobiology, his many contributions to planetary exploration, and his work in enhancing public awareness of geology. —Steven Christian Semken

Joan L. Florsheim (University of California Santa Barbara): Dr. Florsheim has more than 25 years of experience as an expert in natural and anthropogenic effects on watershed. She is a strong advocate for student research, brings science to the public through many venues, and serves on several editorial boards. —Nancy Riggs

Martha Scott Gilmore (Wesleyan University): Marty has published widely and influentially in planetary geology. She is an outstanding mentor, training undergraduate and graduate students, publishing with them, and launching them toward successful careers. And she is a leader and valued colleague, attested to by numerous advisory board appointments with the National Research Council and NASA. —Ronádh Cox

"She is an outstanding educator and researcher with boundless enthusiasm for all things geological."

Bosiljka Glumac (Smith College): Professor Bosiljka Glumac is an outstanding educator and researcher with boundless enthusiasm for all things geological, particularly carbonates. She is a leader in the sedimentology community and is dedicated to broad advancement of the geosciences. —H. Allen Curran

Steven L. Goodbred (Vanderbilt University): For outstanding research and leadership to understand complex sedimentary geology of delta systems and their special place in human-natural system interactions. —George M. Hornberger

Michael N. Gooseff (University of Colorado): Michael N. Gooseff is cited for pioneering critical new areas of hydrogeology in the field of groundwater–surface water interactions and watershed–river water connectivity at all latitudes, and particularly in Polar regions, making important new advancements possible in the fields of geochemical weathering and aquatic ecology. —Judson William Harvey

Timothy J. Grundl (University of Wisconsin–Milwaukee): Dr. Grundl, a chemical hydrogeologist, is a recognized authority on the chemical dynamics of natural water systems, with emphasis on contaminant degradation, and has a distinguished record as a teacher of undergraduate and graduate students in hydrogeology. —Norman P. Lasca Jr.

Stephen E. Haggerty (Florida International University): Stephen Haggerty has made seminal research contributions to a range of geoscience disciplines including basaltic volcanism, oxide mineralogy, mantle petrology, meteorite petrogenesis, lunar mineralogy and petrology, and most recently, kimberlite, and diamond petrogenesis. Together they represent a remarkable body of work from one of the most innovative and productive scientists. —Michael L. Williams

Ralph Haugerud (U.S. Geological Survey): Ralph Haugerud's publications have expanded our knowledge of Mesozoic-Paleogene tectonics, active tectonics, and Quaternary ice-sheet glaciation in the Pacific Northwest. He is a leader in the use of LiDAR topography for geologic research and has helped the geologic community standardize the encoding of geologic maps in a GIS. —Darrel Cowan

Shaul Hurwitz (U.S. Geological Survey): Shaul is recognized for his novel research on heat and fluid transport in hydrothermal systems and for his role in linking hydrothermal fluid flow to deformation and other forms of unrest at volcanic arcs and large calderas where public safety is at risk. —William C. Evans

Manuel A. Iturralde-Vinent (Sociedad Cubana de Geología): Manuel A. Iturralde-Vinent was the president of the Cuban Geological Society 2008–2016. Manuel is very active in geohazard research and prevention about Central America, Dominican Republic, Mexico, and Cuba. He has more than 250 publications and has participated in dozens of documentary films about Cuban nature. —Robert J. Stern

Simon Allen Kattenhorn (University of Alaska–Anchorage): Dr. Simon A. Kattenhorn demonstrates excellence in research in structural geology and planetary geology and is a gifted teacher and valued colleague. —Judith Parrish

Adam John Kent (Oregon State University): Adam is recognized for his geochemical contributions to the origin of igneous rocks and magmatism that include seawater influence on submarine volcanism and volatile, trace element, and timescales of arc magmatism. Adam is both an outstanding teacher and a mentor of graduate and undergraduate researchers. —John Hook Dilles

Marcus M. Key Jr. (Dickinson College): For his distinguished contributions to the training of undergraduate geologists in Dickinson College's Department of Earth Sciences. He engages students thoughtfully and energetically, and has them participate and co-publish in his research. —Noel Potter Jr.

Michelle Anne Kominz (Western Michigan University): Dr. Kominz is a leader in deciphering the relationships between seafloor spreading and long-term sea level and the record of sea-level change on the million year scale. —Kenneth G. Miller

Timothy Michael Kusky (China University of Geosciences Wuhan): Timothy Kusky is nominated for his outstanding career of cutting-edge research in tectonics, particularly in the origin and destruction of continental crust and the evolution of cratons. He has also carried out a range of applied research in the field of geohazards. —Paul Thornton Robinson

Conrad C. Labandeira (Smithsonian National Museum of Natural History): Labandeira has created a unique field of study on the paleobiology and evolution of the plant-insect system, representing most of Earth's macroscopic biodiversity. He works across the time scale and the continents to integrate his vast datasets into a prolific body of work that substantially advances knowledge. —Peter Wilf Conrad

Neil H. Landman (American Museum of Natural History): Dr. Landman is an active and highly productive researcher in paleontology. His geologic contributions include Cretaceous biostratigraphy, the paleobiology and morphology of cephalopods, Cretaceous methane mud mound geochemistry, and the K/T boundary invertebrate fauna. He is a dedicated researcher and a valued contributor at many national and international professional meetings. —Royal H. Mapes

Peter B. Larson (Washington State University): For major career-long contributions to the light stable isotope geochemistry of hydrothermal systems and ore genesis and academic leadership. —John A. Wolff

Kathy J. Licht (Indiana University–Purdue University Indianapolis): Kathy Licht undertakes critical fieldwork one of the most harsh climates on Earth—the interior of Antarctica. Her record in both research, publications, teaching, and service to the profession are of the highest standards. —John T. Andrews

"GSA and geoscience in general have benefitted greatly from his ongoing commitment."

Kelly Hong Liu (Missouri University of Science and Technology): Dr. Liu has been a leader in using seismic data to determine crust and mantle structure, especially using shear wave splitting and seismic anisotropy to determine the nature of tectonic environments. —Kevin Lee Mickus

Gwendolyn L. Macpherson (University of Kansas): Professor Gwendolyn Macpherson is nominated for Fellowship for her excellent publication record in the geosciences, for which she is well-recognized for her diverse contributions to hydrogeochemistry, and for her strong contribution to the training of geology students at the University of Kansas and her valuable service to professional organizations. —Donald O. Whittemore

J. Brian Mahoney (University of Wisconsin–Eau Claire): Brian Mahoney has mentored scores of undergraduates at the University of Wisconsin–Eau Claire and has been an active externally supported researcher in areas of Canadian, northern Rocky Mountain, and Argentine tectonics and sedimentation. —Paul K. Link

Florian Maldonado (U.S. Geological Survey): Florian Maldonado is nominated for his outstanding accomplishments and research in the geosciences. His contributions to geologic research are demonstrated by his publication record and citations, and especially for his leadership, mentorship, and research contributions in stratigraphy, volcanism, geologic field mapping, and structural geology. —Peter D. Warwick

David Roland Marchant (Boston University): Through 34 field campaigns to the Antarctic, David meticulously pieced together the landscape evolution of the Transantarctic Mountains and their response to past climate change. His research is instrumental in predicting future impacts of climatic change and using Antarctic analogues for interpreting glaciation of Mars. —Duncan Martin FitzGerald

Caroline A. Masiello (Rice University): Masiello has made outstanding contributions into understanding the role of organic carbon in soils across Earth's surface, which impacts a wide range of geoscience and other fields, such as agriculture and climate change. —Gerald Dickens

John E. McCray (Colorado School of Mines): Professor John E. McCray has a long and varied background in hydrogeology and his contributions span many areas of research that include groundwater remediation, groundwater quality impacts from natural phenomena, and training of graduate and undergraduate students to analyze climate-change issues from a risk-based perspective. —Robert John Sterrett

"He is an outstanding, widely recognized, innovative leader of research."

Patricia Allison McCrory (U.S. Geological Survey): In short, for her outstanding contributions to our understanding of the geology and geophysics of the Pacific Northwest, and the seismic hazards related to the Cascadia subduction zone, I nominate Dr. Patricia McCrory to be a fellow of the Geological Society of America. —Naomi Oreskes

Donald George Mikulic (Illinois State Geological Survey Prairie Research Institute): Donald Mikulic has been a leader and organizer of some 50 geologic field trips and co-author of about 20 field trip guidebooks or chapters in guidebooks. He has also been at the forefront of fostering public awareness of geology through his work with amateur groups, publications, and open houses. —Joseph Hannibal

Scott A. Minor (U.S. Geological Survey): Scott A. Minor, research geologist with the U.S. Geological Survey, is nominated for consideration as a GSA Fellow. Scott is a nationally recognized expert in fault mapping, fault kinematics, and structural and hydrogeologic properties of fault zones in some of the most tectonically active and dynamic terranes in the country. —Randall Schumann

Joseph N. Moore (University of Utah): Joe Moore is nominated for extensive contributions in applied research into geothermal system exploration and resource assessment. These span concept advancement, publication, mentorship, and public awareness. —Philip E. Wannamaker

Joseph D. Ortiz (Kent State University): Nominated for his research contributions in paleoclimate, paleoceanography, and water quality. He has pioneered the use of non-invasive, geophysical core and well-logging measurements to reconstruct paleoclimate and sediment properties and has applied novel approaches to quantifying algal and cyanophyte biomass in harmful algal blooms. —Daniel K Holm

David R.M. Pattison (University of Calgary): Dave is one of most highly respected metamorphic petrologists in the world and the leading expert on low pressure metamorphism. He has made seminal contributions to the study of contact aureoles, the Al_2SiO_5 polymorphs, the thermal structure of the deep crust, and kinetics in metamorphism. —Frank S. Spear

Timothy Scott Paulsen (University of Wisconsin–Oshkosh): Tim Paulsen has shown excellence in scholarship through his research concerning Gondwana assembly and breakup with emphasis on Antarctica and in teaching at the undergraduate level with emphasis on field geology. Therefore, it is my distinct pleasure to nominate him for Fellowship in the Geological Society of America. —William Niles Mode

Aaron J. Pietruszka (U.S. Geological Survey): Dr. Pietruszka is nominated for fellowship in the Geological Society of America for his pioneering of new geochemical methods and for his innovative studies of the chemistry and structure of magmatic systems in oceanic volcanoes. —Michael O. Garcia

J. Michael Rhodes (University of Massachusetts–Amherst): Professor J.M. Rhodes should be elected a GSA Fellow for (1) his geochemical studies which provided new constraints on the origin and evolution of Hawaiian volcanoes and (2) providing access to the state of the art X-ray fluorescence analytical facility at U. Mass. to geologists from throughout the world. —Frederick A. Frey

William Ian Ridley (U.S. Geological Survey): Pioneering work in lunar petrology and petrology of the oceanic lithosphere. Also, for his leadership roles in administrating USGS research teams. —Dennis Geist

Jeffrey G. Ryan (University of South Florida): Jeff has made significant contributions in geoscience education and through his research on the geochemistry of volcanic rocks at convergent margins. He is an energetic and innovative educator and tireless in his activities at the national level related to improving geoscience education. He has held leadership positions in the Council on Undergraduate Research and National Assoc. of Geoscience Teachers. —Jill K. Singer

Matthew R. Saltzman (The Ohio State University): Prof. Saltzman has made seminal contributions to the chemostratigraphy of the Paleozoic providing insights on carbon dynamics, biological diversity, tectonics, and climate change. —W. Berry Lyons

Kevin M. Schmidt (U.S. Geological Survey): In recognition of his three decades of influential research and publication on mass transport on mountain slopes as well as diverse applications of surficial processes and mapping to tectonic, ecosystem, and fire-disturbance processes. His publications on these subjects are widely regarded as authoritative and have guided public policy decisions. —David M. Miller

Janet L. Slate (U.S. Geological Survey): Janet is nominated for her combination of research contributions, editorial responsibilities, and administration of USGS policy regarding scientific quality of information products. —Ren A. Thompson

Aleksey V. Smirnov (Michigan Technological University): Aleksey is recognized for his advances in fundamental rock magnetism and related innovative applications of paleomagnetism to solve geologic problems, especially concerning the nature of the early geodynamo and core. —John A. Tarduno

Catherine Snelson (Los Alamos National Laboratory): I nominate Dr. Catherine (Cathy) Snelson to GSA Fellowship for distinguished technical and administrative contributions to the Source Physics Experiment, advancing geoscience critical to our national security. —Claudia I. Mora

Scott D. Stanford (New Jersey Geological and Water Survey): For major contributions to the profession through publication of surficial and bedrock geologic maps, high-quality research on Cenozoic landscape evolution and Quaternary geology, and providing information and guidance to geologists, engineers, educators, and the public on New Jersey's geology and groundwater resources. —Peter J. Sugarman

David W. Szymanski (Bentley University): Dave has set a high standard in advancing public awareness of geology, particularly in the public policy domain. GSA and geoscience in general have benefitted greatly from his ongoing commitment. —Jeff Rubin

Neil John Tabor (Southern Methodist University): For outstanding contributions to the study of paleosols, paleoclimatology, Paleozoic paleoenvironments, and isotope geochemistry, coupled with exceptional service to GSA. —Nathan Dale Sheldon

Robert S. Thompson (U.S. Geological Survey): Dr. Robert Thompson is a significant contributor to climate science and science leadership. His continental-scale modeling of climate and distributions of plant species is a major paleoecological underpinning for conservation studies in North America and an important contribution to paleoclimatologists and modelers worldwide for assessing the efficacy of climate models. —Eugene S. Schweig

Todd A. Thompson (Indiana Geological Survey): Todd is internationally recognized for his success and long-term commitment to understanding the coastal geology of the Laurentian Great Lakes. In particular, his reconstructions of Holocene-aged lake levels are baseline data for any studies forecasting water levels, understanding glacio-isostatic adjustment, and managing property in the coastal zone. —Timothy G. Fisher

Hari Selvi Viswanathan (Los Alamos National Laboratory): I nominate Dr. Hari Viswanathan as GSA Fellow for his stellar contributions to earth sciences over the past 20 years, his outstanding publication record on theoretical and applied research in geology and hydrology, his generous mentoring of students and peers, and his commitment to enhancing public awareness of the geosciences. —Carl Walter Gable

Alian Wang (Washington University in St. Louis): Dr. Alian Wang has made important and impressive contributions to planetary science, especially in the field of Mars-relevant hydrous salts that have great significance to Mars' hydrologic history. With three Raman spectrometers scheduled to fly to Mars in 2020, her work in planetary Raman spectroscopy will help to make great discoveries in Martian surface and subsurface mineralogy, geochemistry, and potential astrobiology. —I-Ming Chou

Cathy L. Whitlock (Montana State University): Innovative paleo-ecologist Cathy Whitlock analyzes pollen and charcoal to explore feedbacks and consequences of fire regimes and vegetation changes in response to climate variability and anthropogenic forcing. Her pioneering work in Yellowstone and the Andes has illuminated vulnerabilities, resilience, and response times of biota to internal dynamics and external forcing. —Douglas W. Burbank

Alan G. Whittington (University of Missouri): Alan has an outstanding record of geoscience research, student mentoring, and service to the geoscience community. —Robert Louis Bauer

Alicia M. Wilson (University of South Carolina): Alicia Wilson is an exemplary hydrogeologist, evidenced by her outstanding service in leadership in the GSA Hydrogeology Division, her publication of high-impact papers on groundwater flow in coastal and offshore environments, and her training of students at all levels in science. —Madeline E. Schreiber

Kenneth H. Wohletz (Los Alamos National Laboratory): For his world-class field studies and modelling of hydrovolcanic eruptions; his classified and critical investigations into means and methods for verification and monitoring of participants in the Threshold and Comprehensive Test Ban treaties; and his programming abilities combined with his pioneering use of supercomputer simulation in the earth sciences. —Robert S. Hildebrand

Wenjiao Xiao (Chinese Academy of Sciences): Wenjiao is the current major authority on the crustal/tectonic evolution of the Central Asian Orogenic Belt on which he has published ~260 papers. As co-author/editor of many books, student mentor, and convener of many international conferences, he is an outstanding, widely recognized, innovative leader of research in Central Asia. —Brian Frederick Windley

"He is one of the most innovative and productive scientists."

GSA Celebrates Milestone Member Anniversaries

GSA salutes the following members and Fellows on their **50-year** membership anniversaries. We appreciate their dedication and loyalty to GSA. To view a full list of members who have *surpassed* the 50-year mark, please visit http://rock.geosociety.org/membership/50yearmembers.asp. Asterisks (*) indicate GSA Fellows.

50 Year Members

M. James Aldrich*
Richard T. Bachman*
James L. Bischoff*
Kennard B. Bork*
Peter E. Coffin
John B. Comer
Anita M. Cotton
James C. Dawson
Thomas E. Eastler*
Rolfe C. Erickson
Edward B. Evenson*
Ronald V. Fodor*
Thomas D. Fouch*
Joseph James Gerencher Jr.
Richard I. Grauch*
James T. Gutmann
Weldon W. Hammond Jr.
Don Hermes*
Carlos Garcia Herrera
James R. Hinthorne*
Thomas L. Holzer*
Leonard Jacob Jr.
Philip S. Justus
Edwin Karp
Fred T. MacKenzie*
Edgar J. McCullough Jr.
John A. Minch
Robert D. Nason
Carl E. Norman
Waite R. Osterkamp*
David D. Pollard*
David K. Rea*
Suzanne Rose
Steven Schamel*
Robert B. Scott*
Gerald L. Shideler*
William W. Shilts*
Wm. (Skip) B. Simmons Jr.
Gerry L. Stirewalt
Raymond Sullivan*
Keene Swett
Paul A. Thayer*
Dee D. Trent
Walter E. Trzcienski Jr.*
L. Jan Turk*
Alan Keith Turner*
Richard B. Waitt*
Howard G. Wilshire*
Margaret S. Woyski*

Thank you for your membership!

Now Accepting Penrose Conference and Thompson Field Forum Proposals

Penrose Conferences
bring together multidisciplinary groups for open and frank discussion of geoscience research and ideas on location in some of the most fascinating places in the world.

Thompson Field Forums
capture the essence of exciting discoveries or controversial topics via forays into the field for on-the-spot discussions.

GSA and the GSA Foundation can provide start-up funds for these events.

https//:goo.gl/ODU1Vt

GSA Celebrates Milestone Member Anniversaries

GSA salutes the following members and Fellows on their **25-year** membership anniversaries. We appreciate their dedication and loyalty to GSA. Asterisks (*) indicate GSA Fellows.

GSA Celebrates 25-Year Member Anniversaries

Arvid K. Aase
Pawel Aleksandrowski
Kambra M. Allen
Susan J. Altman
Brian G. Anderson
William M. Andrews Jr.
Ryo Anma
Cathy Baker
Walter A. Barnhardt
Richard Lynn Bartel
Andrey Bekker
James L. Bela
Richard C. Berg*
Paul Bertetti
Lori Bettison-Varga
Keith H. Bettles
Justin B. Bolles
Howell Bosbyshell
Harry S. Brenton Jr.
Madeleine Briskin
Lewis M. Brown
Kathleen Burnham
David C. Campbell
Erin A. Campbell
Matthew R. Campbell
Anne E. Carey*
Mark W. Carter
Henrietta E. Cathey
Michael A. Chamberlain
Roseanne Chambers
Karen Chin
Juliet G. Crider
Rodney A. Crother
Russ D. Cunningham
Brian S. Currie
Shanaka L. de Silva*
Luiz J.H. Del-Rey Silva
John A. Dembosky Jr.
Michael P. Dempsey
William S. Dinklage
Daniel Dorritie
Stan P. Dunagan
John L. Dwyer
Peter Eichhubl
Thomas B. Ervin
Jack D. Farmer
Boris Faybishenko
John A. Feltman
Carlos Fernandez
John P. Fitzgerald
Mark T. Ford
David A. Forsyth Jr.
Henry Frankel*
Jeanne M. Fromm
Tanya Furman
Howard W. Gault
Harold L. Gibson
Thomas Glade
Bosiljka Glumac
Carlos M. Gonzalez-Leon
Doug Goodwin
Frank D. Granshaw
Lisa Grant Ludwig
Sallie E. Greenberg
David A. Grimley
Barbara J. Grubb
Edmund R. Gustason
David B. Hacker
Katharine J. Hakala
Joe L. Hanna
Robyn E. Hannigan*
Christopher J. Harpel
John A. Harper
Stephen B. Harper
Ralph P. Harvey*
J.K. Haschenburger
Thomas H. Hawisher
Anne E. Henry
Eric D. Hetherington
Daiji Hirata
John W. Hoganson
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JoAnn M. Holloway
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Bryce W. Hoppie
George M. Hornberger*
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Eugene D. Humphreys*
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Ronald Jackson
Stefan Jaeger
Craig M. Jarchow*
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Jenda A. Johnson
Terry A. Jones
Thomas W. Kammer*
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William F. Kean Jr.
C. Kent Keller*
Mohamed Khalequzzaman
Christopher Knowlton
Marilyn A. Kooser
Stephen C. Kuehn
Fujio Kumon
Albert L. Lamarre
Bonnie E. Lampley
Lewis A. Land
Arthur L. Lerner-Lam
Shoufa Lin
Staci L. Loewy
Donald K. Lumm
Ernest A. Mancini*
John C. Mars
Charles R. Marshall*
Ole J. Martinsen
Barbara M. Martiny
Shigenori Maruyama*
Dorothy McGarry
Holly Silva McLachlan
Peter P. McLaughlin Jr.*
Jerry F. McManus
Christopher A. McRoberts
Molly A. Michaelson
Susan K. Mickus
Brian E. Miller
Nathan R. Miller
Alfred E. Moffit III
M. Ann Molineux
Laura J. Moore
Claudia I. Mora*
Carolyn Moseley
MaryLynn Musgrove
Peter I. Nabelek*
Gary Newhart
Joseph W. Nicholas
Jeffrey M. Nolan
Jon W. North
Eric Peter Olds
Manuel R. Palacios-Fest
William C. Parcell
Timothy S. Paulsen
William H. Peck
William J. Pegram
Jeanne B. Percival
Michael A. Phillips
William M. Phillips
Michael R. Ponte
Anthony E. Rathburn
Linda M. Reinink-Smith
Frank A. Revetta
Jon L. Riedel
Stephen L. Robbins
Kenneth H. Rubin*
Hiroyoshi Sano
Scott T. Saroff
Kohei Sato
Tadashi Sato
Steven H. Schimmrich
David A. Schneider
Janet L. Slate
Chad A. Smith
Grant Douglass Smith
Constance M. Soja
Nancy C.T. Stangler
Sharon M. Swanson
G. Jeffrey Taylor
Regina N. Tempel
Masaru Terabayashi
Ruben D. Uribe
Charles A. Ver Straeten
Thomas E. West Jr.
Peter J. Whiting
John H. Whitmore
Mark T. Williams
Wilfried H. Winkler
David R. Wunsch*
Kenn-Ming Yang
Zun-Yi Yang*
Marc D. Zamkotowicz
Otto S. Zapecza
Barbara J. Ziegler

2017 GSA Research Grant Recipients

The 2017 GSA Committee on Research Grants awarded US$692,164 to 395 graduate students (50% of the 785 who applied), with an average grant of US$1,752. The committee also selected 10 alternate candidates in the event that any grantees return all or part of their funds due to a change in their research project or receipt of funds from another source. The GSA Graduate Student Research Grant Program is funded by GSA, the GSA Foundation, GSA Divisions, and the National Science Foundation.

Committee Members: Daniel M. Sturmer (Chair), Thomas C. Johnson (Past Chair), Robert S. Anderson, James V. Browning, William C. Burton, Timothy M. Demko, Kristin Dorfler, Joshua M. Feinberg, Rebecca M. Flowers, Martin B. Goldhaber, Laurel B. Goodwin, Timothy W. Grover, Judith L. Hannah, Christopher S. Holm-Denoma, Michael T. Hren, Alexandra R. Isern, Elizabeth A. Johnson, Sharon L. Kanfoush, Todd A. LaMaskin, Nicholas Lancaster, Rebecca A. Lange, Michelle M. Lorah, Kevin H. Mahan, Andrew H. Manning, Bryan A. Oakley, Stephen J. Piercey, William Ian Ridley, Jacob O. Sewall, Ellen Thomas, Jennifer A. Thomson, James Vogl, Richard B. Waitt.

Alternate Committee Members: Jonathan S. Caine, Alan R. Carroll, Ibrahim Çemen, Duane G. Froese, Steven E. Ingebritsen, Mark K. Reagan, Benjamin Schwartz, Robert D. Shuster, and Dylan Ward.

The following awards will be presented at the
GSA 2017 Annual Meeting & Exposition in Seattle, Washington, USA.

THE GEOLOGICAL SOCIETY OF AMERICA®

GSA FOUNDATION

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2017 Outstanding Mentions

(proposals having exceptional merit in conception and presentation)

Janet Barclay, University of Connecticut

Cassandra Brigham, University of Washington

Zheng Gong, Yale University

Pan Liu, Georgia Institute of Technology

Esra Mescioglu, University of California Santa Cruz

Alexandra Nagurney, Virginia Tech

Inoka Peiris, University of Texas at Dallas

Shelby Rader, University of Arizona

Kaitlin Salley, University of Kansas

Alison Tune, University of Texas at Austin

ExxonMobil

2017 ExxonMobil/GSA Student Geoscience Grants

ExxonMobil has recognized 10 of the top 30 GSA student research grant proposals with grants of US$5000 each.

Hannah Blatchford, University of Minnesota

Ibukun Bode-Omoleye, Oklahoma State University

Harrison Gray, University of Colorado

Katherine Guns, University of Arizona

Jonathan Ingram, New Mexico State University

Emily Perry, Colorado School of Mines

Justin Shawler, Virginia Institute of Marine Science

Andrew Walters, University of Wisconsin–Madison

Jeffrey Westrop, University of Nebraska–Lincoln

Emily White, University of Idaho

2017 Specialized Awards

Sponsored by the GSA Foundation

MARLAND PRATT BILLINGS AND KATHARINE FOWLER-BILLINGS RESEARCH AWARD

Graduate Award: **Shannon Neale,** University of Cincinnati
Undergraduate Award: **Katie Woltner,** Keene State College
The Marland Pratt Billings and Katharine Fowler-Billings Research Award encourages and promotes geological fieldwork and related research in New England and adjacent regions.

JOHN A. BLACK AWARD

Paul Russell, The Ohio State University
The John A. Black Award supports graduate student field-based research on coastal processes. All field-based coastal geomorphology research should be located in the USA, Puerto Rico, or Canada. In the event there are no worthy graduate student field-based research projects in coastal geomorphology, the award may be used to support graduate student field-based research in volcanology. All field-based volcanology research should be located in the USA, New Zealand, or Iceland.

GRETCHEN L. BLECHSCHMIDT AWARD

Sarah Kogler, Ohio University
The Gretchen Louise Blechschmidt Award Fund was established for women in the geological sciences who have an interest in achieving a Ph.D. in the fields of biostratigraphy and/or paleoceanography, sequence stratigraphy analysis, particularly in conjunction with research in deep-sea sedimentology, and a career in academic research.

ALLEN V. COX RESEARCH AWARD

Zongbo Xu, Boise State University
The Allen V. Cox Research Award supports research grants in geophysics.

JOHN T. DILLON ALASKA RESEARCH AWARD

Heather Bervid, Oregon State University
Molly Johnson, Western Washington University
The John T. Dillon Alaska Research Award honors the memory of Dr. Dillon who was particularly noted for his radiometric age-dating work in the Brooks Range, Alaska, USA. Two areas that serve as guidelines for selection of the award are field-based studies dealing with the structural and tectonic development of Alaska, and studies that include some aspect of geochronology (either paleontologic or radiometric) to provide new age control for significant rock units in Alaska.

DIVERSITY AWARD

Shondricka Burrell, Temple University
This award is presented to the top student(s), based on applicant race/ethnicity status and overall quality of the research.

ROBERT K. FAHNESTOCK AWARD

Hima Hassenruck-Gudipati, University of Texas at Austin
The Robert K. Fahnestock Award honors the memory of Dr. Fahnestock, a former member of the Research Grants Committee, who died indirectly as a result of service on the committee. The grant is awarded for the best proposal in sediment transport or related aspects of fluvial geomorphology, Dr. Fahnestock's field.

ROBERT D. HATCHER RESEARCH AWARD

Jessica Robinson, University of Connecticut
The Robert D. Hatcher Research Award supports field-based research and geologic mapping through an annual award to an outstanding graduate student in the earth sciences to conduct research for that student's master's thesis or Ph.D. dissertation. Preference may be given to students working in the Appalachian orogeny broadly construed, but is not restricted to this region.

JOHN W. HESS RESEARCH GRANT

James Shelley, Western Kentucky University
The John W. Hess Research Grant in Karst Research Studies supports student research involving any aspect of cave and karst studies aimed at providing improved understanding of how caves and karst work, including how these resources can be better managed.

ROSCOE G. JACKSON II AWARD

Scott Borchardt, University at Buffalo, SUNY
The Roscoe G. Jackson II Award funds one recipient per year in the field of sedimentology.

LIPMAN RESEARCH AWARD

Katie Ardill, University of Southern California
Jade Bowers, Oregon State University
Emily First, University of Hawai'i at Mānoa
Michael Mohr, Boise State University
Mackenzie Taylor, Miami University
The Lipman Research Fund was established in 1993 and is supported by gifts from the Howard and Jean Lipman Foundation. The purpose of the fund is to promote and support student research grants in volcanology and petrology. The president of the Lipman Foundation, Peter W. Lipman, was the recipient of a GSA research grant in 1965.

JOHN T. AND CAROL G. MCGILL AWARD

Scott David, Indiana University
Rachel Glade, University of Colorado Boulder
John Slosson, Syracuse University
The John T. and Carol G. McGill Award, which is in memory of John T. McGill, supports graduate student scholarships and research grants in engineering geology and geomorphology.

BRUCE L. "BIFF" REED SCHOLARSHIP AWARD

Patrick Terhune, University of Alaska–Fairbanks
The Bruce L. "Biff" Reed Scholarship Fund was established to provide research grants to graduate students pursuing studies in the tectonic and magmatic evolution of Alaska primarily, and also can fund other geologic research.

CHARLES A. & JUNE R.P. ROSS RESEARCH AWARD

Sarah Crump, University of Colorado Boulder
Sara El Shafie, University of California Berkeley
Sarah George, University of Texas at Austin
Seana Hood, University of Utah
The Charles A. & June R.P. Ross Research Fund is awarded to support research projects for graduate students, post-graduate students, and post-doctorate researchers in the fields of biostratigraphy (including, but not limited to, fossil age dating and the study of evolutionary faunal successions), stratigraphy and stratigraphic correlation, paleogeography and paleobiogeography, interpreting past environments of deposition and their biological significance, and the integration of these research areas into better global understanding of (1) past plate motions (plate tectonics and seafloor spreading), (2) past sea-level events, including their identification and ages, and/or (3) climate changes and the effects of those climate changes on the earth's inhabitants through geologic time. There should be, over time, a balance of money among the awards across these various subject sub-field categories depending on the merit of the annual project proposals.

ALEXANDER SISSON RESEARCH AWARD

Carsyn Ames, University of Iowa
Family members of Alexander Sisson established a fund in his memory to promote and support research for students pursuing studies in Alaska and the Caribbean.

PARKE D. SNAVELY, JR., CASCADIA RESEARCH AWARD

Jonathan Rivas, University of North Carolina–Wilmington
The Parke D. Snavely, Jr., Cascadia Research Award Fund provides support for field-oriented graduate student research that contributes to the understanding of the geologic processes and history of the Pacific Northwest convergent margin, or to the evaluation of its hazard or resource potential.

HAROLD T. STEARNS FELLOWSHIP AWARD

Katharine Solada, Oregon State University
Dr. Stearns established the Harold T. Stearns Fellowship Award in 1973 for student research on aspects of the geology of the Pacific Islands and the circum-Pacific region.

ALEXANDER & GERALDINE WANEK FUND

Travis Tasker, Pennsylvania State University
The Wanek Fund was established in 2002 to support research dealing with coal and petroleum resources, mapping, engineering geology, marine resources, petroleum economics, appraisal, and evaluation, and the geology of phosphate resources.

LAUREN A. WRIGHT & BENNIE W. TROXEL STUDENT RESEARCH AWARD

Jason Muhlbauer, University of Tennessee–Knoxville
Sarah Wigginton, Utah State University
The Lauren A. Wright & Bennie W. Troxel Student Research Fund supports two graduate students in master's or Ph.D. programs conducting field-based research (1) in the region broadly centered on Death Valley National Park or (2) in the western and southern Basin and Range Tectonic Province. This research grant is associated with the GSA Structural Geology and Tectonics Division.

2017 Research Grant Recipients

(listed in alphabetical order by university)

Arizona State University
Jonathan Zaloumis

Baylor University
Kyrie Baumgartner
Andrew Flynn

Boise State University
Shaina Cohen
Nicholas Ellett
Thomas Harper
Michael Mohr
Clayton Roehner
Zongbo Xu

Boston College
Alana Spaetzel
Brittany Ward

Boston University
Amani Al Abri
Emma Reed

Bowling Green State University
Zachary Cotter

Brigham Young University
Natalie Barkdull

Brown University
Hannah Kaplan
Richard Vachula

California State University–Fullerton
Michaela Adler
Austin Poncelet
Louis Oppenheim

California State University–Northridge
Marius Vilkas

California State University–Sacramento
Marissa Loustale

Central Michigan University
Stephan Hlohowskyj

Central Washington University
Andrew Hoxey
Scott Kugel
Melanie Swick

Colorado School of Mines
John DeDecker
Rania Eldam
Rosemarie Fryer
Mario Guzman
Emily Perry
Allison Severson
Jingqi Xu
Kristine Zellman

Colorado State University
Amanda Doherty
Annette Patton

Cornell University
Alida Perez-Fodich

Dalhousie University
Laura-Ann Broom
Bryan Maciag
Cody Paige

Dartmouth College
Maura O’Brien

Drexel University
Ashley Adams

Duke University
Jacqueline Gerson

Duquesne University
Michelle Valkanas

Florida Atlantic University
Robert Carroll

Georgia Institute of Technology
Pan Liu

Georgia State University
Timothy Herold
Ashley Little

Humboldt State University
Selin Toledo

Idaho State University
Daniel Brennan

Indiana University
Scott David
John Kearney
Matthew Wanker
Alex Zimmerman

Indiana University–Bloomington
Erin Benson
Zhiyang Li
Bei Liu

Indiana University–Purdue University Indianapolis
Maliha Noshin Ahmed

Iowa State University
Jeremy Randolph-Flagg
Katherine Tott
Nathan Young

Kansas State University
Karina Galinskaya
Alexandria Richard
Christopher Wierman

Kent State University
Garrett Blauch
Catherine Ruhm

Lehigh University
James Carrigan

Loma Linda University
Dominic Ombati

Louisiana State University
Edwin Bomer
Marianne Dietz
Abah Omale

McGill University
Kelsey Lamothe
Caroline Seyler
Clara Waelkens

McMaster University
Wen Lin
Tyler Murchie

Memorial University of Newfoundland
Alex Hutter

Miami University
Mackenzie Taylor

Michigan State University
Tyler Hampton
Caitlin Kirby
Kelsey Nyland
Christopher Svoboda

Missouri University of Science and Technology
Xin Zhan

Montana State University
Claire Qubain

Murray State University
Randal Roberson

New Mexico State University
Alicia Bonar
Nicholas Butterfield
Colby Howland
Jonathan Ingram
Michael Mount

North Carolina State University
Dylana Hattenberger

Northern Arizona University
Elinor (Ellie) Broadman
Emma Lodes
Casey Tierney

Northern Illinois University
William Bugbee
Peter Mortensen
Elizabeth Olson
Stephen Perdziola
Joshua Schwartz

Ohio University
Sarah Kogler
Lindsey Schafer
Frederick Twumasi

Oklahoma State University
Ibukun Bode-Omoleye
Pouyan Ebrahimi
Leigha Lynch

Oregon State University
Ruben Aleman
Heather Bervid
Jade Bowers
Anna Glueder

Cedric Hagen
Elizabeth King
Ellen Lamont
Katharine Solada

Pennsylvania State University
Allison Fox
Travis Tasker

Portland State University
Veronica Biesiada
Emily Cahoon
Tessa Carlson
Gregory Martin

Purdue University
William Odom

Queen's University
Mark Ahenda
Svieda Ma
Renaud Soucy La Roche

Rice University
David Blank

Richard Gilder Graduate School
Alexandra Buczek

Rutgers University
Maria Makarova

Saint Louis University
Kayla Lockmiller

South Dakota School of Mines
Broc Kokesh
Scott Kottkamp

Stanford University
Thomas Boag
Jackson Borchardt
Samantha Ritzer

Syracuse University
James Farrell
Joseph Gonzalez
Kristina Gutchess
Marie Jimenez
Kyle Makovsky
Christopher Sant
Amanda Schulz
John Slosson

Temple University
Shondricka Burrell

Texas A&M University
Clyde Findlay
Telemachos Manos
Richard Sullivan
Tyler Winkler

Texas A&M University–Corpus Christi
Jacquelyn Campbell

Texas Tech University
Ethan Backus
John Brotherton

The Ohio State University
Trevor Browning
Paul Russell

Tulane University
Sarah Jaye Oliva

Universidad Nacional Autónoma de México (UNAM)
Fernanda Lases-Hernandez
Ainhoa Lorenzo Merino

Université du Québec à Montréal
Laura Bouvier

University at Buffalo, SUNY
Scott Borchardt
Allison Cluett
Owen Cowling
Avriel Schweinsberg

University of Alabama
Elizabeth Bollen

University of Alaska–Fairbanks
Nathan Graham
Katherine O'Malley
Patrick Terhune
Veselina Yakimova

University of Alberta
Xuyang Meng
Sophie Norris
Joe Young

University of Arizona
Katherine Guns
Jessie Pearl
Shelby Rader
Amy Schott
Jhon Sebastian Jimenez
Christopher Shepard
Alissa White

University of Arkansas
Joshua Blackstock
Alex Breeding

University of Arkansas at Little Rock
Jeffrey Baggett

University of British Columbia
Anna Grau Galofre
Amy Ryan

University of Calgary
Amanda Godbold
Emma Percy

University of California Berkeley
Sara El Shafie
Luke Fairchild
Isabel Fendley
Larry Taylor

University of California Davis
Caroline Hagan Webb
Hannah Palmer
Dylan Vasey
Catherine Wesoloski
Barbara Wortham

University of California Irvine
Kevin Wright

University of California Los Angeles
Kevin Coffey
Abijah Simon

University of California Riverside
Bridget Kelly
Shelly Wernette

University of California San Diego
Brian House

University of California San Diego–Scripps Institution of Oceanography
Marisa Earll

University of California Santa Barbara
William Junkin
Dillon Osleger

University of California Santa Cruz
Kyle Broach
Ana Martinez Fernandez
Esra Mescioglu
Christina Richardson

University of Chicago
Miquela Ingalls
Caitlin Meadows

University of Cincinnati
Josh Bergbower
Zoey Dodson

Andrew Gangidine
Jon-Paul McCool
Shannon Neale
Evan New
Wesley Parker
Sonia Sanchez Lohff
Christopher Sheehan
Jenelle Wallace

University of Colorado Boulder
Sarah Crump
Emily Fairfax
Rachel Glade
Harrison Gray
Kelly Kochanski
Nadine Reitman
Mike Zawaski

University of Connecticut
Janet Barclay
Dawn Beamer
Jennifer Cooper Boemmels
Alex Brittingham
Queenie Chang
Almariet Palm
Jessica Robinson
Rebecca VanderLeest

University of Delaware
Karyn DeFranco

University of Georgia
Christopher Cooper
Danielle Haskett
Abigail Knapp

University of Hawai'i at Mānoa
Daniel Dores
Emily First

University of Houston
Suoya Fan
Yipeng Li

University of Idaho
Emily White

University of Illinois at Chicago
Ancira Emily Baca Marroquin

University of Illinois Urbana-Champaign
Julia Cisneros

University of Iowa
Carsyn Ames
Patricia Webber

University of Kansas
Dakota Burt
Kaitlin Salley
Keelan Umbarger
Fan Zhang

University of Kentucky
Benjamin Currens
Rachel Hoar
Joseph Lucas
Eva Lyon
Alex Reis
Sean Swick
Steven Zotto

University of Maine
Alexandra Balter

University of Maryland
Erin Cunningham

University of Massachusetts
Adriane Lam

University of Michigan
Rebecca Dzombak
Nikolas Midttun

University of Minnesota
Hannah Blatchford
Clementine Hamelin
Colleen Hoffman
Morgan Monz

University of Minnesota–Duluth
Kathryn Vall

University of Montana
Nora Dwyer
Sara Stotter
Robin Welling

University of Nebraska–Lincoln
Justin Ahern
Sabrina Brown
Shamar Chin
Melina Feitl
Wilhelm Fraundorfer
Marques Hatfield
Aaron Hess
Edward Matheson
Ryan Mustacato
Jeffrey Westrop
Mingyu Yang

University of Nevada–Las Vegas
Taylor Craig
Kevin Rafferty
Stephanie Ralston

University of Nevada–Reno
Geoffrey Burtner
Sarah Trubovitz

University of New Hampshire
Richard Knecht
Clarice Perryman

University of New Mexico
Carmen Winn

University of North Carolina–Chapel Hill
Cheng Cao
Kaylyn Gootman

University of North Carolina–Charlotte
Victoria Blumenberg

University of North Carolina–Wilmington
Philip Dalhof
Elise Farrington
Patrick Finnerty
Olivia Koster
Jonathan Rivas
Franklin Rodemer
Lauren Rosul
Krysden Schantz

University of Notre Dame
Alejandra Cartagena Sierra
Keith O'Connor

University of Oklahoma
Steven Adams

University of Oregon
Michael Hudak
Allan Lerner
Kathleen Lipshultz
David Zakharov

University of Pittsburgh
Angela Chung

University of Rochester
Fabiana Richter

University of Saskatchewan
Christopher West

University of South Florida
Nasser Al-Qattan
Matthew Hayes
Elodie Macorps

2017 Research Grant Recipients

University of Southern California
Katie Ardill
Olivia Piazza

University of Tennessee
Miles Henderson
Cameron Hughes
Maggie Limbeck

University of Tennessee–Knoxville
Jason Muhlbauer

University of Texas at Arlington
Emma Gaines
Min Gao
Michael Read
Lu Zhu

University of Texas at Austin
Grace Beaudoin
Rachel Bernard
James Biemiller
Hannah-Maria Brame
Tomas Capaldi
Miguel Cisneros
Megan Flansburg
Sarah George
Evelin Gutierrez
Hima Hassenruck-Gudipati
Lily Jackson
Ingrid Lundeen
Margaret Odlum
Eirini Poulaki
Natasha Sekhon
Lily Serach
Benjamin Smith
Alison Tune

University of Texas at Dallas
Inoka Peiris
Naomi Plummer Nichols

University of Texas at El Paso
Claire Bailey
Cora Gannaway
Kate Grisi
Amanda Labrado
Piper Poe
James Rutkofske

University of Toledo
Jonathan Luczak

University of Toronto
Kira Holland

University of Utah
Benjamin Breeden
Seana Hood
Keegan Melstrom
Ellen Reat

University of Washington
Cassandra Brigham

University of Waterloo
Xinze Lu

University of Wisconsin–Madison
Cameron Batchelor
Soo Hyun Kim
Sarah Shields
Andrew Walters

University of Wisconsin–Milwaukee
David Cordie
Sheryl Stephenson

University of Wyoming
Christopher Doorn
Tanner Waggoner

Utah State University
Krishna Borhara
Harriet Cornachione
Tyler King
Ashley Provow
Brandt Scott
Skyler Sorsby
Sarah Wigginton

Vanderbilt University
Kristy Barnes
Sebastian Belfanti
Eva Biedron
Elli Ronay

Villanova University
Amber Carter

Virginia Institute of Marine Science
Justin Shawler

Virginia Tech
Kiersten Formoso
Christopher Griffin
Alexandra Nagurney
Mitchell Riegler

Washington State University
Gregory Clark
Jesslyn Starnes

West Virginia University
AnnaSofia Andeskie
Miles Reed

Western Kentucky University
Shelby Bowden
Allison Quiroga
James Shelley

Western Washington University
Saba Asefa
Sarah Francis
Molly Johnson
Kristiana Lapo
Masoud Mirzaei Souzani
Kristopher Phillips
Jeremy Rosen

Yale University
Sarah Arveson
Eric Bellefroid
Zheng Gong

2017 GSA Division, Section, and Interdisciplinary Interest Group Student Research Grants

GSA Divisions, Sections, and Interdisciplinary Interest Groups (IIGs) have recognized the following student research grant recipients who submitted proposals of exceptionally high merit in conception and presentation in their fields. These students will be honored at the GSA 2017 Annual Meeting in Seattle, Washington, USA.

DIVISION GRADUATE RESEARCH GRANTS

Geophysics Division

Allan V. Cox Research Award and Supplement
Zongbo Xu, Boise State University
Geophysics Student Research Grant Award and Supplement
Zheng Gong, Yale University

Hydrogeology Division

Hydrogeology Division Student Research Grant Awards and Travel Grants
Inoka Peiris, University of Texas at Dallas
Kaitlin Salley, University of Kansas
Tyler King, Utah State University
Kayla Lockmiller, Saint Louis University
Christina Richardson, University of California Santa Cruz

Karst Division

John W. Hess Research Grant
James Shelley, Western Kentucky University

Mineralogy, Geochemistry, Petrology, and Volcanology Division

MGPV Division Student Research Grant Awards
Recipients to be Announced

Quaternary Geology and Geomorphology Division

Peter Birkeland Soil Geomorphology Research Award
Catherine Opalka, University of North Carolina–Charlotte
Arthur D. Howard Student Research Award
Alexandra Balter, University of Maine
J. Hoover Mackin Student Research Award
Sarah Crump, University of Colorado Boulder
Marie Morisawa Research Award
Elizabeth Olson, Northern Illinois University

Sedimentary Geology Division

Sedimentary Geology Division Student Research Grant Award
Edward Matheson, University of Nebraska–Lincoln

Structural Geology and Tectonics Division

Structural Geology and Tectonics Division Student Research Travel Grant Awards
Mark Ahenda, Queen's University
Cassandra Brigham, University of Washington
Suoya Fan, University of Houston
Nadine Reitman, University of Colorado Boulder
Brandt Scott, Utah State University

SECTION GRADUATE RESEARCH GRANTS

Southeastern Section Graduate Research Grants
Jennifer Bauer, University of Tennessee
Jeremy Dunham, University of Tennessee
Ashley Manning-Berg, University of Tennessee
Shifat Monami, Auburn University
Stephanie Sparks, University of Kentucky

SECTION UNDERGRADUATE RESEARCH GRANTS

Rocky Mountain Section Undergraduate Research Grants
Allison Barbato, Louisiana State University
Christopher Denker, Boise State University
Elizabeth Evenocheck, Winona State University
Otto Lang, Fort Lewis College
Noah McCorkel, University of Colorado
Brandie Oehring, Missouri State University
Anna Ternova, Stockton University

North-Central Section Undergraduate Research Grants
Kathleen Fast, Hope College
Max Huffman, Hope College
Rachel Jackson, Missouri State University
Abigail Michels, Gustavus Adolphus College
Elizabeth O'Brien, Miami University
Lauren Silverstein, University of Wisconsin–Madison

Northeastern Section Stephen G. Pollock Undergraduate Research Grants
Emily Geyman, Princeton University
Spencer Gray, College of the Atlantic
Donald Koepp, Bucknell University
Celia LaPorta, Slippery Rock University
Samuel LoBianco, Harvard University
Kaylee Pennell, Juniata College
Anna VanDusen, Juniata College

South-Central Section Undergraduate Research Grants
Jason Ronza, University of Arkansas at Little Rock
Sydney McKim, University of Arkansas at Fayetteville
Joshua Wynn, Wayland Baptist University

Southeastern Section Undergraduate Research Grants
John Durica, Coastal Carolina University
Andew Flack, Virginia Tech
Stephanie Hibberts, Clemson University
Jillian Laird, Clemson University
Sara Morgan, Radford University
Nathanial Newlin, University of Tennessee at Martin
Olivia Paschall, Appalachian State University
Holly Pettus, West Virginia University
Amy Plechacek, Virginia Tech
Adrianne Reeder, Radford University
Delaney Ryan, Appalachian State University
Jesse Scholpp, University of South Florida

INTERDISCIPLINARY INTEREST GROUP (IIG) GRADUATE RESEARCH GRANTS
GSA International
Farouk El-Baz Student Research Grants
Karem Abdelmohsen, Western Michigan University for "How do Aquifers Respond to Wet and Dry Periods? A Case Study from the Nubian Aquifer."
Jennifer Haskell, University of California Davis for "Understanding Mosaic Carbon Storage in Drylands to Inform Climate Models Under Desertification Regimes."
This grant is to encourage and support desert studies by students world-wide, either in their senior year of their undergraduate studies, or at the masters or Ph.D. level.Excellence

2017 GSA/ExxonMobil Field Camp Excellence Award Winner

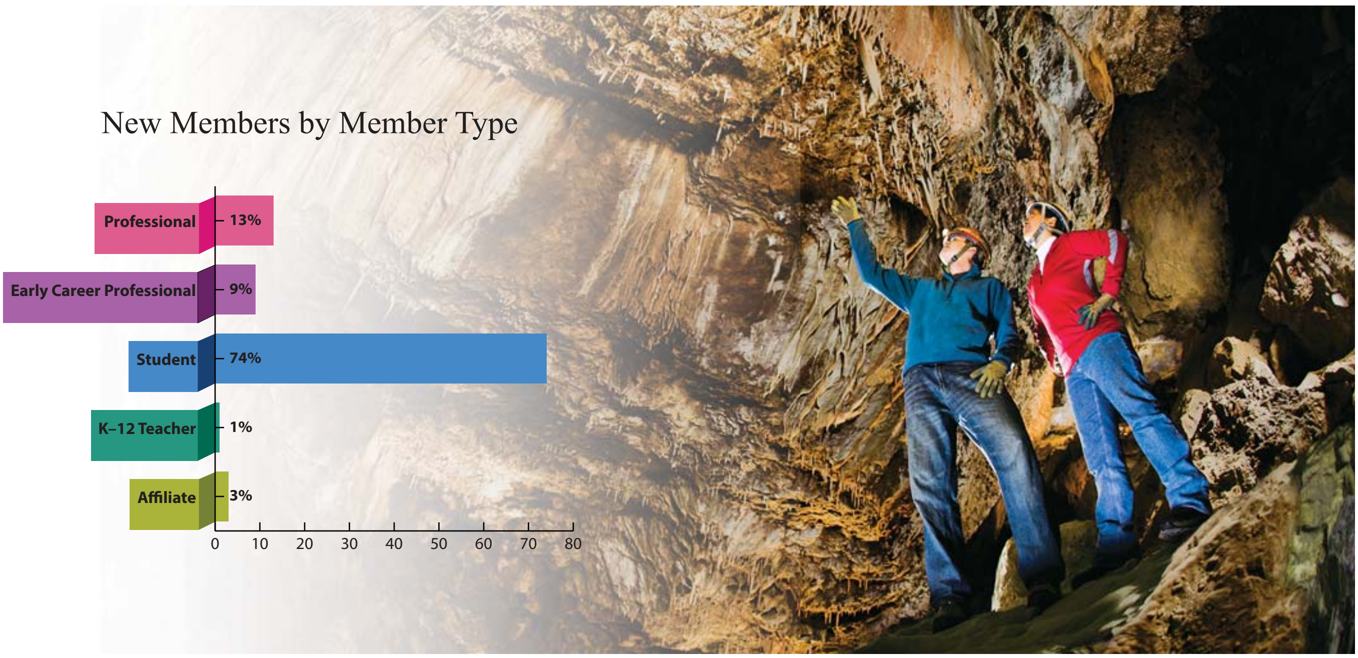
ExxonMobil

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.
Rocky Mountain Field Camp: David Malone, Illinois State University

THE GEOLOGICAL SOCIETY OF AMERICA®

Welcome New GSA Members!

The following new members joined 16 August 2016–15 March 2017
and were approved by GSA Council at its spring meeting.



PROFESSIONALS

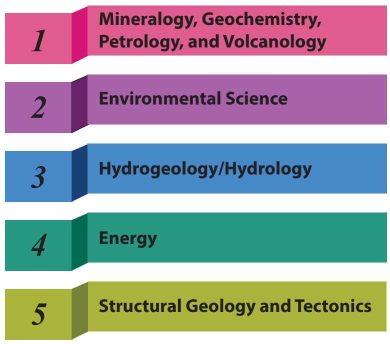
Celena Abrahamsen
Alexandra Abrajevitch
Aubreya Adams
Tammy Mast Adams IV
David Alderks
William C. Aley IV
David J. Allison
Eleonora Ammannito
June Anderson
William Casey Armstrong
Cindy Jo Arrigo
Wade Lee Aubin
Bridget Ayling
Chris A. Badurek
Gail Bakker
Batkhuu Baldorj
Kathryn A. Baldwin
Kailas Sekhar Banerjee
Tracy Bank
Wendell L. Barner
Samuel H. Baughman II
Jill Betts
Kim Mills Bishop
Herb Black
Daniel John Bliley
Charles Mark Bowers
Thomas Duke Bowman
David R. Boyce
Ronald Breitmeyer
Benjamin Breland
Scott C. Brooks
Emily Buchholtz
John Herbert Cann
Concepcion Carreon-Diazconti
Eduardo Carrillo
Jody Castle
Michael R. Caudill
Jose Cerrato
Tugba Cevik
Jeffrey Ashton Chandler
Beverly Chomiak
Ellie D. Chuparova
Camile Angelee Clarke
Daniel P. Conran
Sharon Katz Cooper
Clovis Moura Costa
Yvette Counts
Lindsay D. Craig
Paul Crevello
Joseph Csoltko
Arthur Curtis
Brett Davidheiser-Kroll
James A. Davies
Andy Davis
Ethan Davis
Gene Davis
Lisa Davis
Charles Demets
Alyce Ann Dengler
Richard A. Denne
Robert DePalma
Ana Ibis Despaigne Diaz
Thomas Andrew Dewers
Cid Ira Dillard
Grady Dixon
Daniel Corey Dobson
Pamela Dodds
Nl Dongre
William M. Donoghue
Lisa Dosmann
John W. Dougherty
Agnieszka Drobniak
Adriana Dutkiewicz
Rita C. Economos
Jacob Eisel
Eric M. Erkenbrack
John Esch
Jaime Escobar
Jennifer S. Fehrenbacher
Corri A. Feige
Mark Finke
Sarah A. Finkelstein
Michael Fischer
Cynthia G. Fisher
Leonard Neal Ford Jr.
Benjamin Freiberg
Sabreen Gad
William Brent Garry
Mesfin Wubeshet Gebremichael
Lynn Gelhar
Stefania Gerbaudo Laronga
Sylvie Giral Kacmarcik
Seth Goad
Theodore Godo
W. Thomas Goerold
Anne Gogola
Anne U. Gold
Karin Goldberg
Jaime Goode
Shuwei Guan
Marte Gutierrez
Michael P. Gutmann
Daniel Guy
Alexandra Hakala
Brian C. Ham
Vicki L. Hanna
John A. Hanson
Richard Harris
Andrew Ross Harrison
David Harwell

Christopher Ryan Haugstad
Chris John Hawkesworth
Alexander Gerard Hayes
Jennifer C. Haywood
Jason Heath
Eric Joseph Heidecker
Mark A. Henry
Caroline Hern
Celina Hernandez
Kevin Hon
Silvan Hoth
Karen L. Huber
Alecia Hurst
Sung Pil Hyun
Kurt R. Illig
Donald M. Jacobs
Maria Ansine Jensen
Hui Jin
Alastair Mark Johns
Paul Johnson
Imants Kavalieris
Fred B. Keller
Anthony Ivan Kemp
Michael Kendrick
Andrew Kennedy
Mohammad Nasir Khan
Ruy Kenji P. Kikuchi
Rosamond Kinzler
Scott L. Knight
Donald Koglin
Daniel J. Kontak
Niranjala Kottachchi
Cary Phillip Kuminecz
James W. Langman Jr.
Daniel Philip Lapikas
Elisabeth Lavigne
Juan Carlos Laya
Byungsun Lee
Toby Leeson
Patrick Leiggi
Richard Leigh
Loren Leiker
Vedran Lekic
Adrian Lenardic
Gregory J. Lewis
Santosh Lohar
Jonathan Lovekin
Clifford Roy Lundgren
Craig Manning
Phillip Lars Manning
Julia A. Maresca
Erika Marín-Spiotta
Gary Martek
Charles E. Martin
Nahysa Martinez-Kulikowski
Molly Mccanta
Brian E. Mcgurk
Diane Marie Mcknight
Nichola Mcmillan
Stanley Mcmillian Jr.
Jeffrey Mecham
Scott Mensing
Caitlin Jae Mercier
Michael T. Meyer
Kurt Alan Miller
John M. Mitsdarfer
David W. Mittlefehldt
Kyaw Soe Moe
Gaspar Monsalve
Clara Luz Mora
Gabriele Morra
Alexander Morrison
Joanne Muller
Kelsey Murphy
Seiji Nakagawa
John Naliboff
Pilar Navas-Parejo
Jessica Nelson
Joseph Alan Newhart
Brad Talon Newton
Gene-hua Crystal Ng
Kristi Miller Nichols
Osborne B. Nye Jr.
Olamide O. Oladele
David R. O'Leary
Brian C. O'Meara
Marcus J. Origlieri
Amador Osoria Hernandez
Douglas C. Pasley Jr.
Julia N. Perdrial
Maria Rose Petrizzo
Santino S. Piccoli
Jeffrey William Pike
Diego Pol
Aaron Powers
Thomas H. Prettyman
Barbara A. Price
Matthew E. Pritchard
Zhenghui Qu
Diana Quintana
Anthony Dale Rainey
Mohan Ramamurthy
Michael Andrew Ranney
Thomas Regan
Rong Ren
James Edward Rexius
Stephen D. Richardson
Sarah Rieboldt
William T. Ripley
Scott M. Ritter
Andrew Rivkin
Eric M. Roberts
Jonathan C. Roger
Charles E. Rogers
Daniel J. Rohmer
Marcelo Rosensaft
William B.F. Ryan
Nordine Sabaou
David C. Sassani
Daniel D. Schelling
Shanna Schmitt
Hans P. Schönlaub
Paul C. Schwering
Joanne Scott
David Selby
Patrick Shabram
Anat Shahar
Suresh Sharma
Leo Sheehan Jr.
Richard Michael Showman
Richard Silver
Efrosyni-Maria Skordaki
James C. Slone
Gerald Ray Smith
Neil Smith
Daniel Snyder
Karamoko Soumah
Sarah A. Spaulding
Gregory L. Stanek
Kenneth K. Steele
Robert Victor Steiner
Heidi Steltzer
Charles R. Stern
Junjie Sun
Katherine Telfeyan
Arnaud J. Temme
Maurits Thayer
Ted G. Theodore
Scott Ellis Thornton
Jessica Tierney
Hitoshi Tomaru
Allan H. Treiman
Brittany L. Trent
Erin Trone
Takanobu Tsuihiji
Orkan Mehmet Umurhan
Giovanni Vadurro
Heyo T. Van Iten
Carl Vanorden
Edy Teodoro Vasquez Sr.
Patrick T. Vescovo
Robert G. Vicars
Javier Vilcaez
Reno Voss
Glen Gallagher Wade
Roger Wagerle
William Joseph Walker
Mingli Wan
Michael Wangler
Kelly Waymire
David C. Weindorf
Christopher G. Weisener
Betty J. Wheeler
Joseph Daniel White
Kyle A. Whittinghill
Bruce A. Williams
Patrick Thomas Williamson
Jeff D. Wilson
Lynn Wnuk
Sharon Marie Woods
Joseph M. Wright
Michael Wright
Jie Xu
Laurence Y. Yeung
Hongkyu Yoon
Christopher Michael Young
Jerry Zieg

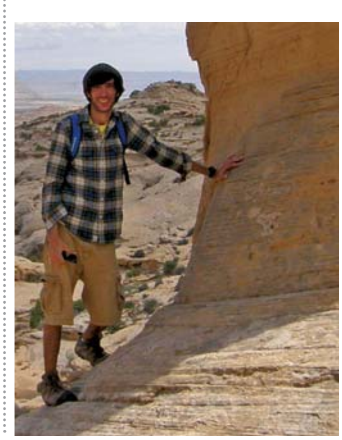
EARLY CAREER PROFESSIONALS

James Michael Adams
Kenan Akbayram
Kareem Hesham Ali
Sheikh Nawaz Ali
Said Almusharrafi
Nicholas Amerin
Leeli Amon
Scott Wallace Anderson
Madeline Ang
Emmanuel Aponte
Dustin Bryant Atkin
Sofia Avendano
Matthew Baird
William R. Baker
Ellen Barnett
Eric S. Beebe
Florence Bégué

Top 5 Professional Interests of New Student Members



Luke Belanus
Matthew Aaron Benz
Sebastien Biass
Andrea Blaine
Karoline J. Bohlen
Brent Bowman
Marco Brenna
Scott Daniel Brewster
Denise Bristol
Alexander David Bromhead
Kallie Flaxington Brown
Erinn Buhyoff
Stephen Marshall Busby
Maria Gracia Bustamante Rosell
Daniel Cade
Catherine S. Carter
Daniel Robert Carter
Karina Casey
Mariana Aurora Castro-Branez
Michael Charles
Jingyi Chen
Matt Chojnacki
Cori Jean Christensen
Kendra R. Clark
Roger Close
James Coble
Cameron James Coffey
Pamela Collins
Jennifer Elizabeth Connell
Rory M. Cowie
Zeke Currey
Saikat Das
Timothy Davis
Brian De Corte
Anna Degeorge
Elle Derwent
Joel William Desormeau
Shimelis Behailu Dessu
Charles Dietrich
Zachary James Dobey
Charl Dirkse Du Toit
Makenna Edgington
Angela M. Espinoza
Ellen Fehrs
Harry Riordan Ferdon
Matthew Ferdon
Anjali M Fernandes
Naiara Fernandez
Paul Foley
Nicholas J. Fortman
Benjamin Foster
Kelsey Franko
Amy Gartman
Kelley Gee
Behzad Ghanbarian
Ian Ross Gilbert
Holly Goggin
Kay Louise Gorzko
Jacob Greenawalt
Andrew Thomas Griffin
Austin Griffin
Darwina Griffin
Miranda Leigh Griffith
Ashley Grimm
Scott Groat
Amy Grogan
Tricia Lynn Haas
Maxwell Hain
Zachary Bruce Hatfield
Miles Hearn
Daniel D. Hemmerlin
Kevin A. Henderson
Dana Heston
Alyssa L. Hintz
Tuan A. Ho
William Hoskins
Hina Imtiaz
Crystal Johnson
Betul Kacar
Elliot Mujune Kim
Jonathan King
Marley Kirkham
Anna J. Klein
Hunter Knox
Carrie M. Kubacki
Nicole Kurtz
Pierre Lanari
Xianguo Lang
Virginia Latane
Sandi Lawson
Karen Lefebre
Karla Leslie
Joshua Levy
Jing Li
Man Liang
Jeffrey T. Liles
Ajay Limaye
Chao Liu
Nathan Lockhart
Kathy Mae Loftis
Juan Manuel Lora
Amber Marie Lutey
Tyler Ranse Lyson
Xiaogang Ma
Nicholas Macklem
Allison Makosky
Matthew Marin
Samuel Z. Mark
Jill Marshall
Johannes Mattes
James McCullum
Carolyn Marie McDonough
Kelly Theresa McGowan
Luke McGuire
Lacie Anne McIntire
Sydney McKim
Samuel Leigh Metteer
Matthew Meyer
Tara Mitchell
Michael James Mohrbacher
Patrick Morton
Nima Moussa Egueh
Meadow Lynn Muench
Catherine Claire Murphy
Grant Myers
Tyler Myers
Andrew Najafiarab
Brian Neff
Katie Neff
Matthew Nelsen
Olivia Parrish Nicholson
Loveness Njogela
Brady Nock
Jean-Arthur Olive
Kristin Elena Orellana
Abbe Jane O’Rourke
Austin Ozolins
Mara Page
Jianzhang Pang
Ethan Parrish
Thai Phan
Ethan Philips
Jennifer Pickering
Elizabeth Plumb
Regina Michelle Povirk
Jahnavi Punekar
Christopher Carl Putzer
Feifei Qian
Md Sayad Rahaman
Jenna Ramsey
Zack Robertson
Jake Irving Ross
Matthew W. Rossi
Chelsey Lynnece Roth
Sonia Jane Rowley
Uri Ryb
Nicolas J. Saintilan
Gabriela Saldana
Stephen Paul Saller
Lucas Salmons
Matias G. Sanchez
Lydia R. Schneider
Sean Schroeder
Kevin A. Schwab
Stephen Schwartz
Matt Sheehan
Christina Sheldon
Christopher R. Shelton
Corliss Kin I. Sio
Elizabeth Sklute
Tristan Storey Solano
Roberto Spina
Byron Steinman
Peter Stevens
Julie Stopar
Amber N. Strick
Benjamin Sweeney
Denise Lai Kwan Tang
Micheal Tekle
Rebecca Thomas
Jesse Thompson
Ruth Tinnacher
Stacy Rose Trowbridge
Amanda Tudor
Nathan Vinhateiro
Sean Vitousek
Joe Hugh Vivash
Robert Benjamin Vogel
Erica Louise Volansky
Kelly Vreeland
J. Sage Wagner III
Jacob Ablow Wall
Ron D. Waterbury
Jessica Watkins
Heather Nicole Webb
Thea Whitman
Camilla Maya Wilkinson



Keith Williams
Nicole Wilson
April Marie Wright
Xiangyang Xie
Drew Joseph Yetter
Andi Zhang
Tieyuan Zhu
Kovas Saulius Zygas

STUDENTS

(Listed by Professional Interest)

Archaeological Geology

Allison Nicole Abbott
Ashley Barebo
Ahmed Benkhayal
Suryakanthie Chetty
Kathryn Victoria Creecy
Allison Curley
Gavin Preston Curry
Leila Donn
Matthew Spalding Evans
Caleb Ferbrache
Elizabeth Fillion
Jayson Peter Gill
Kevin Alexis Guerra
Amy Elizabeth Johnston
Jean Teachout Larmon
Xiaodan Lin
Liam Cole Mazur
Tyler James Murchie
Auraliz Perez
Craig Phelps Jr.
Kelsey M. Reese
Brandi Reger
Gabriel Elias Rehm
Elena T. Skosey-LaLonde
Francesca Van Soest
Antonio Velazquez
Michael J. Wille

Biogeosciences

Joshua Anthony Abbatiello
Evelyn S. Becerra
Sequoya Bua-iam
Michael Richard Campbell
Drew Ceglinski
Jennifer Chan
Perry Patrick Chesebro
Phillip Darias
Rebecca Forgrave
Fotios Fouskas
Andrew Gangidine
Austin Harrison Gilly
Rebecca R. Greenberg
Michael Avi Gross
Jennifer M. Haskell
Spencer Hellert
Megan Herrmann
Angeline Nicole Higby
Colleen Lynn Hoffman
Jacob Hogue
Luke A. Ingles
Elizabeth Katherine King
Sarah Kogler
Nicholas Lambrecht
Jake Harris Lefeuvre
Haoran Ma
Claire MacMurray
Ruth Brooke MacNeille
Emma T. Martin
Sandy McLachlan
William Gregg McMahan
Esra Mescioglu
Ezequiel Arturo Moreno Flores
Devin E. Morse
Caleb R. Norville
Celestine Nwite Nwojiji
James Patrick Peoples
Danielle Perez
Clarice Perryman
Claire Qubain
Sophia Rodriguez
Rocio Rojas
Sara Ruch
Christine E. Schlarbaum
Melissa Sedler
Rebekah A. Stein
Jurnee N. West
Simin Zhao

Climatology/Meteorology

Lisa M. Champagne
Kyle Clifton
Evan Frederick Green
Sierra Lake Grguric
Jun Miyama
Jonathon Nowiski
Kyle O'Keefe
Lainey Nicole O'Neill
Brandon Michael Owen
Mark Donald Peaple
Alejandra Pesqueira
Derek Prunty
Kayla Quinn Root
Rebecca Anne Smith
John Strzempka
Thomas J. Worm
Peng Zhou

Economic Geology

Adam Adkisson
Lee Alford
Labdan Nijr Alqahtani
Victor Daniel Aviles
Erin Benson
Josh Neal Bergbower
Courtney Birdsall
Jacob Bowser
Jason Burwell
Kaitlyn Elyse Caltrider
Rocky Casino
Macey E. Crockett
Stephen Delgaudio
Nicholas Drew Di Sessa
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Shaolin Meliora Censullo
Ikram Cheref
Bradley Wayne Claggett
Matthew Scott Clodfelter
Christopher Stephen Cooper
Marco Pasquale de Pompa III
Ting Ding
Rohan Uday Dusane
Karl Christian Fetter
Kiersten Kelly Formoso
Allison C. Fox
Jordan Gibbs
Abigail Marie Glass
Amanda Glynn
Anne Marie Griffis
Sara K. Gross
Nicholas R. Hebdon
Seana Claire Hood
Jinbo Hou
Reiss D. Hozak
Rudolph Russell Hummel
Becky Humphrey
Cassidy Jester
Lana Jewell
Michael D. Karaus
Mark Krippner
Mckenzie R. Langford
Laura J. Larocca
Fernanda Lases-Hernandez
Brian Anthony Lauters
Nicole M. Lees
Liane Christine Linehan
Samuel Joseph Cole LoBianco
Rachel Lombardi
Sarah Rose Losso
Ingrid Karena Lundeen
Zoneibe Silva Luz
Leigha Lynch
Chad Richard Mason
Emily Nichole Mason
Andrew Mcgrath
Ryan S. Mckay
Scott Lucas Melander
Keegan Melstrom
Kayleigh A. Muilenburg
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Evan New
Nathaniel Tyler Newlin
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1 Career Development
2 GSA Meetings
3 GSA Publications

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M. Catherine Wilsbacher
Charles Henrik Woolley
Susannah Wright

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Joe M. Young

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Grace Hansen
Julie Christine Heins
Aditya Easwaran Krishnan
Stephen Robert Maglio
Kaya Morelli
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Leiaka Welcome
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Jingqi Xu
Zachary Tyler Yates
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Mike Zawaski

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Mark Ahenda
Erik Kristian Anderson
Jose Ricardo Ardila
Emma Maria Armstrong
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Javaria Aziz
Julian Rafael Barboza Treviño
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Tyler Miller
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Jeremy Neundorff
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Lacie Planer
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Ronita Williams
Jeremy R. Wyman
Peter Wynn
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Tina Thai
Harrison Togia
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Conevery Bolton Valencius
Gary Wuchner

In Memoriam

It is with regret that GSA notes the deaths of the following members. Notifications were received between 1 Mar. and 1 May 2017. To honor someone with a memorial, go to www.geosociety.org/GSA/Pubs/mmlGuid.aspx to learn how. Contact the GSA Foundation at www.gsafweb.org to make a gift in his or her memory

Joseph L. Brewton
Pearland, Texas, USA

Robert Cluff
Denver, Colorado, USA

Hugh Thomas Kelly
Waxahachie, Texas, USA

Donald H. McLaughlin Jr.
South Orleans, Massachusetts, USA

Georges Pardo
Naples, Florida, USA

Gene Rosendahl
Littleton, Colorado, USA

Neil E. Tibert
Fredericksburg, Virginia, USA

Bernie Troxel
Woodland, California, USA

Warren E. Yasso
Garden City, New York, USA

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Term: July 2017–June 2018

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Illinois State Geological Survey
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PAST PRESIDENT
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Los Alamos National Laboratory
Los Alamos, New Mexico, USA

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Term: July 2014–June 2018

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University Park, Pennsylvania, USA

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Term: July 2015–June 2019

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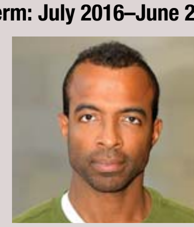
Bethlehem, Pennsylvania, USA

Christopher (Chuck) M. Bailey
College of William & Mary
Williamsburg, Virginia, USA

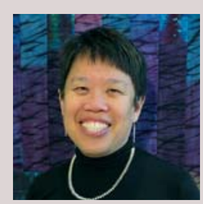
Mary J. Kraus
University of Colorado Boulder
Boulder, Colorado, USA

Term: July 2016–June 2020

F. Edwin "Ed" Harvey
Hydrogeologist
Fort Collins, Colorado, USA



Mark Little
University of North Carolina–Chapel Hill
Chapel Hill, North Carolina, USA

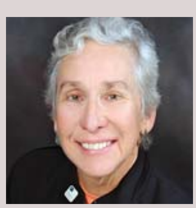


Marjorie A. Chan
University of Utah
Salt Lake City, Utah, USA

NEWLY ELECTED

Term: July 2016–June 2021

Carmala N. Garzione
University of Rochester
Rochester, New York, USA



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San Bernadino, California, USA

Suzanne O'Connell
Wesleyan University
Middletown, Connecticut, USA

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University of North Carolina
Chapel Hill, North Carolina, USA

2016–2017 GSA-USGS Congressional Science Fellow Report

Kirstin L. Neff

Dr. Smith Goes to Washington

As the 2016–2017 GSA-USGS Congressional Science Fellow, I arrived in D.C. for orientation and placement in September 2016, just two short months before the presidential election that took most of America and the world by surprise. I began my placement in the office of Sen. Martin Heinrich (D-NM), where I am working on water, space, science, and technology issues, at a time when many staffers had taken leave to go work on campaigns across the country. With the national focus on the campaign, I had ample time to settle into the process and culture of "the Hill." After the election, congressional offices quickly filled with staffers returning to a very different political reality than most had expected, and the final work period of the 114th Congress took on the high-strung nature of what is called a "lame duck session."

It's easy to arrive in D.C. with the optimism that your unique perspective can shake up the system, not unlike the titular character of the classic film *Mr. Smith Goes to Washington*. Instead, I've learned that an understanding of the system and how to operate within it is critical to getting anything accomplished in Washington, where process and procedure rule.

It didn't take long for my own idealism to be confronted with a legislative moment seemingly perfectly designed to bring me down to reality. In December, in the last hours of the 114th Congress, the House of Representatives seemed poised to pass a version of the Water Resources Development Act of 2016 that represented years of bipartisan work and compromise, led by Senate Environment and Public Works Chairman James Inhofe (R-OK) and Ranking Member Barbara Boxer (D-CA). The bill would be Boxer's final piece of legislation before retirement after 34 years in Congress, the last 24 of which were in the Senate. Assuming responsibility for the water portfolio in my office, I was excited to be involved in eleventh-hour, late-night votes so soon in my tenure. However, as the Senate prepared to vote on the House-passed legislation, renamed the Water Infrastructure Improvements for the Nation Act, or WIIN Act, it became clear that Sen. Dianne Feinstein (D-CA) and Rep. Kevin McCarthy (R-CA) had inserted what Boxer called a "poison pill" rider that she argued would undermine protections for the Delta smelt, an endangered native fish species in the Sacramento–San Joaquin Delta in California, which has long pitted environmentalists against Central Valley farmers in search of more water for irrigation during a historic drought.

Having moved to D.C. from California, I was well aware of this issue and was torn over the vote. Our office, along with a bipartisan coalition representing states along the San Juan River in the Four Corners region, had succeeded in lobbying for our bill to compensate communities along that river that had been affected by 2014's Gold King Mine spill to be included in the WIIN Act. Our office wanted to make sure our constituents would get compensation for the damages caused by the release of acid mine drainage into their river, and we therefore supported the bill. The WIIN Act passed after a 1:00 a.m. vote, and I returned home in the wee hours with a new appreciation for the difficult compromises necessary to pass legislation in this political climate.

While votes tend to make the headlines, I've found that a majority of the work I do as a legislative staffer never makes it to the Senate floor. This work includes meeting with constituents and interest groups who have a stake in federal programs or legislation, conducting oversight of the executive branch, and advocating for our constituents with federal agencies. In water resources, there is a complex web of interactions between federal, state, and local authorities. My work includes facilitating federal dam operations, tracking interstate water issues like the *Texas vs. New Mexico* Supreme Court case on the Rio Grande and the development of drought contingency plans along the Colorado River, as well as helping small water providers in rural New Mexico get the funding they need to comply with Safe Drinking Water Act regulations. Without a legislative win to point to, it can be hard to evaluate the job you are doing, but in the end what matters is serving the Senator's constituents in whatever way you can.

One of the great strengths of the Congressional Science Fellowship is that the GSA-USGS Fellow receives training in science policy and communication along with other fellows, sponsored by a number of different scientific societies. Through the experiences of my fellow Fellows, I have gotten exposure to many different science policy avenues throughout Capitol Hill and the administration. My colleagues hosted in executive branch agencies have had a front seat to a presidential transition, and understanding that branch of government and its processes has helped me to be a more effective congressional staffer. The opportunities I've had to collaborate with my congressional colleagues, including recently on the Scientific Integrity Act, have shown me the power of having not just one, but a cadre, of scientists working on the Hill. As I sit here six months into my fellowship, I'm excited to continue developing my skills as a representative of the geosciences community and as an effective congressional staffer.

The manuscript is submitted for publication by Kirstin Neff, 2016–2017 GSA-USGS Congressional Science Fellow, with the understanding that the U.S. government is authorized to reproduce and distribute reprints for governmental use. The one-year fellowship is supported by GSA and the U.S. Geological Survey, Department of the Interior, under Assistance Award Number G16AP00179. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. government. Neff works in the office of Sen. Martin Heinrich (D-NM) and can be contacted by e-mail at Kirstin_Neff@heinrich.senate.gov.

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USGS science for a changing world

Geosciences and Energy Policy

GSA members are invited to submit comments and suggestions regarding the following Position Statement draft by 15 Aug. 2017 at **www.geosociety.org/PositionStatements.**

Development of a comprehensive energy policy that significantly reduces greenhouse gas emissions is essential for the future economic vitality, environmental well-being, and health and security of the citizens of the United States as well as other nations. Geoscientists locate, quantify, and help develop energy resources, and, along with professionals in other disciplines, assess and mitigate the impact of energy-resource development, operations, and use on the environment. Accordingly, input from geoscientists must be an integral part of all energy policy deliberations.

PURPOSE

This position statement summarizes the importance of the geosciences in developing fundamental data upon which sound energy policy should be based, and the contributions geoscientists can make to the framing of energy policy. Most energy sources have important and distinct geologic factors that should be considered when analyzing the life-cycle impacts related to exploration, extraction, development, operations, waste disposal, decommissioning, and reclamation.

The abundant and cheap fossil fuels that made the United States an economic power and have raised the standard of living for much of the developed world represent an energy business model that must change. We now know that the greenhouse-gas emissions from fossil fuel combustion have a profound impact on global climate, with effects on local and regional ecosystems, and public health. In addition, over the last few years, other energy sources have become economically competitive with fossil fuels.

The challenge for energy policy makers is to develop a plan that will provide cost-effective improvements for the efficient and sustainable use of Earth's energy resources, reduce carbon emissions, and provide secure and affordable energy to the world's developing economies as well as the developed nations of the world. The knowledge and expertise of geoscientists takes on an added importance as countries and industries worldwide adapt to climate change and work to reduce carbon emissions.

RATIONALE

The Geological Society of America (GSA) adopted a Position Statement on Climate Change in 2006 that recognized that anthropogenic emissions of carbon dioxide (CO_2) and other greenhouse gases are the primary cause of global warming since 1880, and that this warming has significant impact on humans and global ecosystems[1]. Revisions and updates of the GSA Position Statement on Climate Change in 2010, 2013, and 2015 are consistent with the findings of the National Academies of Science, Engineering, and Medicine[2] and position statements of professional societies that deal with geoscience and climate change, such as the American Geophysical Union[3], American Meteorological Society[4], American Chemical Society[5], American Association for the Advancement of Science[6], and the Geological Society of London[7].

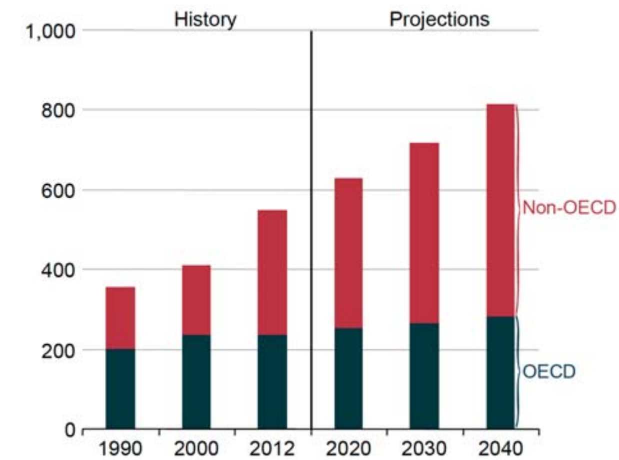


Figure 1. World Energy Consumption 1990–2040. Source: EIA, International Energy Outlook 2016. The IEO2016 Reference Case projections do not include the effects of the recently finalized Clean Power Plan (CPP) regulations in the United States (link: http://www.eia.gov/forecasts/ieo/world.cfm). Organization for Economic Co-operation and Development (OECD) member countries include most European countries, Australia, Canada, Chile, Korea, Iceland, Israel, Japan, Mexico, New Zealand, Turkey, and the United States.

As the human population continues to surge beyond seven billion, and developing and emerging countries transition to consumer-based economies, global demand for energy is predicted to grow significantly through 2040, as seen in Figure 1.

The energy sources for projected energy use through 2040 as estimated by the U.S. Energy Information Agency are indicated in Figure 2.

According to the U.S. Energy Information Administration (EIA) "International Energy Outlook 2016," fossil fuels will continue to provide as much as 78% of total world energy consumption by 2040, declining from 84% in 2012. But in real energy

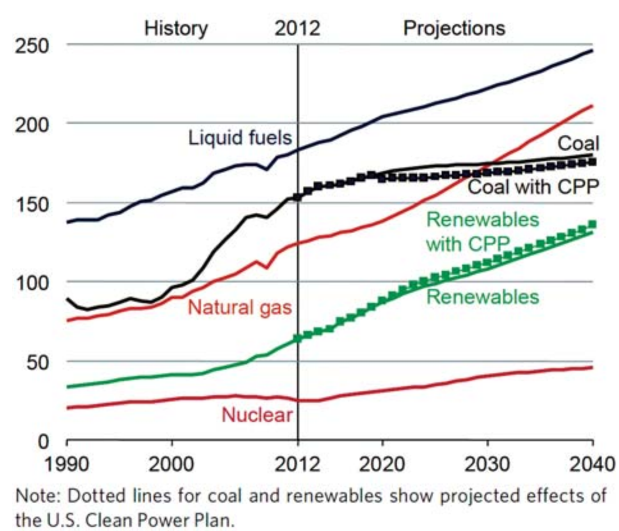


Figure 2. World Energy Consumption by Energy Source 1990–2040. Source: EIA, International Energy Outlook 2016. These IEO2016 Reference case projections include the effects of the contested Clean Power Plan (CPP) regulations in the United States (link: http://www.eia.gov/forecasts/ieo/world.cfm).

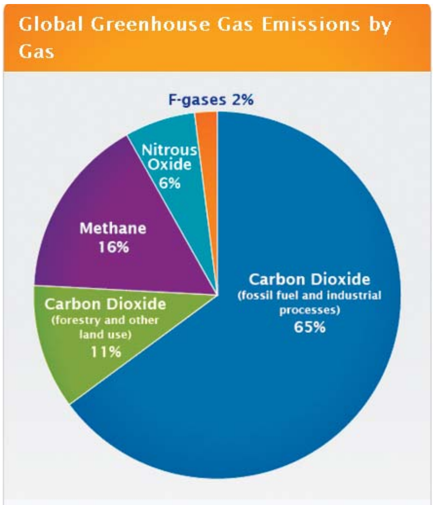


Figure 3. Global Greenhouse Gas Emissions by Gas. Source: IPCC (2014; https://www.ipcc.ch/report/ar5/wg3/) based on global emissions from 2010. Details about the sources included in these estimates can be found in the "Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change."

terms, this implies a 40% increase in fossil fuel burning over those 28 years as a result of the increase in total energy demand. Petroleum liquids consumption continues to decrease as a percentage of the global mix, but in absolute terms is projected to still increase through 2040, primarily as a transportation fuel as a function of increased demand in China and India. Natural gas consumption slightly increases in the mix from 23% to 26%, principally as a fuel for electric power generation and for industrial use. Coal as a percent of total energy has continued to slowly rise to 28% today, but is projected to flatten out toward 2040 (22%). Renewable energy resources are projected to grow from 11% of total global power generation in 2012 to 16% in 2040, which is more than a doubling of the 2012 generation capacity. Nuclear power, which emits no direct greenhouse gases, but has serious public acceptance challenges, is projected to also increase. The mix of energy sources and their magnitudes that are predicted to meet current and growing energy demand will greatly influence the economy, environment, national security, and public health of the world's citizens. These projected energy sources needed to fulfill future energy demand will increase the rate of CO_2 emissions. The CO_2 emissions from the burning of fossil fuels constituted 65% of the overall anthropogenic greenhouse emissions in 2010 (Fig. 3, "Fifth Assessment Report" [AR5] of the United Nations Intergovernmental Panel on Climate Change [IPCC])[8].

The historic increase in anthropogenic CO_2 emissions since the late nineteenth century, and the cumulative amount of anthropogenic CO_2 emissions, are illustrated in Figure 4 and show the dominant contributions from fossil fuel burning.

Human-sourced emissions of CO_2 and other greenhouse gases have strongly impacted those earth processes that regulate the terrestrial climate, ecosystems, and seawater composition (e.g., pH). The IPCC "Climate Change 2014 Synthesis Report" (p. 8)[9] states:

> Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks.

The United States, together with 173 other nations, signed the UN Paris Agreement on Climate Change[10] on 22 April 2016. Under the terms of this agreement, the signatories have committed to reduce their carbon output "as soon as possible" to do their best to keep global warming "to well below 2 °C." The short summary above of CO_2 fluxes from the past 100 years and the associated rise in atmospheric CO_2 and projected energy use for future demand are incompatible with requirements for reductions in carbon outputs.

THE POLICY CHALLENGE

There is a clear policy rationale and a United Nations mandate to reduce global carbon and other greenhouse gas emissions in order to mitigate the impact of climate change. However, forecasts by the United States Energy Information Agency[11], the International Energy Agency[12], and industry forecasts, such as those published by ExxonMobil[13] and BP[14], all indicate a significant increase in fossil fuel consumption through 2040. The challenge for policy makers and scientific innovators is to find a way to reduce carbon emissions and accelerate the transition to renewable energy without adversely impacting global standards of living.

GSA has recommended in its position paper on climate, that

> Strategies for reducing greenhouse-gas emissions should be evaluated based on their impacts on climate, on costs to global and national economies, and on

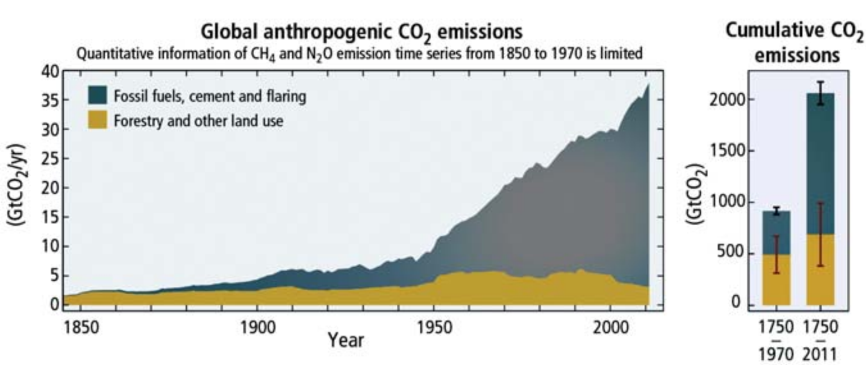


Figure 4. Global Anthropogenic CO_2 Emissions. Source: "Climate Change 2014 Synthesis Report," IPCC 2015, p. 3.

> positive and negative impacts on the health, safety, and welfare of humans and ecosystems.[15]

In its 2016 pamphlet titled "Geoscience for America's Critical Needs," the American Geosciences Institute stated the importance of energy and the role of the nation's geoscientists as follows:

> Energy supports economic growth, national security, and all the elements of daily life—food, water, transportation, communication, and entertainment. The United States' historically robust and secure energy systems have contributed to our high quality of life. Geoscientists find and develop earth and ocean-sourced energy, such as oil, natural gas, coal, uranium, and geothermal. They also find and develop the raw materials needed for renewable energy sources, such as cement and metals for dams, and rare earth elements for wind turbines and solar installations. In addition, geoscientists help determine suitable locations for energy infrastructure, including refineries, transmission lines, dams, and wind farms.

Geologists who work in the petroleum, coal, uranium, and geothermal industries; engineering geologists; hydrologists; geochemists; oceanographers; meteorologists; and climatologists all play important parts in evaluating and implementing the development of all forms of energy. It is the geoscience community that also assesses the impact of energy development on water resources, ecosystems, air quality, and climate. Geoscientists understand the dynamics of Earth's natural processes and are able to reconstruct climates from the past with their atmospheric CO_2 levels, and the associated sea level stands, ecosystem diversity and distribution, and sea water composition. For those reasons, geoscientists can assess how human activities can influence nature, and which activities are environmentally sustainable. Accordingly, geoscientists have an essential role to play in energy policy.

Earth scientists can provide a balanced and realistic perspective in the oftentimes contentious debate about the pros and cons of fossil fuels versus renewable energy and the scope and timing of the transition to energy resources that reduce greenhouse gas emissions. Resolution of the energy issues that are presently being debated will have significant economic, strategic, and environmental consequences. Input from geoscientists is critical to informing the public and policy makers about the consequences of different options.

GSA supports scientific knowledge as a guide to public decisions about the exploration, exploitation, and stewardship of finite energy and mineral resources.

RECOMMENDATIONS

- GSA recognizes that all forms of energy production will be required to meet global energy demand through this century and that no form of energy is perfectly secure or completely devoid of potential negative impacts. However, in order to mitigate negative climate change impacts, GSA encourages policy makers to mandate reductions in carbon and other greenhouse gas emissions through appropriate regulation and legislation that fully considers the economic and security impacts of such mandates, and to facilitate the responsible transition away from fossil fuel energy resources by supporting renewable energy and climate research.
- Research on energy sources and on the environmental, economic, and social impacts and benefits of their development is vital. Continued monitoring and research are necessary to improve forecasts of climate change and impacts to geological and ecological systems.
- Given the dynamic nature of energy markets, state, federal, and global energy policies must be developed in a way that is adaptive to circumstances and innovations and continuously updated to reflect changing conditions. Geoscientists need to be at the forefront of discussions, so that science-based energy policies can be formulated and implemented. The continued responsible development of all forms of energy resources, and the advancement of emerging energy sources, will ensure reliable supplies for the future.
- Global coal resources are abundant. However, the continued use of coal for electric generation will not be possible without continued improvement in technologies to reduce carbon dioxide, sulfur dioxide, nitrous oxides, mercury, and particulate emissions. GSA supports continued research into clean coal technologies, carbon gasification, and carbon capture and storage to consider how best to reduce CO_2 emissions from coal.
- Nuclear power generation emits no carbon. GSA recommends that a national nuclear waste storage solution be developed, and that the U.S. Congress approve the construction and operation of said solution. The recycling and reuse of spent fuels from nuclear power plants should be explored, and the U.S. should determine where and if these opportunities exist, and when and how to implement the process. Research into power technologies such as fusion and thorium-based fission must continue.
- Wind and solar power projects require the permitting and construction of new power transmission corridors, because the optimum sites for wind and solar generation are often remotely located from existing transmission infrastructure. GSA recommends that state and federal regulatory bodies support the permitting of these transmission corridors to facilitate a growing renewable energy portfolio. The geoscience community can provide an assessment of the environmental impact of such transmission corridors and find and develop the natural resources necessary for energy infrastructure construction.
- GSA recognizes that energy efficiency and conservation is one of the most effective, scalable, and near-term solutions to reducing greenhouse-gas emissions from fossil fuels. Much progress has been made recently in mandating increased fuel efficiencies for automobiles; for increased efficiencies in electric appliances; in home insulation; in lighting; and much more. Without energy efficiency measures developed and deployed since the early 1970s, the U.S. would today consume significantly more energy every year than the 100 quads we currently consume. However, more can be done. GSA recommends that state and federal legislative bodies implement policies through regulation and incentives to further increase fuel efficiencies for all forms of transportation; enhance insulation and "smart" electric power and distribution technologies in homes, schools and other public buildings, offices, warehouses, and manufacturing facilities; improve lighting systems; and incentivize and implement

comprehensive recycling programs that are evaluated on the basis of overall societal cost.
- GSA recognizes that the United States has the potential to become energy independent through responsible development of all forms of energy. This would have profound beneficial economic and security consequences. GSA supports efforts to make America energy independent as the nation transitions to an economy with low greenhouse-gas emissions.

REFERENCES AND INTERNET LINKS

1. GSA Position Statement on Climate Change: http://www.geosociety.org/documents/gsa/positions/pos10_climate.pdf
2. National Academies climate information: http://nas-sites.org/americasclimatechoices/
3. Climate position statement of the American Geophysical Union: http://sciencepolicy.agu.org/files/2013/07/AGU-Climate-Change-Position-Statement_August-2013.pdf
4. Climate position statement of the American Meteorological Society: https://judithcurry.com/2012/08/27/ams-statement-on-climate-change/
5. Climate position statement of the American Chemical Society: https://www.acs.org/content/dam/acsorg/policy/publicpolicies/sustainability/globalclimatechange/climate-change.pdf
6. Climate position statement of the AAAS: http://www.aaas.org/sites/default/files/migrate/uploads/aaas_climate_statement1.pdf
7. Climate position statement of the Geological Society of London: http://www.geolsoc.org.uk/~/media/shared/documents/policy/Statements/Climate%20Change%20Statement%20Addendum%202013%20Final.pdf?la=en
8. *Fifth Assessment Report (AR5)* of the United Nations Intergovernmental Panel on Climate Change (IPCC): http://www.ipcc.ch/report/ar5/
9. IPCC Climate Change 2014 Synthesis Report: http://www.ipcc.ch/report/ar5/syr/
10. United Nations Paris Agreement on Climate Change: http://newsroom.unfccc.int/paris-agreement/
11. United States Energy Information Agency International Energy Outlook 2016: http://www.eia.gov/outlooks/ieo/
12. International Energy Agency: http://www.iea.org/statistics/
13. ExxonMobil Outlook for Energy: http://corporate.exxonmobil.com/en/energy/energy-outlook
14. BP Statistical Review of World Energy: http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html
15. GSA Position Statement on Climate: http://www.geosociety.org/documents/gsa/positions/pos10_climate.pdf

OPPORTUNITIES FOR GSA AND ITS MEMBERS TO HELP IMPLEMENT RECOMMENDATIONS

To facilitate implementation of the goals of this position statement, the Geological Society of America recommends the following actions:

- GSA members should seek opportunities to communicate effectively the role and importance of geoscientists to society in locating, evaluating, and developing all forms of energy resources, and assessing the impact of energy resource development and operations on the natural environment.
- GSA members should make clear to national, state, and local governments, community groups, local decision makers, and the general public the link between fossil fuel use and climate change, and the importance of reducing carbon and other greenhouse gas emissions by transitioning to renewable energy resources.
- GSA members should emphasize the importance of including geoscientists in the process of developing and implementing energy policy, because it is the geoscience community that understands Earth's natural processes, the Earth's capacity to produce energy from fossil and renewable resources, and the impact of energy use on the environment.

The Geological Society of America

- Can provide members with readily accessible print, Web, and personnel resources that support geoscientists' communications with decision makers regarding the value of the geoscience community in developing energy policy.
- Can raise awareness of the role of geology and government in mineral and energy resources by publishing articles and conducting symposia, technical sessions, and workshops at annual and sectional meetings on these subjects.
- As GSA members rise to the challenge of informing the public and decision makers about energy, climate, and energy policy, it is important that members' positions and recommendations be supported with objective and reliable energy and climate data.

Some of the best sources for energy statistics include the following:

- U.S. Energy Information Agency (EIA): http://www.eia.gov
- International Energy Agency (IEA) http://www.iea.org/statistics/
- Petroleum Services Association of Canada (PSAC): http://www.psac.ca/business/industry-statistics/
- International Energy Forum (IEF): https://www.ief.org/resources/energy-outlooks.aspx
- ExxonMobil Outlook for Energy: http://corporate.exxonmobil.com/en/energy/energy-outlook
- BP Statistical Review of World Energy: http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

Comprehensive information about climate change can be found at the following sources:

- National Academies: http://nas-sites.org/americasclimatechoices
- NASA: https://climate.nasa.gov
- National Oceanic and Atmospheric Administration: http://www.noaa.gov/climate
- U.S. Environmental Protection Agency: https://www.epa.gov/climatechange
- University of Maine Climate Change Institute: http://climatechange.umaine.edu/about/overview
- United Nations Intergovernmental Panel on Climate Change: http://www.ipcc.ch

Get to Know Your Geoscience ROCK STARS

Florence Bascom with compasses, ca. 1910. Sophi Smith Collection, Smith College.

Bob Garrels conducting fieldwork in the late 1930s or early 1940s. Photo courtesy Cynthia Garrels.

GSA Today's Rock Stars series was developed by the GSA History of Geology Division (now the History and Philosophy of Geology Division), with the first series publication in 1995. Over the years, only 36 articles have appeared in print. We'd like to see more. All articles are submitted to and vetted by the Division. Find out how you can contribute to this series at **www.geosociety.org/RockStarGuide.** The following list and highlights are in order by Rock Star last name. Read the complete articles at **www.geosociety.org/gsatoday/RockStars.htm.**

A Life of Firsts: Florence Bascom, by Jill S. Schneiderman, July 1997, p. 8–9. "Heeding her father's suggestion that she 'make work an immediate joy,' geology, education, and Bryn Mawr were her life."

Norman L. Bowen: The Experimental Approach to Petrology, by H.S. Yoder Jr., May 1998, p. 10–11. "The greatest petrologist of the 20th century is clearly Norman Levi Bowen (1887–1956)."

Thomas Chrowder Chamberlin (1843–1928), by Robert H. Dott Jr., Oct. 2006, p. 30–31. " 'Born on a moraine,' was how America's pioneer glacial geologist in the late nineteenth century, T.C. Chamberlin, described himself."

Preston Cloud: Peripatetic Paleontologist, by J. Thomas Dutro Jr., Aug. 1999, p. 16–17. "Add a mission, in the waning stages of a career, to alert the public to the dual dangers of burgeoning population and steadily decreasing natural resources, and you have the peripatetic Preston Cloud (1912–1991)."

Reginald Aldworth Daly (1871–1957): Eclectic Theoretician of the Earth, by James H. Natland, Feb. 2006, p. 24–26. "In his earliest book, he presented what he called an 'eclectic theory' of volcanic action and magmatic differentiation, and thus I describe him as an 'eclectic theoretician of the Earth.'"

James Dwight Dana (1813–1895): Mineralogist, Zoologist, Geologist, Explorer, by James H. Natland, Feb. 2003, p. 20–21. "To many of his contemporaries, James Dwight Dana was the foremost American geologist of the nineteenth century."

Darwin the Geologist, by Léo F. Laporte, Dec. 1996, p. 8–10. "Today, few people are aware that Charles Darwin (1809–1882) was an accomplished geologist before becoming renowned as a biologist with *On the Origin of Species* in 1859."

George Mercer Dawson: Pioneer Explorer of Western Canada, by Charles H. Smith, Aug. 2002, p. 16–17. "George Mercer Dawson (1849–1901) rendered an extraordinary service in exploring the geology and resources of western Canada—on the prairies, in the foothills, and in the mountains of British Columbia and the Yukon."

John William (Sir William) Dawson: Geologist and Educator, by Susan Sheets-Pyenson, Sept. 1998, p. 14–15. “Despite Dawson’s claim to follow ‘a quiet middle course’ in his scientific work, he loved to plunge into the heat of scientific controversy.”

Kenneth Orris Emery (1914–1998): Pioneer Marine Geologist, by Donn S. Gorsline and Kelvin S. Rodolfo, Nov. 2003, p. 18–19. “The difficult years spanning the Great Depression and World War II were ‘sink or swim’ times for an entire generation and they greatly affected Emery’s development as a person and scientist.”

William Maurice Ewing: Pioneer Explorer of the Ocean Floor and Architect of Lamont, by William Wertenbaker, Oct. 2000, p. 28–29. “During the extraordinary expansion of marine geology after World War II, he was the indispensable leader of the discipline.”

Robert M. Garrels (1916–1988): Pioneer of Modern-Day Sedimentary Geochemistry and Geochemical Cycling, by Fred T. Mackenzie, Oct. 2007, p. 25–27. “His one overriding goal was to understand the origin and evolution of the surface environment of Earth from a geologist’s point of view.”

Robert Minard Garrels (1916–1988), by Lee R. Kump, Feb. 2016, p. 20–21. “One of many pieces of advice Garrels (1916–1988) gave his students was, ‘If you find yourself saying *it’s hard to imagine* … imagine harder!’ Imagining hard is what characterized Garrels’ approach to the earth sciences.”

Model Survey Geologist: G.K. Gilbert, by Joanne Bourgeois, Feb. 1998, p. 16–17. “It would have been hard to predict that a rather sickly, quiet boy from Rochester, New York, would become one of the most famous geologists to explore the American West.”

Charles Frederick Hartt—A Pioneer of Brazilian Geology, by William R. Brice and Silvia F. de M. Figueirôa, Mar. 2003, p. 18–19. “With today’s mechanical and computer-aided tools, it is easy to forget that 100 years ago geological work was accomplished on foot or from the backs of animals, using only great determination, a hammer, and a compass.”

Arthur Holmes: An Ingenious Geoscientist, by Cherry L.E. Lewis, Mar. 2002, p. 16–17. “Holmes lived just long enough to see the dawn of plate tectonics. In 1963, the theory of seafloor spreading was proposed, validating his theories by then almost forgotten.”

Clarence King: Pioneering Geologist of the West, by K.R. Aalto, Feb. 2004, p. 18–19. “Under King’s sound leadership, the USGS became a successful government agency, and by personal example, he put an end to internecine warfare among geologists mapping the American West.”

Andrew Cowper Lawson (1861–1952): How a Boy from Canada Became a Legendary Professor of Geology at Berkeley, by Gerard V. Middleton, Apr./May 2006, p. 50–51. “A ruthless critic, he was rarely persuaded to alter his own opinions. His personality earned him the nickname ‘The King’ at Berkeley.”

Sir William Edmond Logan, Father of Canadian Geology: His Passion Was Precision, by Charles H. Smith, May 2000, p. 22–23. “He raised Canadians’ pride in their geological endowment and competence and in their stature in the international community. He laid the groundwork for the Geological Survey of Canada, which continues the work Logan began.”

A Scientist Concerned about Society: Kirtley F. Mather (1888–1978), by Kennard B. Bork, July 1996, p. 8–10. “The Bolivian work generated an unanticipated response—a search committee from Harvard University was sufficiently impressed by Mather’s presentation at the 1923 meeting of the Geological Society of America that he was invited to join the Harvard faculty.”

Grand Vision of Edwin D. McKee, by Earle E. Spamer, Nov. 1999, p. 18–19. “We geologists are all attached to places—our home landscape, the place we did our first field work, a locality where we discovered something—but few of us devote our careers to one place and use it as a prism through which to view the world. Edwin McKee fell in love with the Grand Canyon and did just that.”

Raymond Cecil Moore: A Great 20th Century Geological Synthesizer, by Daniel F. Merriam, Aug. 2003, p. 16–18. “Moore had a steel-trap mind and total recall so that he never forgot a person, detail, or place.”

Israel Cook Russell (1852–1906), by K.R. Aalto, Feb. 2009, p. 14–15. “Russell traveled alone some 5500 km on horseback through the northern Great Basin, undertaking reconnaissance in a region he was to visit repeatedly throughout his career. He rather liked the wild.”

Francis Parker Shepard, 1897–1985, by Joseph R. Curray, Dec. 2001, p. 20–21. “Shepard conveyed his enthusiasm to all those around him and to two generations of graduate students over his long years of teaching.”

Eugene M. Shoemaker and the Integration of Earth and Sky, by Mary G. Chapman, Apr. 2001, p. 20–21. “He helped train the Apollo astronauts in geologic fieldwork around Flagstaff, and, as the first lunar landing was televised, gave expert geologic commentary from a seat next to Walter Cronkite of CBS-TV.”

George Gaylord Simpson (1902–1984), by Léo F. Laporte, Sept. 2004, p. 16–17. “Later, in college, he had come to the conclusion that ‘life is the most important thing about the world, the most important thing about life is evolution.’”

William “Strata” Smith, by Hugh Torrens, Sept. 2015, p. 38–40. “For much of his life, Smith was ignored or treated as an outsider; in any case, there was not yet much of a proper geological community that could take interest in such an unusual man.”

Laurence L. Sloss and the Sequence Stratigraphy Revolution, by Robert H. Dott Jr., Mar. 2014, p. 24–26. “By the 1930s, Laurence L. Sloss noted that stratigraphy was beset with 'stupefying arguments' about abstract time versus actual rocks and how to classify such things."

Marie Tharp—Plate Tectonics Pioneer, by Hali Felt, June 2017, p. 32–33. "Tharp's unconventional education history made possible her 1952 discovery of the worldwide mid-oceanic rift valley."

W.H. Twenhofel: Patriarch of Sedimentary Geology, by Robert H. Dott Jr., July 2001, p. 16–17. "He walked 700 miles around Anticosti Island while his supplies followed by dories rowed just offshore. It was worth it, because 'Anticosti is ramjammed full of beautiful fossils.'"

Formative Years of the Scientific Career of T. Wayland Vaughan, by Robert N. Ginsburg, Nov. 1995, p. 233–234. "A photograph of Vaughan hangs outside my office, and when students ask who he was, there is an opportunity to explain how curiosity, drive, and making the most of every opportunity helped him to become a leading scientist."

From Farmer-Laborer to Famous Leader: Charles D. Walcott (1850–1927), by Ellis L. Yochelson, Jan. 1996, p. 8–9. "If there was ever a geologist who deserves to be better known in America, and incidentally one who had the most inappropriate middle name, it is Charles Doolittle Walcott."

Johannes Walther (1860–1937): More than the law of facies correlation, by Eberhard Gischler, Aug. 2011, p. 12–13. "It is also interesting to learn that Walther engaged in networking in that he visited most of the well-known geologists and paleontologists of his time in Germany, Austria, and Switzerland."

David White (1862–1935): Pioneer in Coal, Petroleum, and Paleobotanical Studies, by Paul C. Lyons and Elsie D. Morey, June 2006, p. 54–55. "White never missed an opportunity to inspire a young mind, pose a scientific problem, and guide a scientist to its solution."

The Father of Modern Volcanology: Howel Williams (1898–1980), by Alexander R. McBirney, Aug. 2000, p. 26–27. "Though known to most of his friends as "Willie," the title Howel Williams cherished most was one given to him by his students on the occasion of his retirement: The Last of the Ordovices."

J. Tuzo Wilson, by Derek York, Sept. 2001, p. 24–25. "Tuzo Wilson lived for ideas, and those he created were weird and wonderful. Many were wrong, but some were marvelously right. And, until his death in 1993, he never stopped creating ideas."

Geoscience Jobs & Opportunities

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

Classification	Per Line for 1st month	Per line each addt'l month (same ad)
Positions Open	$9.25	$9.00
Fellowship Opportunities	$9.25	$9.00
Opportunities for Students		
First 25 lines	$0.00	$5.00
Additional lines	$5.00	$5.00

Positions Open

FACULTY POSITION IN GEOLOGICAL SCIENCES YONSEI UNIVERSITY

The Department of Earth System Sciences at Yonsei University, Korea, invites applications for a tenure-track faculty position in sedimentology, petrology-geochemistry, resource geology, and other related fields. All (assistant, associate and full) professor levels are considered. The Department of Earth System Sciences supports undergraduate, M.S. and Ph.D. programs in Geological and Environmental Sciences. Yonsei University is one of the premier universities in Korea, located in Seoul. The University may offer reasonable moving expenditure and initial housing for foreign nationals.

Qualifications Required: A successful candidate is expected to build his/her original independent research programs and to seek interdisciplinary collaborations with the Department faculty members and/or other researchers worldwide. The applicant should also have strong passion for teaching and advising students and must have a Ph.D. degree in geological sciences and related fields with postdoctoral research experience.

Application Procedure: Candidates should submit a CV with a list of publications, a statement of research and teaching plans, and the names and contact addresses for two references. Applications that arrive by 7/7/2017, will receive full consideration. Applications should be submitted to Yonsei University following the guideline outlined at the homepage (http://www.yonsei.ac.kr/en_sc/). Other inquiries can be E-mailed to: Tae-Kyung Hong, Chair, Department of Earth System Sciences, Yonsei University, Seoul 120-749, Korea, tkhong@yonsei.ac.kr.

CLINICAL TEACHING FACULTY GEOLOGY, UNIVERSITY AT BUFFALO STATE UNIVERSITY OF NEW YORK

The Geology Department, University at Buffalo, seeks a clinical teaching faculty member, with a title of Clinical Assistant Professor. The successful candidate will teach four courses per semester, or equivalent, and may carry additional service and/or administrative responsibilities associated with the Department's undergraduate programs. The successful candidate will primarily teach courses in the undergraduate curriculum on the following topics: introductory geology, introductory geology laboratories, sedimentary geology/stratigraphy/paleontology, Earth materials, and field courses. Opportunities (depending upon interest and aptitude) include advancing pedagogy and scholarship through attendance at professional meetings and/or mentoring undergraduate research students. This is a 12-month position with additional responsibilities in the summer and winter sessions.

The successful candidate will have earned a PhD in Geology or a closely related field with a conferral date no later than the start of the appointment. Demonstrated teaching ability is required; university teaching experience is preferred. The ability to lead field trips for assigned courses, as well as bend and lift up to 30 pounds is also required.

The initial one-year appointment begins on August 24, 2017, and is renewable for two additional years. Applications, including cover letter, CV, teaching statement and list of 3 references, must be submitted electronically at www.ubjobs.buffalo.edu/postings/9588. The position is open until filled. UB is an AA/EOE and welcomes all to apply including veterans and individuals with disabilities.

HYDROGEOCHEMIST GEOHYDROLOGY SECTION KANSAS GEOLOGICAL SURVEY THE UNIVERSITY OF KANSAS–LAWRENCE

Full-time position to lead KGS hydrogeochemical investigations. Faculty-equivalent, sabbatical-eligible position at Assistant or entry-level Associate Scientist rank. Requires Ph.D. with emphasis on aqueous geochemistry related to groundwater resources, and scientific leadership potential. Background in hydrogeochemistry applied to regional-scale groundwater investigations is desired. The Geohydrology Section has 6 full-time professionals with additional support personnel. Emphasis on state-of-the-science field studies and complementary theoretical research. Complete announcement/application info at www.kgs.ku.edu/General/jobs.html. Review of applications will begin Sept. 30, 2017. Apply online at http://employment.ku.edu/academic/8718BR. For further information contact Geoff Bohling (geoff@kgs.ku.edu) or Don Whittemore (donwhitt@kgs.ku.edu). KU is an EO/AAE, http://policy.ku.edu/IOA/nondiscrimination.

PETROLEUM GEOSCIENTIST (2 POSITIONS AVAILABLE) KANSAS GEOLOGICAL SURVEY UNIVERSITY OF KANSAS–LAWRENCE

Full-time, faculty-equivalent, sabbatical-eligible positions at Assistant or entry-level Associate Scientist rank. Complete announcements/application information at www.kgs.ku.edu/General/jobs.html.

Positions are expected to conduct, publish, and present the results of fundamental and applied research in petroleum geology and related areas that is of national stature and relevant to Kansas. Ph.D. in the geosciences or related field is required. Review of applications will begin Sept. 1, 2017. For further information contact Eugene Holubnyak (eugene@kgs.ku.edu) or Tandis Bidgoli (tbidgoli@ku.edu). For

other questions contact Annette Delaney, KGS Human Resources, adelaney@ku.edu. KU is an EO/AAE, http://policy.ku.edu/IOA/nondiscrimination.

Opportunities for Students

Graduate studies in experimental planetary science, University of Tennessee, Knoxville. The Dygert group at the Department of Earth and Planetary Sciences, University of Tennessee, Knoxville seeks to recruit an MS or PhD student to start in spring 2018. Research topics include experimental and analytical investigations into the thermal and chemical evolution of lunar and planetary interiors, and the origins of Earth's mantle lithosphere. Motivated candidates with strong organizational and communication skills are encouraged to apply. The successful applicant is expected to assist in assembling and calibrating a high pressure experimental petrology laboratory; technical, mechanical, and/or quantitative expertise of any type is preferred. Interested parties are encouraged to contact Nick Dygert at nick.dygert@gmail.com; please include a CV or resume in your message. Applicants attending the 2017 Goldschmidt conference in Paris can organize an in-person meeting. Knoxville has a growing downtown arts and nightlife scene, low cost of living, a pleasant climate, and excellent outdoor recreation opportunities in the nearby Smoky Mountains.

ETH zürich

Assistant Professor (Tenure Track) of Mineral Resources

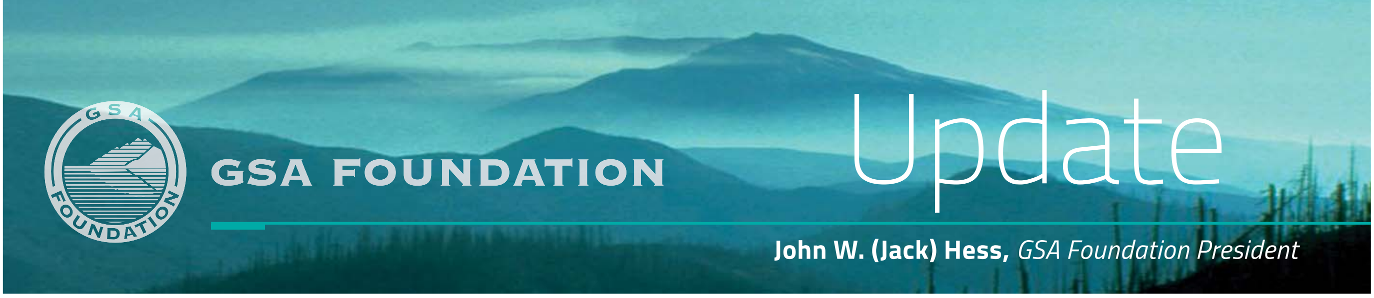
→ The Department of Earth Sciences (www.erdw.ethz.ch) at ETH Zurich invites applications for the above-mentioned position. The professorship offers long-term funding to establish new laboratories and a dynamic research team that should be created at the core of an innovative research program. Research fields may comprise physical and chemical processes as well as time scales of ore formation, mineral precipitation from fluids and melts, the processing of man-made resources or aspects of resource evaluation. The program is in part field based but may also include experimental aspects.

→ The successful candidate has a strong analytical background, and will combine analytical and theoretical investigations of ore and related resources. He or she is a leading scientist connected to the industry of ore exploration as well as companies or government agencies dealing with man-made deposits. The new professorship will contribute to introductory and advanced courses on ore formation and related fields, and teach field and laboratory methods relevant to ore exploration. Generally, undergraduate level courses are taught in German or English and graduate level courses are taught in English.

→ Assistant professorships have been established to promote the careers of younger scientists. ETH Zurich implements a tenure track system equivalent to other top international universities.

→ **Please apply online at: www.facultyaffairs.ethz.ch**

→ Applications include a curriculum vitae, a list of publications, a statement of future research and teaching interests, and a description of the three most important achievements. The letter of application should be addressed **to the President of ETH Zurich, Prof. Dr. Lino Guzzella. The closing date for applications is 31 July 2017.** ETH Zurich is an equal opportunity and family friendly employer and is responsive to the needs of dual career couples. We specifically encourage women to apply.



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

Discovering Talented Young Geoscientists: Corporate Hiring from GSA's Student Membership

Worthy programs like GSA's GeoCareers Day have been supported by corporate partners since their earliest years during GSA's Annual Meeting. While formats have shifted to best serve both students and participating organizations, the aim endures: to inform students about a variety of geoscience career paths across sectors—including necessary preparation to enter these different sectors—as well as providing mentorship and networking opportunities with professionals. Employees from some of the same supporting companies also join together to teach short courses at GSA's meeting, or serve as small-group and one-to-one mentors. They confirm a notable benefit to participating in our student programs: The Society's large student membership brings together a wealth of bright, talented young geoscientists from a diverse reach beyond the relatively restricted number of the usual recruiting schools. Chevron Energy Technology Company is one of GSA's longtime corporate participants in these programs, including its support of the careers program since 2007.

Since 2009, Morgan Sullivan, a geologist with Chevron, has helped instruct a short course at GSA's Annual Meeting. He has been pleased to notice a number of interns and full-time employees within the company who were initially discovered through GSA programs like the short courses or careers sessions. "Selecting interns is a challenging process with so many qualified students, but we have one starting in May whom I met during the short course at GSA last fall. He is from a university that Chevron doesn't recruit at, and we would have never met him otherwise."

That student is Dreadnaught Stubbs, a second-year master's student of geological sciences at Ohio University, who says

> I attended GSA Denver in order to get exposed to professionals in prospective industries I was interested in. I made sure to sign up for a short course because they are great opportunities to learn subjects and methods which are not offered at most universities. The Sequence Stratigraphy for Graduate Students short course was taught by industry geologists who gave clear explanations of complex principles and provided applicable teamwork-oriented exercises. The short course gave me the opportunity to apply the critical thinking skills I have developed during my education. It was also a great way to meet other students who were interested in the same subjects. After the course I was offered an opportunity to participate in an internship program with Chevron, an opportunity I would otherwise be hard-pressed to come by because companies do not recruit geologists at my university.

GSA's students are one of our greatest strengths. If you would like more information on how you as an employee, or your organization, can be involved in greater interaction with students through GSA programs, please contact Debbie Marcinkowski at +1-303-357-1047 or dmarcinkowski@geosociety.org.

Morgan Sullivan teaching a sequence stratigraphy short course at GSA 2016 Denver, Colorado, USA.

Dreadnaught Stubbs at field camp in Badlands National Park, South Dakota, USA.

Dreadnaught presenting a poster during GSA 2015 Baltimore, Maryland, USA.

The Need for a Paradigm Shift in Science Advocacy

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Sixteen years into the twenty-first century, many are dismayed at the resiliency of skepticism about science in the United States. On wide-ranging subjects, such as vaccinations, genetically modified foods, climate change, evolution, and the age and origin of the Earth and universe, a sizable percentage of the population continues to hold and promote views that run counter to common scientific understanding. An oft-cited Gallup poll (2015) illustrates the lack of progress. In 1982, a question was posed regarding beliefs about human evolution. At the time, 44% believed God made humans in their present form. After a quarter century of improved educational materials, upgraded K–12 science standards, and several successful court battles to curb anti-science influences, that number has remained essentially unchanged. The last poll in 2014 pegged the number at 42% (Gallup, 2015).

Other polls tell a similar story. A 2014 poll by the Associated Press found that 4 out of 10 people in the United States have doubts about the validity of a 4.5-billion-year history for the Earth and about the evolution of life forms through a process of natural selection. A 51% majority is skeptical about the "Big Bang" (Borenstein and Agiesta, 2014). The Pew Foundation took a different approach, asking people whether they thought scientists were in agreement on these topics. More than half the people surveyed believe scientists are currently divided on the origin of the universe, and more than a third believe scientists still lack internal consensus on evolution (Funk and Rainie, 2015).

The outlook for the near future is not encouraging. Berkman and Plutzer (2011) report that nearly three quarters of high-school science teachers are reluctant or unwilling to teach evolution or ancient earth history. According to their survey, 13% of science teachers reject evolution outright, while an additional 60% ride the fence, being uncertain of the veracity of scientific evidence or simply fearful of generating controversy. This not only means that earth history is not being adequately taught, it also means that many young people are being diverted from eventual careers in the earth sciences at a time when it is predicted that available geologist positions will substantially outpace college graduates (Wilson, 2014; LaDue and Manning, 2015).

It should be clear at this juncture that the strategies employed to improve science education and public understanding, while arguably worthwhile, have fallen far short of expectations. It is time for a paradigm shift. We suggest that this shift needs to come in two parts. The first is a more realistic understanding of the opposition. Modern scientific skeptics are often characterized as backward, uneducated, religious and political conservatives, blindly adhering to outdated beliefs, who can be shamed, browbeaten, educated, or outvoted into submission. Yet, in reality, their ranks include successful doctors, engineers, lawyers, business leaders, and politicians (even presidential candidates). If we simplify the discussion to consider just creationists holding to a recent origin of the Earth, up to a third are college educated (Duncan and Geist, 2004). Creationist leaders include individuals like John Baumgardner, a retired Los Alamos engineer with a Ph.D. in geophysics from the University of California at Los Angeles, and Kurt Wise, a vertebrate paleontologist who earned his Ph.D. from Harvard under the late champion of evolution Steven Jay Gould. Mental deficiency and poor education are not adequate explanations for belief in creationism.

The one stereotype that is justified is religious affiliation. All religions, by definition, disavow purely mechanistic explanations for our existence, though not all are inherently opposed to the findings of modern science. Islam, Judaism, and Christianity share a common story of the universe brought into being by a singular deity. Within these traditions, beliefs vary whether the story is to be properly considered as a literal telling of six days of creation, or a poetic rendering of God's action that leaves room for deep time and evolutionary development of life (e.g., Haarsma and Haarsma, 2011; Kaya 2012). Other world religions, such as Hinduism and Buddhism, while adhering to spiritual or mystical dimensions of this or other worlds, are generally comfortable with the descriptions of modern science as the visible workings of the natural realm and are not at the forefront of anti-science rhetoric.

For those who have been convinced that science is antithetical to the Bible, the Torah, or the Quran, improved secular educational materials serve no purpose because they go unread. Contrary to popular perception, it is not simply a willful blindness. There is a measure of practicality. With all the material competing for attention, few will take the time to read or study material that advocates for something they believe is based on inherently false assumptions, or that attacks their fundamental beliefs.

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This brings us to a second essential element of a paradigm shift, one that recognizes the importance of trust when challenging entrenched beliefs. According to a study by Kahan et al. (2011) on why "scientific consensus" fails to persuade, the degree to which "experts" are trusted depends on how well they align with the cultural values of the audience. Put bluntly, if the scientists arguing a case are avowed atheists or promote views openly antagonistic to all forms of religious belief, the message is effectively dead on arrival. Ironically, books and speaking tours of touted atheists striving to advance science education can actually make the situation worse. The science-against-religion message effectively vaccinates the science-skeptical public against ever considering the evidence and deepens the divide.

If we are serious about science advocacy, it is time to recognize the important role that scientists of faith can play as liaisons and resources for outreach. A scientist who affirms the basic religious views of an audience is much more likely to be listened to when arguing for the legitimacy of modern scientific understanding. One has only to peruse the websites sponsored by BioLogos, the American Scientific Affiliation, and AAAS's Dialogue on Science, Ethics, and Religion program, to see that there are many religious scientists interested in bridging this gap. Our own experience in visiting Christian seminaries, colleges, and churches has been very encouraging. Once the requisite trust is established, minds become much more open to considering the veracity of natural evidence. We have seen former skeptics become excited even on subjects like evolution when presented by someone who affirms their own faith and who can explain how they themselves have wrestled through the apparent conflicts.

This in no way suggests that the scientific community must *affirm* religious belief. The argument is more in keeping with the successes achieved by scientists such as E.O. Wilson in finding ways to cooperate with those of differing belief systems toward a common objective. For Wilson, a self-professed secular-humanist, it has been finding common ground between religious and non-religious communities to promote the care and stewardship of nature (Wilson, 2006).

So what does this mean in terms of practical science advocacy? This could be as simple as keeping a short list of sources (websites, blogs, or books) that promote good science from a religious perspective that can be recommended to someone struggling between faith and science. For our part, we are excited about the recent release of a multi-author project aimed principally at the educated, religious public—*The Grand Canyon, Monument to an Ancient Earth*—an irenic, full-color book, describing why Noah's flood cannot explain the geology of the Grand Canyon or the Earth's fossil-bearing layers (Hill et al., 2016). Eight of the authors are Christians; three are not. All are committed to the advancement of good science.

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GROUNDWORK

Furthering the Influence of Earth Science

Advancing Geoscience Research through CIDER

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With growing technical sophistication in the earth sciences and increasing specialization within its subdisciplines, geoscientists face an organizational problem when we want to tackle grand research challenges that span many disciplines. How do we bring the various fields together to leverage their individual strengths and create something more than the sum of the parts? This is the problem that CIDER (Cooperative Institute for Dynamic Earth Research) attempts to solve.

CIDER is an institute "without walls" that brings together experts from a wide range of disciplines with the goal of advancing understanding on grand challenges that require a multidisciplinary approach and engages geoscientists at all levels to look at the entire Earth as a system. It has been funded by the National Science Foundation (NSF) since 2003, most recently through the Frontiers in Earth Systems Dynamics (FESD) program.

Why CIDER? Even though almost half a century has passed since the acceptance of the plate tectonics theory, many fundamental components of Earth's dynamic systems remain poorly understood. Some examples of questions that CIDER addresses include (a) connections between mantle convection and the forces that drive plate motions; (b) coupling between the dynamics and geochemical fluxes of Earth's surface and interior; and (c) Earth's evolution from its early violent beginnings to its modern state. Significant progress on these questions can only be achieved through efforts involving several fields (e.g., seismology, geodynamics, mineral physics, petrology, geochemistry, geomagnetism, geology), which provide complementary constraints on Earth's structure, dynamics, and evolution. All these fields have evolved to very high levels of specialization, making the latest research presented at conferences and in publications less accessible to non-specialists. Appreciating the robustness but also the uncertainties in a field other than one's own presents a growing challenge.

In establishing its format, CIDER was initially inspired by the Kavli Institute for Theoretical Physics (KITP) in Santa Barbara, California, USA, which provides an immersive environment for informal interactions among researchers in physics. KITP has a dedicated building, where each visitor has office space and access to research and information infrastructure. There are few formal activities, but interactions among participants are facilitated by the building layout, with many open areas for meetings equipped with blackboards and chairs and abundant access to coffee and tea.

Adapting this model to the specific needs of the geoscience community, and specifically to provide an intellectual framework for integrated multidisciplinary research and education, was the work of a pioneering group of enthusiasts, including Adam Dziewonski and Stan Hart, and evolved over several years by successive approximations to its present steady state.

CIDER activities are organized around a five- to six-week–long summer program, the core of which is a four-week tutorial aimed at advanced graduate students, post-docs, and faculty. CIDER encourages sustained, in-depth interactions among participants. To achieve this, senior participants are required to spend at least two weeks on site, while students and post-docs commit to the entire tutorial session.

The four-week tutorial includes two weeks of structured and intense lectures and tutorials, designed to bring both junior and senior participants up to speed in the different disciplines, with a focus on a particular "theme." The lectures and hands-on exercises target the non-specialists in a particular discipline and progressively build from basics toward current research questions and multidisciplinary challenges. All the lectures are recorded and posted publicly on the CIDER wiki (see http://www.deep-earth.org/wiki_cider/CIDER_Lecture_Collection). Lectures are designed so that informal interruptions are encouraged, inviting questions that frequently lead to unexpected discussions involving both students and senior participants. Cross-disciplinary education across generations is a valued aspect of the summer program. Most senior participants attend most of the lectures, which frequently results in stimulating discussions among several experts in the same discipline. This open environment means that the lectures differ from conventional teaching environments, providing different points of view and a better sense of the challenges and state of knowledge in a given discipline, and how the different disciplines complement each other. Assessments and evaluations by participants are administered and collected by an independent team (see http://www.deep-earth.org/wiki_cider/CIDER_Program_Evaluations).

As the tutorial session progresses, time is set aside for several plenary sessions, in which junior and senior participants together are encouraged to propose topics for multidisciplinary research projects. Their relevance to CIDER and to the annual theme, as well as timeliness and feasibility, are discussed. This is a remarkable self-organizing process—while nothing is planned or preprogrammed, it always seems to work!

By the end of the two-week lecture session, five to seven research topics emerge, each involving groups of about five to eight participants, balanced in disciplinary

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expertise, composed of individuals at all stages of their career. Examples of such projects include evaluation of the possible processes leading to growth of the inner core, assessment of the global scales of mantle heterogeneity, and evaluation of fluxes of subducted volatiles.

Once the groups are formed, they spend the following two weeks working on the selected research topics (Fig. 1). Typically, a group will start by reviewing the relevant literature and performing simple computations. In two weeks, there is rarely sufficient time to complete the research, but many of the groups are able to identify a roadmap for future steps, and continue working together over the following year, with modest support from CIDER. This can have various outcomes, ranging from presentations at American Geophysical Union (AGU) to publications and collaborative proposals.

The progress of the research groups is presented to the community at a one-day workshop held at The University of California Berkeley right before or after the meeting of the AGU each December. In addition, CIDER provides support for two or three multidisciplinary working groups each year (see reports at http://www.deep-earth.org/wiki_cider). These working groups, formed independently of the summer programs, bring together 10–20 scientists from different disciplines to advance the understanding of, or define research goals for, specific topics or concepts. For example, a working group was formed in 2013 to define what is needed to construct the next seismological global Reference Earth Model (REM), with input from the mineral physics and geodynamics community. It was decided that the next REM should include long-wavelength 3D structure, which is by now well constrained. An international effort to construct the REM is now under way, supported by the NSF.

Most importantly, CIDER provides a platform for successive generations of very early career scientists to encounter their peers from different disciplines, forming lasting professional relationships, and to interact with some of the leading senior experts in our field. Conversely, for the senior participants, it is an opportunity to get to know the upcoming generations. CIDER summer sessions include many opportunities for informal interactions, such as joint lunches and twice-weekly dinners/barbecues. Also, because CIDER is such a long program, we make all possible efforts to be family friendly. Numerous dual-career couples with young children have participated in the CIDER programs. Many former CIDER students have gone on to faculty jobs and are now returning, five or more years later, as lecturers, substantially improving the age and gender distribution of the latter. Such was the case for six of the lecturers in the 2016 CIDER program. Other alumni have gone on to successful careers in business, politics, or government, benefiting from CIDER through experience in building and leading teams, working on open-ended problems, thinking about complex multidisciplinary problems, and learning how to communicate across disciplines. A future challenge is to assess and quantify how CIDER experiences have impacted the careers of participants, the nature of their research, and the impact on interdisciplinary collaborations, over both short and long time scales.

Summer programs on topics related to the deep Earth have been held every two years at KITP since 2004. CIDER participants take advantage of exposure to concurrent KITP programs with some relevance to geoscience, such as, for example, a program on "Dynamos" in 2008 and the "Physics of Glasses" in 2010. The FESD funding has allowed CIDER to broaden its scope and, in alternate years, include themes related to research questions at the interface of the solid Earth and the fluid envelopes (e.g., "Mountain Building" or "Solid Earth and Climate").

Many of the same "grand challenge questions" have been brought up repeatedly in discussions at CIDER, and progress is tangible over the past 12 years; for example, the stated goal of our first program in 2004 was to combine information from geochemistry and seismology to better constrain deep Earth dynamics. This is an extremely ambitious goal, because geochemistry samples the Earth locally and global coverage is spotty, whereas at the global scale, seismic tomography best constrains long-wavelength structure. In the past decade, tomographic resolution has improved significantly, as has global coverage of geochemical sampling. Geochemists and seismologists understand each other better and, together with geodynamicists, are now better poised for such multidisciplinary analysis. Several such efforts are under way, and CIDER will revisit the questions of the origin and implications of mantle heterogeneity in its 2018 summer program, to be held at KITP.

Judging by the momentum gained over the past decade, CIDER helps fill an important need for the geoscience community, stimulating research on outstanding interdisciplinary geoscience problems and engaging geoscientists at all levels in this effort. This need, as discussed at the community workshop held at the Marconi Conference Center (Marshall, California, USA) from 5–8 May 2016, will continue with the arrival of successive new generations of early career geoscientists. We are looking forward to continuing CIDER for the foreseeable future and to broadening international participation.

For more information about CIDER, visit http://www.deep-earth.org.

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Figure 1. Research group at work during the 2016 CIDER summer program at KITP.

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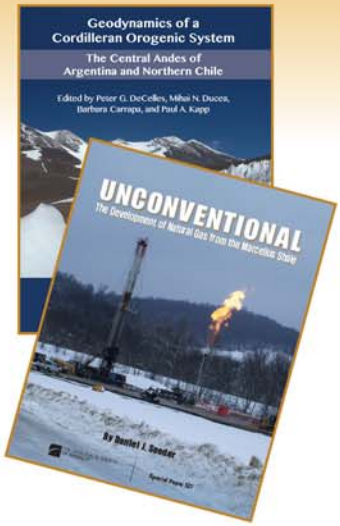

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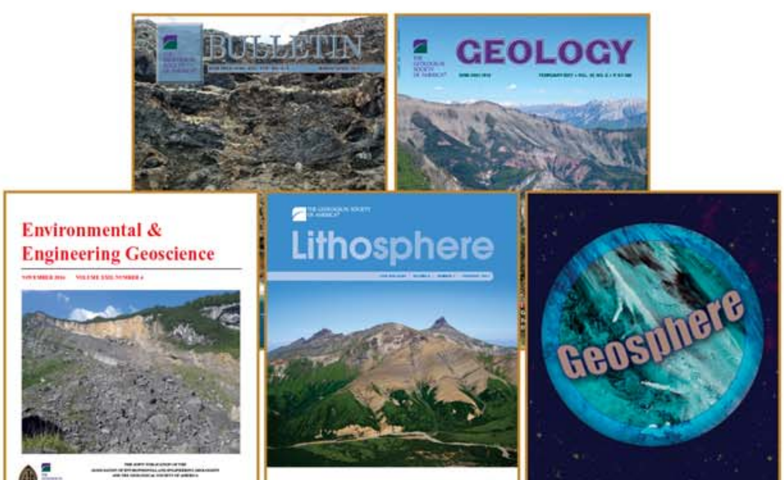

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