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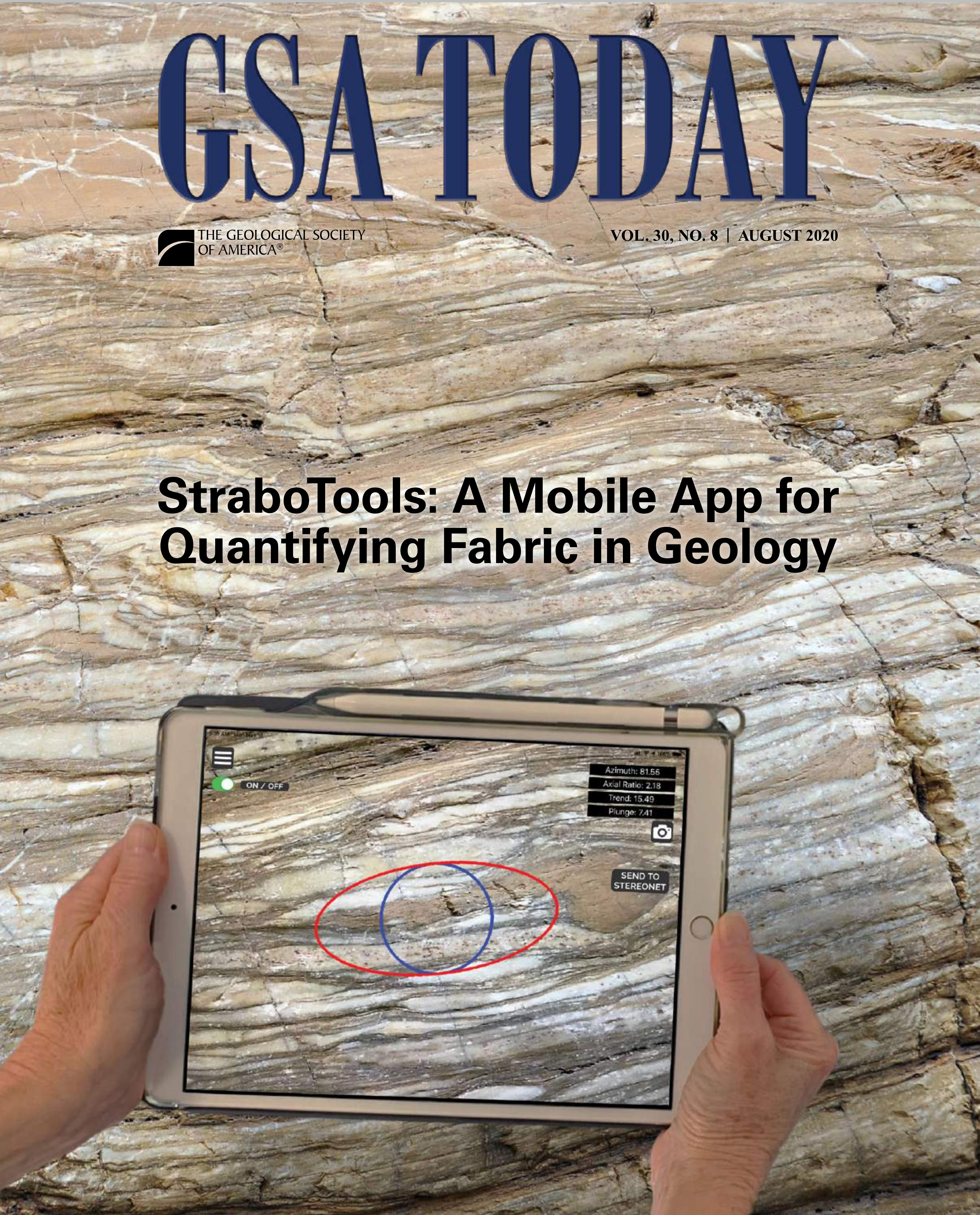
StraboTools: A Mobile App for Quantifying Fabric in Geology



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SCIENCE

Cover: StraboTools app in action, measuring the strength of fabric in highly deformed Proterozoic Noonday Dolomite, Death Valley National Park, California, USA. For the related article, see pages 4–10.

GSA 2020 Connects Online

StraboTools: A Mobile App for Quantifying Fabric in Geology

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ABSTRACT

Quantification of field observations is an essential step in making them reproducible and shareable, but field geologists have few tools for quantifying field observations of important features such as foliation intensity, crystal alignment, vesicle elongation, joint intensity, and mineral proportions. Here we describe a mobile app, StraboTools, which offers two ways to rapidly and objectively quantify these variables. The edge fabric tool examines grayscale gradients in a photograph and summarizes them with the edge fabric ellipse. For deformation of a homogeneous material with passive markers, this ellipse tracks the strain ellipse. Edge fabric ellipses can be determined on the outcrop and make quick work (5 seconds) of formerly time-consuming and subjective strain-analysis tasks (e.g., Fry and R_f/ϕ analysis). They are remarkably sensitive to subtle deformations that are difficult to see by eye. The color index tool determines the proportion of any component in the photograph whose grayscale level can be isolated (e.g., dark minerals in a granitic rock, feldspar phenocrysts in a lava, or blue epoxy in a thin section). Estimating proportions by eye has poor precision and accuracy; the color index tool is both accurate and precise if a suitable rock face is available. These tools can be used with photomicrographs and aerial photographs as well as in the field.

INTRODUCTION

The granite outcrop in Figure 1A is clearly deformed, with a nice shear fabric running from lower left to upper right in the photo, and a field geologist could easily measure its orientation with a compass. How strong is the fabric? That is harder to quantify, and the geologist would likely apply an adjective such as "moderate" or "strong" in the field and bring an oriented sample back to the lab for further analysis if desired.

Is the granodiorite in Figure 1B deformed? Most observers would say no, but this image, of an originally isotropic granodiorite, was digitally distorted by flattening in one direction and stretching in the perpendicular direction (pure shear). We venture that few would call this a measurable fabric in the field. Being able to detect and measure such subtle features would greatly aid studies of deformation, flow alignment, and related fabrics.

Is there a pebble imbrication in Figure 1C that gives the local direction of current flow? What is the proportion of dark minerals in Figure 1D? These can be difficult questions to answer, and recently at the outcrop in Figure 1D, several professional geologists gave answers ranging from 5% to 30%. This illustrates how difficult this simple and important measurement can be using the eye alone.

This sort of observation and measurement has occupied much of the field workflow in structural geology, petrology, and sedimentary geology for a century or more. Still, such work can be frustratingly qualitative and incomplete. Quantitative and repeatable measurements are the backbone of much of scientific inquiry, yet field geologists have few tools available for making them on many types of features.

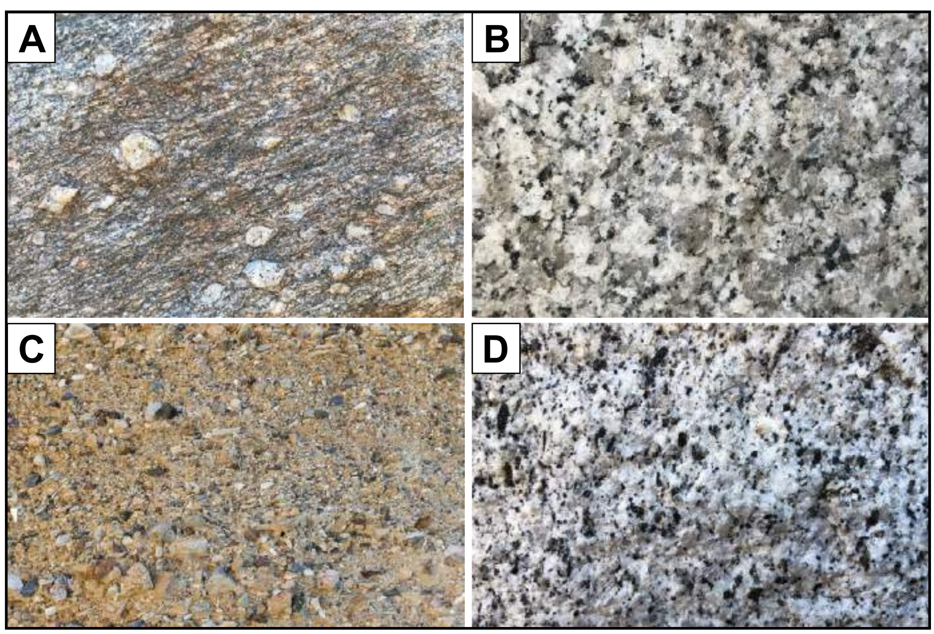

Figure 1. Examples of difficult field problems that can be solved with StraboTools. Answers are in Appendix 1. (A) Deformed granite. The foliation is obvious and easy to measure, but quantifying its strength is difficult to do in the field. (B) Subtly deformed image of a granodiorite outcrop. Do you see a fabric? What deformation was applied? (C) Shadowed outcrop photograph of a cliff in alluvial fan deposits. Is there a pebble imbrication indicating the direction of stream flow? (D) What is the proportion of dark minerals in this granodiorite?

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Today, tools available to the field geologist are much the same as they were a century ago: devices for measuring angles, bearings, and distances, and a few categorical measurement aids such as an acid bottle and a magnet. Although mobile phones and laser rangefinders are replacing the compasses and tape measures of yore, the domain of properties that can be measured is largely the same. Field studies are typically the prelude to a comprehensive set of laboratory measurements of chemical composition, porosity, mineral age, mineral or clast preferred orientation, remanent magnetism, and other useful things. Such laboratory studies could be significantly enhanced if some of these properties could be measured in the field. If such measurements could become routine and ubiquitous, then field studies would produce richer results.

It is possible to bring devices into the field to measure chemical composition, magnetic susceptibility, gamma-ray emissions, rock hardness, and other rock properties. These tools are valuable for mapping subtle variations that may be unmappable by eye (e.g., Parkinson, 1996; Aydin et al., 2007; Dühnforth et al., 2010; Coleman et al., 2012), but they are expensive and not widely employed. As a result, aside from orientation measurements, fieldwork is still done in a mostly qualitative or semiquantitative manner, using phrases such as "strong fabric," "coarse-grained," "dark," or "poorly sorted," rather than quantitative measures. For structural analysis, several algorithms have been developed for semi-automated fabric determination from images (e.g., Launeau et al., 1990; Ailleres and Champenois, 1994; Vinta and Srivastava, 2012), but these require processing in the lab.

In this paper, we introduce a mobile app, StraboTools, which allows rapid field measurement and quantification of three quantities: fabric orientation, fabric strength, and the percentage of dark or light minerals in the field of view.

STRABOTOOLS

The StraboTools app provides quantitative data at the outcrop that are otherwise difficult or impossible to estimate in the field or that might be subject to large uncertainty and user-to-user variation. The app was developed for work in plutonic rocks such as granite, but it can be used for fieldwork in any type of rock and for study of thin sections and aerial photographs as well. The analysis uses a photograph taken within the app or imported into it.

The app, currently available for iOS only, comprises two principal tools: edge fabric (EF), for measuring and quantifying preferred orientation, and color index, for determining the percentage of dark minerals. The color index (CI) tool can be used to estimate the abundance of any component that can be separated from others based on grayscale, such as light-colored phenocrysts in a volcanic rock.

THE EDGE FABRIC TOOL

Edge Fabric

Measuring fabrics such as bedding, foliation, and lineation is a large part of geologic fieldwork in structural geology, petrology, and sedimentology. The resulting data (strike and dip or trend and plunge) are quantitative and easily digitized. However, a quantitative assessment of the strength of the fabric is difficult with traditional field tools, and weak fabrics are difficult to reproducibly measure and quantify if they can even be seen at all.

The EF tool provides rapid measurement of preferred shape orientation of grains and can pick up fabrics too subtle to detect by eye alone, such as in Figure 1B. The EF tool works by examining the orientations of grayscale gradients, which are typically particle edges, in the image. To illustrate, Figure 2A shows a 50-by-50 pixel image of two gray stripes and a gray dot. At each pixel, there is a direction of maximum grayscale brightness increase, and its length corresponds to the sharpness of the gradient. These vectors are shown in Figure 2B; blank areas are where the brightness does not vary, and the vectors have length zero. Most of the long brightness vectors point away from the centers of the stripes, and a smaller number point at various other directions. In Figure 2C, all of the vectors from B have been translated to the origin and rescaled. There is a clear concentration perpendicular to the trends of the stripes, which defines the orientation of the long axis of the edge fabric ellipse (EFE; Fig. 2D).

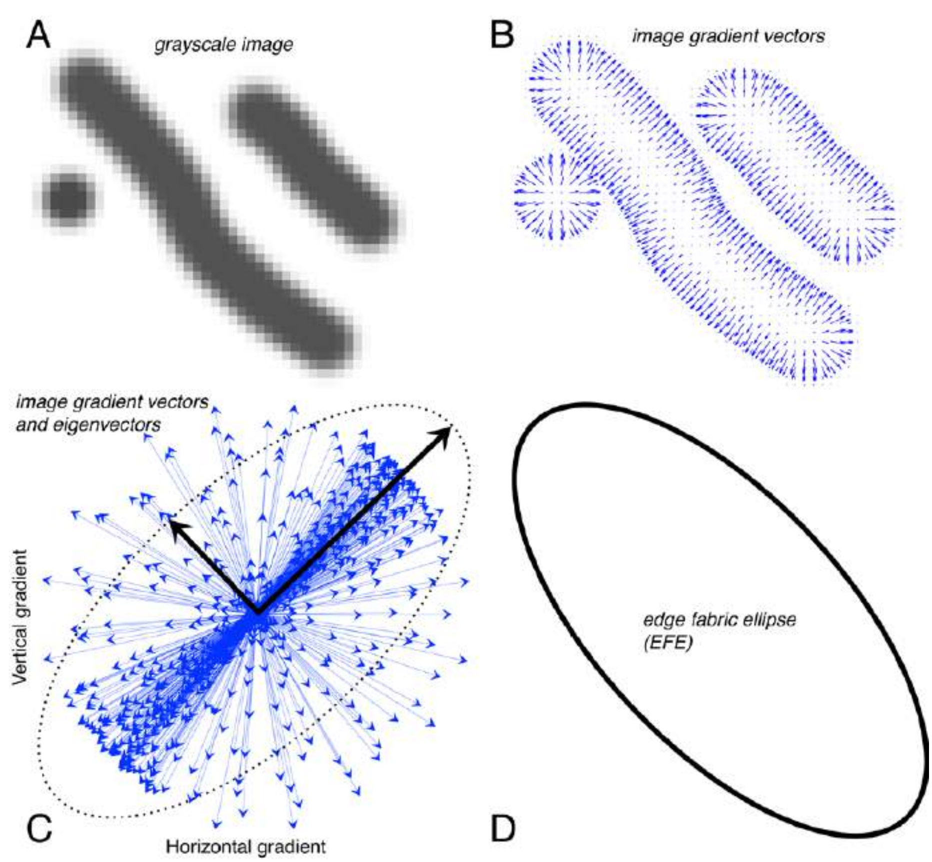


Figure 2. (A) An image of gray stripes 50 pixels on a side. (B) Vectors showing magnitude and direction of the brightness gradient at each pixel. (C) Vectors in B translated to the origin, showing strong grouping perpendicular to dominant edges, along with scaled eigenvectors and ellipse defined by them. (D) Edge fabric ellipse (EFE) derived by rotating ellipse in C 90°.

Axis lengths and orientations are computed using the eigenvectors and eigenvalues of the variance-covariance matrix (Appendix 2). Because the vectors are oriented perpendicular to edges, and we want the dominant edge direction, we simply rotate the ellipse 90° to produce the EFE (Fig. 2D). The aspect ratio of the EFE, designated E, is a measure of the strength of the fabric defined by edge alignment.

The EFE determined from grayscale gradients should be equivalent to the strain ellipse in the case of deformation of a homogeneous material with passive markers. However, empirical tests show that for images deformed digitally by pure shear,

$$E = R^k, \qquad (1)$$

where R is the standard strain ratio (ratio of long and short axes of the strain ellipse), and the exponent k typically lies in the range 1.2–1.5 for images of natural samples (e.g., granite or sandstone). Because $k > 1$, the aspect ratio of the EFE, E, is less than that of the strain ellipse, R. This is likely a consequence of image pixelization, and a full treatment of this is beyond the scope of this paper.

Measuring Edge Fabric

To determine EF, the user takes a photograph of a suitable rock face with the mobile device held parallel to the face. The app then calculates the EFE. The tool gives a measure of the fabric's magnitude by reporting the axial ratio E of the ellipse and its orientation by giving the azimuth and trend and plunge of its long axis (Fig. 3). Azimuth is the orientation of the long axis in the plane of the device, and trend and plunge give the orientation of this line in space using the internal magnetometer, gyroscope, and accelerometer of the mobile device to determine its attitude at the time an image is captured. If the feature on the image is produced by, for example, the intersection of foliation with the rock face, then the long axis of the EFE is an intersection lineation that lies in the foliation plane.

Quantifying Strength of Fabric

Fabrics observed in the field can range from mylonites with simple shear strains in the thousands to barely discernible foliations or pebble imbrications. Although the strength of mineral alignment, shape-preferred orientation, and other features can be quantified in the lab, on the outcrop, one is left with qualitative descriptions such as "strong fabric."

The EF tool gives a quantitative measure of fabric strength. In Figure 4, a shear zone comprises various high-strain zones cutting weakly foliated granodiorite. By making EFEs in subareas, a gradation in strength and orientation of fabric is clear. This can be done rapidly on the outcrop.

Making Fabric Measurement Portable and Fast

Perhaps the most commonly used text on quantitative strain analysis is Ramsay and Huber (1983) Sessions 5–8 (pages 73–149). They describe methods and give exercises appropriate to the sorts of rocks discussed here, with the analyses commonly performed using the Fry (1979) center-to-center technique or the R_f/ϕ technique of Dunnet (1969). The former involves finding anticlustered markers and graphing their center-to-center distances; the latter measuring the aspect ratios and elongation directions of elliptical markers, and then finding a finite-strain ellipse that best

Figure 3. Using the edge fabric tool. The mobile device is held parallel to the plane being photographed. The app calculates the edge fabric ellipse and reports its azimuth (long axis of the ellipse, relative to "up" on the screen), its trend and plunge in space, and its axial ratio *E*. Calculations take 5 seconds or less. The analysis can be captured as a screenshot, and the trend and plunge can be copied for pasting into Stereonet Mobile (Allmendinger, 2019). StraboTools locks to landscape display.

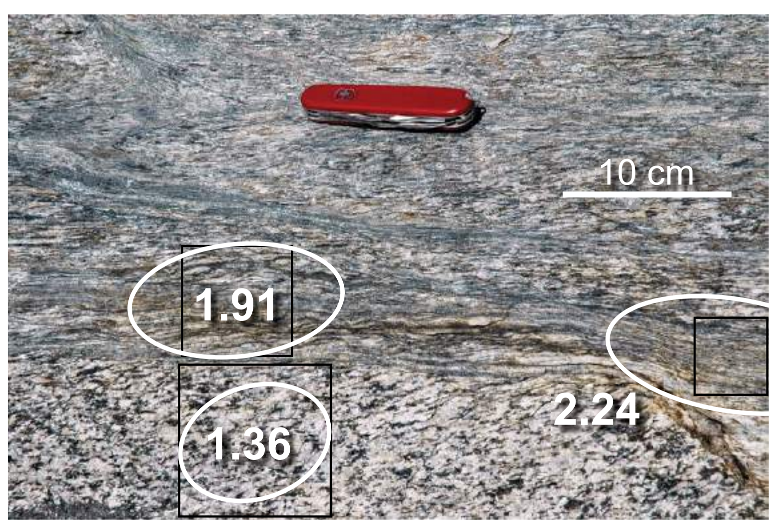


Figure 4. Edge fabric ellipses of three subareas of this shear zone provide field-obtainable, objective measures of fabric intensity and orientation. Shear zone cuts Jurassic granodiorite near Chickenfoot Lake, Sierra Nevada, California, USA.

explains them. Both techniques are labor-intensive and subjective, even with image analysis and automation.

EFEs allow rapid analysis of deformed markers in the field or laboratory. Figures 5A–5D show three artificial examples, and in each case, the EFE determined from StraboTools provides a close estimate of the imposed strain. Figure 5C shows randomly oriented, randomly shaped ellipses, deformed by 10% pure-shear stretching (strain ratio $R = \frac{1.1}{1/1.1} = 1.21$) along an azimuth of 065. The EFE (red) is almost coincident with the imposed strain ellipse (blue), yielding an EFE aspect ratio E of 1.18 and an azimuth of 063. This is a classic subject for R_f/ϕ analysis, but it is difficult to see how one could infer the true deformation (blue star in Fig. 5D) from the scatter of R_f/ϕ points. The EFE solution (red star) again aligns well with the true deformation.

Figure 5E is a thin-section view of deformed quartzite from Ramsay and Huber (1983, *their* figure 7.16, p. 118). Their Fry plot is given in Figure 5F along with the EFE. In such a plot, the shape of the hole in the center is an estimate of the strain ellipse. Ramsay and Huber (1983, p. 124) noted, “It is not an easy matter to identify with confidence the dimensions of the elliptical form of the point data,” highlighting the subjectivity involved in determining R. The EFE provides a good fit to the Fry plot and is an objective measure of the fabric.

EFEs have utility in other fields as well. At the micro scale they allow measurement of orientation and strength of microlite alignment, vesicle elongation, compaction fabric, and other textural features in thin section. At the macro scale they offer a way to measure and quantify the orientation and frequency of joints, dikes, and other features on aerial photographs. Because of its speed and ease of use, StraboTools makes taking many measurements a practical and efficient reconnaissance exercise.

Caveats

It is important to note that the EFE is simply a measure of the preferred orientation of grayscale gradients in the image. If we take a homogeneous image to start, whether it be a rock or artificial random pattern of circles, E correlates with the distortion we apply to the image, which approximates the finite strain.

Sedimentary compositional or textural banding typically produces EFEs with large Es, but these are not a result of deformation. In thin section, plagioclase twinning, perthitic texture, and other phenomena will generate edge alignments that are unrelated to deformation. In these cases, however, the EFE is still a quantitative measure of edge alignment and fabric in the image. Conversely, many fabric patterns that are obvious to the eye will be invisible to EFE analysis. For example, alternating layers of black and white circles will produce an isotropic EFE, even though layering is quite apparent.

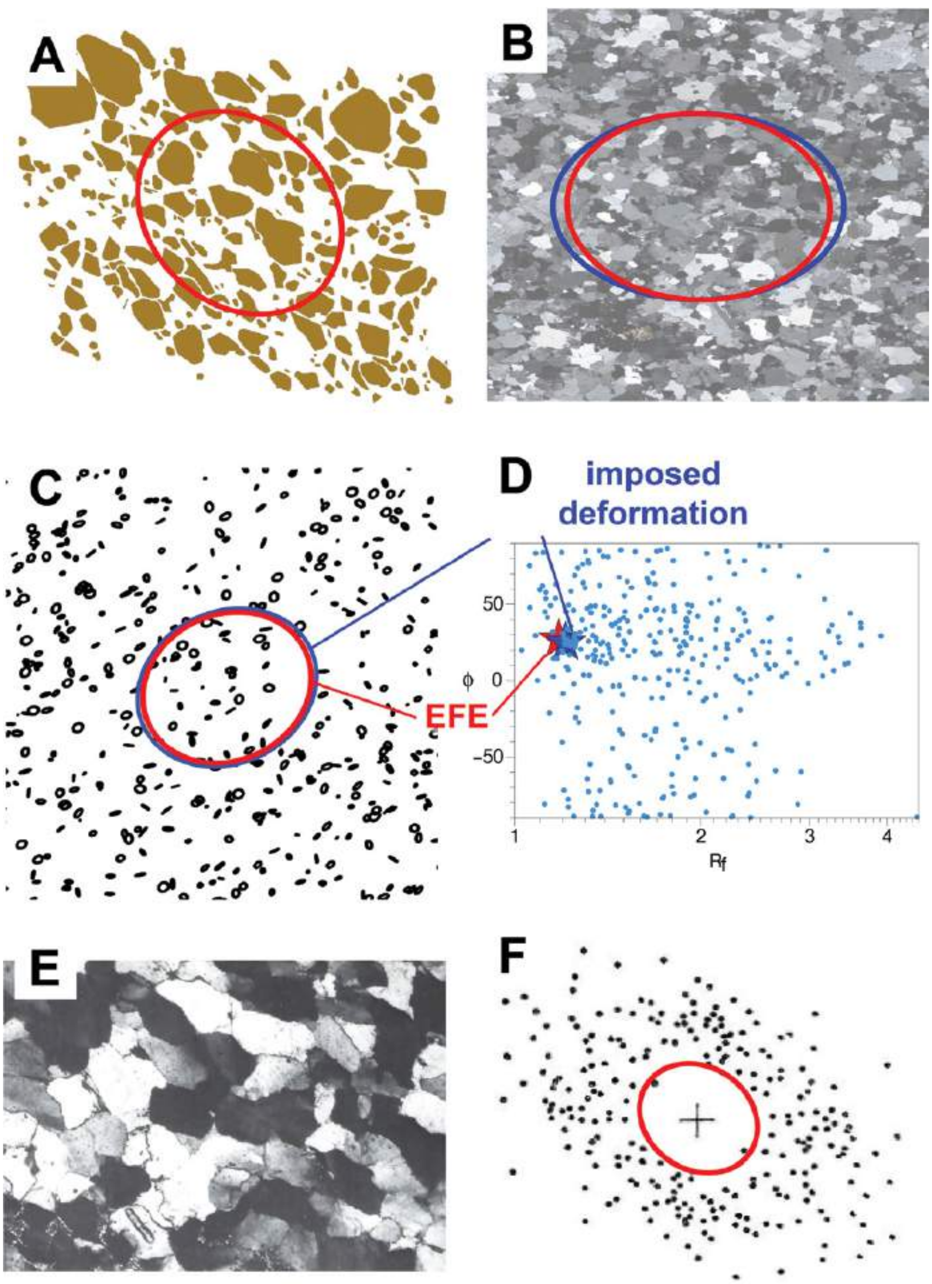


Figure 5. Examples of strain analysis using StraboTools. Red figures are edge fabric ellipses (EFEs) determined with the app, and blue figures are the imposed deformation. (A) Artificial pattern from Waldron et al. (2007), deformed along an undefined axis with strain ratio R = 1.3; the edge fabric tool gives E = 1.21 with an elongation azimuth of 133°. Correcting using Equation 1 with k = 1.3 gives E = 1.28, very close to imposed strain. (B) Cross-polarized thin section view of an isotropic aplite dike deformed by 20% shortening in the vertical direction and 25% stretching in the horizontal (R = 1.56), with EFE (E = 1.41, which corrects with Equation 1–1.56). (C) Ellipses with random axial ratios and orientations that were stretched 10% along an azimuth of 065. Agreement between the imposed strain (blue) and computed EFE (red) strain is excellent. (D) R_f/ϕ plot of data from C, with the imposed deformation and EFE solutions indicated by stars. It is hard to see how one could infer the imposed deformation (blue star) from the scatter of points, but the EFE solution matches it well. (E) Thin section view of deformed quartzite from Ramsay and Huber (1983, p. 118). (F) Their Fry plot derived from it, with EFE. The EFE agrees well with the elliptical void.

E values are not necessarily equal to the finite strain. As reviewed in Ramsay and Huber (1983), determining finite strain means understanding all of the possible deformation mechanisms (e.g., creep, grain-boundary sliding, etc.). StraboTools does not give this information, but *E* correlates with strain, and the EFE aligns well with fabric, even fabrics that are too subtle to see (Fig. 1). For an igneous rock, the EFE may capture a subtle grain shape fabric or crystal alignment not evident in the field.

There are several cautions about using EFEs. First, they are highly sensitive to shadows and cracks or fractures. In tests on glacially polished outcrops, a low sun angle can produce an elongate EFE whose axis is perpendicular to the sun azimuth even when visible shadows are not apparent. It is good practice to work with evenly shadowed surfaces. Second, although one can snap photos of images from computer screens, many artifacts, such as moiré patterns and the rectangular nature of pixels, can affect the results. High-resolution original images should be used whenever possible.

COLOR INDEX

Color index (CI), the volume percent of dark minerals visible in an outcrop of plutonic rock, is commonly estimated in the field. In granitic rocks, dark minerals such as biotite, hornblende, clinopyroxene, Fe-Ti oxides, and titanite are commonly easy to observe, but estimating their percentage by eye, especially when the percentage is small, is a notoriously difficult endeavor even for experienced observers. Comparison charts (Folk, 1951; Compton, 1985) are helpful, but it is still difficult to estimate CI accurately or precisely by eye, with visual psychology playing a prominent role in introducing biases (Allen, 1956; Dennison and Shea, 1966).

Accurate measurement of CI in the field could allow the delineation of zoning patterns that previously required laboratory or thin-section analysis. For example, the Half Dome and Cathedral Peak plutons in Yosemite National Park form a gradationally nested pair with a consistent inward decrease in CI that accompanies significant parallel changes in bulk composition (Bateman et al., 1988). The Cathedral Peak Granodiorite ranges from CI ~10 and SiO_2 ~68 wt% at its outer contact to CI ~4 and SiO_2 ~72 wt% at its inner. The gradual factor-of-two variation in CI is well within the typical error range of visual CI estimates (see Fig. 1D) and would be difficult to pick up by visual means alone.

The CI tool (Fig. 6) provides a rapid, precise, and accurate tool for estimating CI. In practical use on suitable rock faces, CI is typically reproducible within 1 or 2 absolute percent (e.g., 15 ± 2). The values determined by the CI tool match those determined by point counting within the same range.

FIELD GEOLOGY IN 2020 AND BEYOND

Using StraboTools can significantly enhance the practice of field geology by providing objective ways to collect data types that are impractical or impossible to collect in the field, subject to poor precision, or arduous and time-consuming to do later in the lab. StraboTools lets the field geologist examine rock fabrics in situ or back in the lab with thin sections or cut slabs. Because the app requires the user to capture an image and work on that same picture, it can be used to thoroughly document the data collected and can be reproduced or tested on the same source by other scientists. The tools also record the location and orientation of the image, so it becomes more practical to reproduce the actual field observations at a later date.

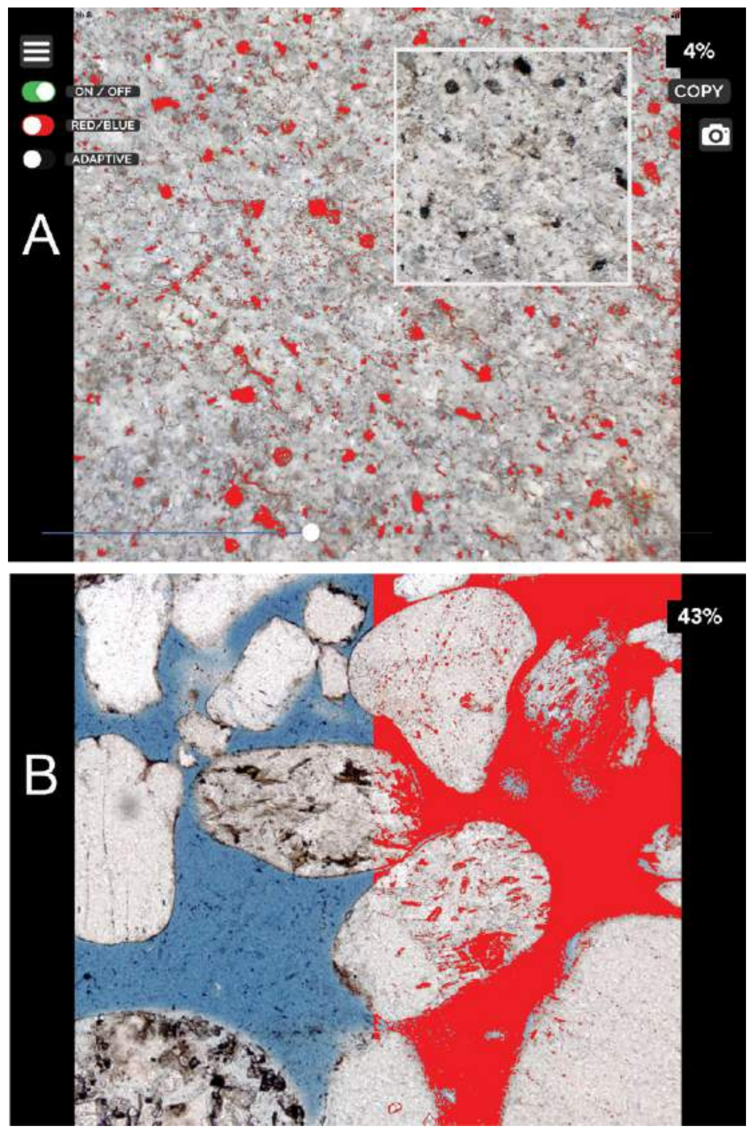


Figure 6. The color index (CI) tool in use. The user takes a photograph of a clean, shadow-free rock face and then uses the slider (lower left) to highlight the desired pixels in red or blue. (A) Determination of CI in a leucocratic granodiorite. The CI is displayed at upper right. A portion of the highlighted pixels has been erased to show the unhighlighted image below. (B) Using the CI tool for quick estimation of the percentage of porosity, as represented by blue epoxy, in a sandstone. The left half of the image is the original photomicrograph; on the right half the slider has been adjusted to highlight the epoxy. Dark inclusions represent ~3% of the image (as determined with the slider); thus, the porosity is 40%. Photomicrograph by Michael C. Rygel.

In his Presidential Address to the Geological Society of America, "New Technology; New Geological Challenges," B.C. Burchfiel (2003 [published in 2004]) made a compelling case that the geological community must embrace new modes of data collecting. At that time, precise GPS measurements were revolutionizing active tectonics and opening entirely new avenues of research. Developing and adopting new mobile technology can advance our ability to perform basic field geology at the individual investigator level. Images and interpretations can be easily shared, discussed, and interpreted by scientists and the interested public. Citizen scientists could have a role in collecting and evaluating geologic data in ways similar to that done for plants and animals with iNaturalist (https://www.inaturalist.org), with over 275,000 species identified, and eBird (https://ebird.org), with more than 100,000,000 bird sightings each year.

SHARING DATA

We envision that StraboTools will lead to more sharing of data and make fieldwork more transparent, reproducible, and searchable. StraboTools was developed as a spinoff of the StraboSpot project, which allows field geologists to collect, store, and share geologic data more easily. StraboSpot is currently focused on collecting general field data for structural geology, petrology, sedimentary geology, and volcanology (Walker et al., 2019). Although not yet a direct part of StraboSpot, StraboTools data and images can be entered into StraboSpot and StereonetMobile (Allmendinger et al., 2017).

SUMMARY

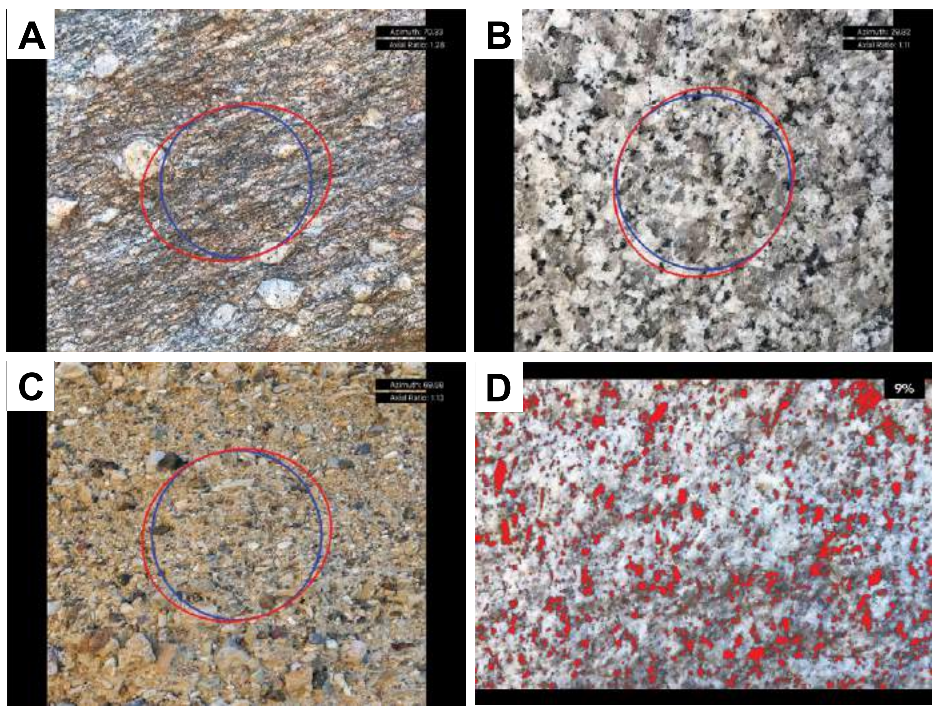
We have developed a mobile app that allows field geologists to make quantitative measurements of features such as foliation orientation and intensity, mineral alignment, and mineral proportions rapidly, precisely, and reproducibly. The app can pick up subtle fabrics (e.g., weak foliation, flow alignment, or pebble imbrication) that can be difficult to see. It allows objective measurement of features that were heretofore subjectively evaluated or just not seen, and can be used to quantify fabrics in photomicrographs and aerial photographs. It rapidly and objectively performs fabric analyses that were formerly time-consuming, subjective, and of low precision.

ACKNOWLEDGMENTS

Jason Ash is a crucial partner in this effort, doing the hard work of turning Matlab code into a stable app. We thank all the participants at various StraboSpot workshops and field trips for their input into how to improve the app. We thank an anonymous reviewer and editor Peter Copeland for reviews that greatly improved the presentation. John Bartley and Kevin Stewart were valuable sounding boards during development, and they and Andreas Möller provided constructive reviews of the manuscript. This work was supported in part by National Science Foundation grants EAR 1639724 to AFG and EAR 1347331, ICER 1639734, and ICER 1639738 to JDW, and by the Mary Lily Kenan Flagler Bingham Professorship at the University of North Carolina.

APPENDIX 1

Puzzle Answers



Screenshots of answers to the puzzles in Figure 1. Blue circles are for reference. (A) Foliation in deformed granite (Inyo Range, California, USA) has an edge fabric ellipse (EFE) aspect ratio (*E*) of 1.28 at an azimuth of 070 in the photo. (B) This image of granodiorite (Yosemite National Park, California, USA) was deformed by pure-shear stretch of 10% along a bearing of 030 (*R* = 1.22); EFE gives *E* = 1.11 along 030. (C) Shadowed vertical face cut into alluvial deposits (Death Valley National Park, California, USA), downstream to right, yields an EFE long axis rotated 20° counterclockwise from horizontal. The camera was held with a horizontal horizon, and layering is essentially horizontal, but EFEs in this and several other photos of the same face are consistently aligned with their long axes rotated 20° to 30° counterclockwise from horizontal. We attribute this to pebble imbrication and suggest that EFEs may aid the detection of these subtle fabrics. (D) Color index determination on this granodiorite (Peninsular Ranges, California, USA) yields 9% dark minerals. EFE (not shown) detects the rather obvious steep fabric defined by alignment of the dark minerals. See the original photos in the Supplemental Material.[1]

APPENDIX 2

Calculation of Edge Fabric

At each pixel in an image, there is a direction of maximum grayscale brightness increase. We compute this vector at each point by convolving the grayscale image with a 3-by-3 Sobel kernel (Sobel and Feldman, 1968) to get the horizontal brightness gradient at each pixel, and with the transpose of the kernel to get the vertical gradient. Vectors defined by these two components are shown in Figure 2B.

The StraboTools app downsamples the image to 1000 pixels on the long edge. Hence, a typical image has 10^6 pixels, at each of which there is a horizontal and vertical component of gradient. We form a 2-by-2 variance-covariance matrix from this 10^6-by-2 gradient matrix and calculate its eigenvectors and eigenvalues. These eigenvectors, scaled by the corresponding eigenvalues' square roots, are plotted in Figure 2C along with the ellipse that they define. As the vectors point perpendicular to edges, and we want the dominant edge direction, we rotate the ellipse 90° to produce the EFE (Fig. 2D).

The aspect ratio of the EFE is given by the square root of the ratio of the eigenvalues of the variance-

[1]Supplemental Material. Original photos from Figure 1. Please visit https://doi.org/10.1130/GSAT.S.12429926 to access the supplemental material, and contact editing@geosociety.org with any questions.

covariance matrix. The eigenvalues are the variances of the data projected onto the corresponding eigenvectors; the longer eigenvector is the direction that maximizes this projected variance (Dunteman, 1989, p. 29), and we take square roots to convert to the actual data spread (standard deviation). The aspect ratio is thus the ratio of the data spread in the direction of the longer eigenvector to that in the direction of the shorter eigenvector (Spruyt, 2014).

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26–30 October

GSA 2020 CONNECTS ONLINE

Letter from the General Chair

As many of you know, Montréal has been severely hit with the pandemic, which forced the cancellation of the on-site Annual Meeting of the Geological Society of America. We are, however, excited by the challenge that setting up a virtual meeting represents. I am confident that such format change offers the possibility of fostering scientific discussions and exchange of ideas in ways that a normal meeting cannot achieve. For this sake, the GSA staff are working very hard to select the best technopedagogic tools to optimize your virtual experience. We are also aware that many of you were looking forward to this meeting for living the unique cultural experience that Montréal has to offer. Although it is impossible to replicate the live experience, members of the local organizing committee and I are preparing special activities to tease you with typical Montréal treats. We hope that this new virtual meeting format combined with a taste of local flavor will entice you to participate in the 2020 meeting and ….come visit us live for the GSA Annual Meeting in 2027 in Montréal!

Be safe,

Félix Gervais
GSA 2020 General Chair
Associate Professor at the Department of Civil, Geological and Mining Engineering, Polytechnique Montréal

GSA 2020 Connects Online SCHEDULE*

Times in Eastern Time.

WEDNESDAY, 21 OCTOBER

Short Courses: 10 a.m.–6 p.m.

THURSDAY, 22 OCTOBER

Short Courses: 10 a.m.–6 p.m.

Field Trips: 10 a.m.–6 p.m.

FRIDAY, 23 OCTOBER

GeoCareers Webinars: 10 a.m.–3 p.m.

Short Courses: 10 a.m.–6 p.m.

Field Trips: 10 a.m.–6 p.m.

MONDAY, 26 OCTOBER

Morning Wake Up: Coffee & Conversation: 10–11 a.m.

GeoCareers Spotlight on Industry: 10 a.m.–1:30 p.m.

GSA Presidential Address: 11 a.m.–noon

Résumé/CV Clinic and Drop-in Mentoring: 1–5 p.m.

Lunch Break: noon–1:30 p.m.

Oral & Poster Technical Sessions: 1:30–5:30 p.m.

Pardee Symposium: 1:30–5:30 p.m.

Networking Events: 5:30–8 p.m.

Early Career Panel: 5:45–6:45 p.m.

TUESDAY, 27 OCTOBER

Morning Wake Up: Coffee & Conversation: 9–10 a.m.

Oral & Poster Technical Sessions: 10 a.m.–noon

GeoCareers Spotlight on Government: 10 a.m.–1:30 p.m.

GSA Resource & Innovation Center: 11 a.m.–3 p.m.

Lunch Break: noon–1:30 p.m.

Feed Your Brain: 12:15–1:15 p.m.

Résumé/CV Clinic and Drop-in Mentoring: 1–5 p.m.

Oral & Poster Technical Sessions: 1:30–5:30 p.m.

Pardee Symposium: 1:30–5:30 p.m.

Networking Events: 5:30–8 p.m.

Women in Geology Panel: 5:45–6:45 p.m.

WEDNESDAY, 28 OCTOBER

Morning Wake Up: Coffee & Conversation: 9–10 a.m.

Oral & Poster Technical Sessions: 10 a.m.–noon

GSA Resource & Innovation Center: 11 a.m.–3 p.m.

GeoCareers Spotlight on Academia and Teaching: 10 a.m.–1:30 p.m.

Lunch Break: noon–1:30 p.m.

Feed Your Brain: 12:15–1:15 p.m.

Résumé/CV Clinic and Drop-in Mentoring: 1–5 p.m.

Oral & Poster Technical Sessions: 1:30–5:30 p.m.

Networking Events: 5:30–8 p.m.

Diversity, Inclusion, and Ethics Panel: 5:45–6:45 p.m.

THURSDAY, 29 OCTOBER

Morning Wake Up: Coffee & Conversation: 9–10 a.m.

Oral & Poster Technical Sessions: 10 a.m.–noon

GeoCareers Spotlight on Non-Traditional Careers: 10 a.m.–1:30 p.m.

GSA Resource & Innovation Center: 11 a.m.–3 p.m.

Lunch Break: noon–1 p.m.

Feed Your Brain: 12:15–1:15

Résumé/CV Clinic and Drop-in Mentoring: 1–5 p.m.

Oral & Poster Technical Sessions: 1:30–5:30 p.m.

Pardee Symposium: 1:30–5:30 p.m.

Networking Events: 5:30–8 p.m.

Accessibility in the Geosciences Panel: 5:45–6:45 p.m.

FRIDAY, 30 OCTOBER

Morning Wake Up: Coffee & Conversation: 9–10 a.m.

Oral & Poster Technical Sessions: 10 a.m.–2 p.m.

Pardee Symposium: 10 a.m.–2 p.m.

*This draft is to give you a general idea of the schedule; it is subject to change.

The Geological Society of America®

GEOCAREERS

If you are entering the job market or are supporting someone who is and want more information about career pathways in the geosciences, plan to attend one or more of the GSA 2020 GeoCareers events below.

https://community.geosociety.org/gsa2020/geocareers

GeoCareers Events

- Résumé, USAJOBS, CV, Cover Letter, and Workforce Outlook Webinars
- Career Panels
- Drop-In Mentoring
- Early Career Professional Coffee
- Geology Club Meet Up
- Résumé/CV Review Clinic
- Women in Geology Panel
- Diversity, Inclusion, and Ethics Panel
- Accessibility in Geosciences Panel

Transform Your Career by Attending a Short Course

- Learn a new topic
- Build your skills
- Network
- Take courses taught by industry professionals
- Earn continuing education credits (CEUs)

Register for a short course today! *Course costs go up US$30 after 21 Sept.*

https://community.geosociety.org/gsa2020/program/short

Be a Mentor and Make a Difference

GSA has given me a platform to share my story and help students prepare for a career. —Brandy Barnes, Draper Aden Associates

- Drop-in Mentor
- On To the Future Mentor
- Résumé or CV Mentor

Learn more at **https://forms.gle/bZeKibPue7BXEsyQ9.**

Poster Advice from Students

Brooke Birkett, *Missouri S&T;* ***Larry Collins,*** *Washington State University-Pullman;* ***Jordan Foote,*** *University of Texas at Arlington; and* ***Marie Aurore Niyitanga Manzi,*** *Texas Christian University*

Presenting a poster at a GSA meeting is an exciting opportunity to interact with experts and get feedback on your research outside of your institution. While GSA 2020 will be in a new online format this year, poster presentations will still be an important component of the meeting, and a chance for you to network, practice your presentation skills, and contribute to the scientific dialogue.

Before you begin, read through the poster guidelines carefully, because these may vary depending on event and event format (online vs. in-person). When beginning to craft your poster, think about your overall layout, and ask yourself, "What are my most salient points?" and "What do I want my audience to learn most from my poster?" Think about how your work is informative to your subdiscipline of geology and to the broader geoscience community.

Here are a few tips for preparing the text of your poster:

- The title should be short to draw interest.
- Make it clear why the topic is important in the first sentence or two.
- Place your research in context with the published, primary literature.
- Briefly describe the approach you used to test your hypothesis.
- Skip lots of background information, definitions, and acronyms.

For poster layout, make any figures the main focus and put them front and center. They will pull your audience in and are the most useful tool for telling your story. Keep your text minimal, but clear enough to explain key points. If it is possible, use bullet points and numbering versus a paragraph format. Try to mix your poster up with tables, graphs, pictures, and text, but keep in mind that important information should be readable from ten feet away.

A few additional things to keep in mind:

- Posters should flow visually to aid reading and have a simple color scheme.
- They should be consistent and have a clean layout.
- Keep your text boxes the same width so that it is visually appealing.
- Balance the text with tables, graphs, pictures, and other presentation formats.
- Provide standalone captions for figures.
- Use a photo or illustration to help communicate your research question.
- Use figures, flow charts, or photographs to help describe your methods.
- Always check the poster guidelines for the meeting.
- Aim for 1,000 words or fewer, including your figure captions.

In preparation for your first poster presentation, develop and practice a one-minute elevator pitch for visitors who might be more broadly interested in your research and another more in-depth pitch (three to five minutes) for those whose research more closely aligns with your own. Consider making business cards to hand out and connect post-meeting with those who showed great interest in your research.

Some visitors to your poster will be experts in your area, and others will have a limited background. Most visitors to your poster will be genuinely curious and want to learn more about your research and have a lot of questions. However, if a visitor is overly critical, acknowledge their concerns and questions in a simple and respectful manner. It is acceptable to say you don't know the answer to a question and to offer to look into it. If they feel heard, things will likely go smoother, and remember that their comments may be very useful even if they are not delivered in the most appropriate manner.

If you find that a poster visitor has behaved in an inappropriate manner, excuse yourself from the conversation and file a complaint through the RISE (Respectful Inclusive Scientific Events, https://www.geosociety.org/GSA/About/Ethics/GSA/About/Ethics/home.aspx) process. Never feel like you have to stay in an uncomfortable situation.

Some final advice includes:

- Have a "critical friend" give you feedback—especially someone who may not be familiar with your project.
- Check all citations and acknowledgments before printing your poster; you do not want to accidentally leave someone out who significantly contributed to your work.
- Print your poster before arriving at the meeting (if applicable).
- Connect with your audience by making eye contact—don't face your poster—instead use it as a visual aid.
- Read the audience's facial expressions to know if you should repeat something or explain something further.
- Smile and be excited about your hard work. Enthusiasm is contagious!

The best presentation advice is to simply be yourself and be open-minded. You know your project better than anyone else, so present it with confidence. It's a conversation, and you can learn a lot from the people with whom you talk while presenting your poster.

2019–2020 GSA SCIENCE COMMUNICATION FELLOWSHIP WRAP-UP

Propelling Geoscience Communication into the Future

Terri Cook

Last July, just a few days after being named GSA's 2019–2020 Science Communication Fellow, my first official task was to write a blog celebrating the 50th anniversary of the first moon landing (see https://speakingofgeoscience.org/2019/07/19/a-giant-leap-for-the-geosciences/). Since I grew up in a home whose cornerstone was a meteorite, I have always been fascinated by anything related to space. This is especially true of the Apollo 11 mission, which landed in the Sea of Tranquility before I was born, but whose technological and scientific achievements, as well as sheer audacity, have long inspired me to "reach for the stars."

Arguably, the most impressive fact about that mission is that 600 million people—one-sixth of the planet's population—all paused together to breathlessly share in the triumph of watching a fellow human leave that first, indelible footprint on the lunar surface.

Now humanity has once again paused—only this time, it's for a virus, and the response has been anything but unified.

The current pandemic has resulted in a terrible death toll and forced many of us to make significant changes in almost every aspect of our lives, from working and socializing to dining and travel. The pandemic has also changed scientific research, publishing, and discourse. Although many changes within these realms are likely to be temporary, some may herald new, long-term trends in research funding, teaching, conferences, and ultimately how science is communicated.

As GSA's Science Communication Fellow, my primary responsibility during the past ten months has been to scan the thousands of abstracts submitted for the annual meeting and papers nearing publication in GSA journals. In collaboration with GSA's communications staff, I selected an average of one article or abstract per month that I believed would be of broad interest to the general public (and therefore likely to be picked up by media outlets) and wrote a press release about it.

The diversity of the topics I've covered, which has ranged from Zealandia, Earth's hidden continent, to how extra-terrestrial impacts may have triggered bursts of plate tectonics, is indicative of the broad range of exciting geoscience research that GSA regularly publishes. But of all the press releases I wrote, the one with by far the widest distribution—with a potential reach of more than one billion people—covered a hypothesis that the ancient Incan sanctuary of Machu Picchu may have been intentionally built on faults (see these and other GSA press releases at https://www.geosociety.org/GSA/News/Releases/GSA/News/pr/Releases.aspx).

Based on this success, we decided to take advantage of my additional experience as a travel writer to highlight more place-based research topics using traditional press releases combined with a new communications product: video research summaries. These present key research findings for lay audiences in short (approx. two-minute), imagery-driven videos especially well suited to sharing on social media.

To date, GSA has issued two such summaries: one about glacier detachments in Wrangell–St. Elias National Park and Preserve (https://www.geosociety.org/GSA/News/pr/2020/20-12.aspx) and a second about the discovery of two previously unknown super-eruptions along the Yellowstone hotspot (https://www.geosociety.org/GSA/News/pr/2020/20-18.aspx). These videos clearly have the potential to help expand the audience and diversify the outlets in which GSA-published research results appear; even though the format requires fine-tuning, these pilots were widely viewed and shared, especially considering the current, limited coverage of non-coronavirus–related stories in the media.

GSA likewise moved to the forefront of science communication trends when it hosted its first virtual section meeting in May. This event featured pre-recorded oral presentations with live question-and-answer periods as well as "flash" talks, during which the authors of poster presentations were allotted two minutes to present their findings. Like the video research summaries, flash talks inherently required presenters to narrow down their scope to just a few, key points—e.g., what truly matters.

The recent announcement that this year's annual meeting will also be completely online, while still offering many quintessential GSA experiences such as field trips and networking events, will offer novel opportunities for GSA members to participate in what promises to be an innovative and exciting experiment. As the exploration of space has aptly demonstrated, change is often positive and can unify us; the current pandemic, despite its many negative consequences, has the potential to lead to substantive improvements in how geoscience research is conducted and communicated.

By experimenting with new forms of scientific discourse, we all have an unparalleled opportunity to not only seek out new scientific findings, but to also explore better ways of communicating these to each other and to the public to propel ourselves into the future.

GSA Scientific Divisions Celebrating Milestones

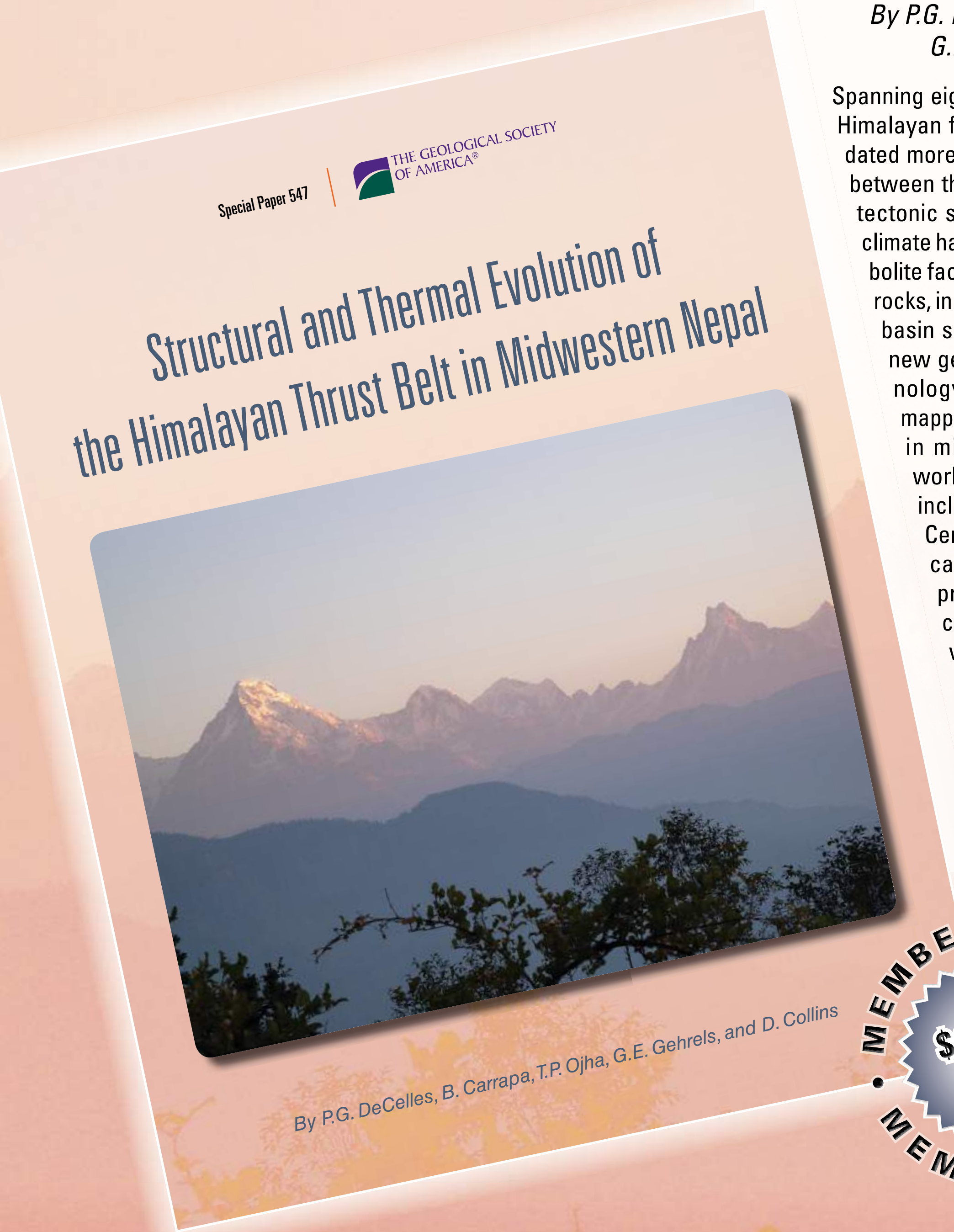
GSA has 22 scientific Divisions that any member can join. Divisions generally meet at the GSA Annual Meeting, and most have their own newsletters, which are published at various times throughout the year. GSA's scientific Divisions help you stay connected with your colleagues worldwide and receive specific information related to your area of interest. Scientific Divisions provide opportunities for leadership and service, specialty meetings, awards, student support, and development of the GSA meeting technical program.

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

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

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

15 Years: GSA's **Geology and Health Division** (est. 2005) focuses on the intersection of natural or anthropogenic geological conditions with health, disease, pathology, and death in modern and fossil humans, animals, and plants. This Division fosters communication and collaboration among scientists and health practitioners with an emphasis on the interdisciplinary relationship of geology to medicine, biology, chemistry, and other sciences. Division awards include the Meritorious Service Award, the Distinguished Service Award, and the Best Publication Award for students.



Structural and Thermal Evolution of the Himalayan Thrust Belt in Midwestern Nepal

By P.G. DeCelles, B. Carrapa, T.P. Ojha, G.E. Gehrels, and D. Collins

Spanning eight kilometers of topographic relief, the Himalayan fold-thrust belt in Nepal has accommodated more than 700 km of Cenozoic convergence between the Indian subcontinent and Asia. Rapid tectonic shortening and erosion in a monsoonal climate have exhumed greenschist to upper amphibolite facies rocks along with unmetamorphosed rocks, including a 5–6-km-thick Cenozoic foreland basin sequence. This Special Paper presents new geochronology, multisystem thermochronology, structural geology, and geological mapping of an approximately 37,000 km² region in midwestern and western Nepal. This work informs enduring Himalayan debates, including how and where to map the Main Central thrust, the geometry of the seismically active basal Himalayan detachment, processes of tectonic shortening in the context of postcollisional India-Asia convergence, and long-term geodynamics of the orogenic wedge.

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THE GEOLOGICAL SOCIETY OF AMERICA®

The Lady and Her Fossils: Katherine Van Winkle Palmer (1895–1982)

William R. Brice, *professor emeritus, University of Pittsburgh at Johnstown, wbrice@pitt.edu*

Katherine Van Winkle Palmer, ca. 1940. (Courtesy of the Paleontological Research Institution [PRI].)

After God made Katherine, he broke the mould. —Gilbert D. Harris.

INTRODUCTION

Katherine Evangeline Hilton Van Winkle was born in Washington State on 5 February 1895, the only child of Jacob Outwater Van Winkle, a doctor, and Mary Edith Hilton Van Winkle, a nurse. Katherine grew up in the small town of Oakville, southwest of Tacoma, and not too far from Olympia. She and her father, a local physician, had a very close bond, and it was he who introduced her to nature and the out-of-doors. No doubt given the proximity of their home to outcrops of the Tertiary-age[1] Cowlitz Formation, she and her father had fun collecting fossil mollusks, and it was on these trips that she developed her love of science and her fascination with fossils. As she said later in life, "I knew fossils as a child, so by the time I went to the University of Washington I knew I wanted to study geology" (Allmon, 2007, p. 31). As a young girl, she attended the local schools, and she was the only girl in her class to go to college.

It was at the University of Washington that Katherine started her formal work in paleontology under the watchful eye of Professor Charles E. Weaver (1880–1958), a well-known expert on Paleogene fossils. She graduated with her B.S. in 1918 and published her senior thesis on age determinants within faunal provinces that same year[2]. The fieldwork she did in 1916–1917 for the thesis was "... by means of a compass and tape traverse…" up and down several creeks. This first paper, which was almost 30 printed pages, plus plates, proved to be the first of many long publications devoted to paleontology.

After briefly working as a post-graduate laboratory assistant to Dr. Weaver, and upon his recommendation, Katherine applied for and received a Goldwyn Smith Fellowship (1918–1920) to do graduate work at Cornell University with the east coast Paleogene expert, Gilbert D. Harris (1864–1952)[3]. Later (1921–1925), she received an assistantship in paleontology and historical geology to continue her work with Professor Harris.

LIFE AS A CORNELL STUDENT

Because Gilbert Harris was an expert in Katherine's chosen field of Paleogene paleontology, it was natural that she would be working with the east coast expert. But there was another reason she was to become a student of G.D. Harris at Cornell, for, at that time, he was the only professor in the geology department who would accept women as students (Brice, 1996). Katherine received her Ph.D. in paleontology in 1925, but not before she had to set the type, make the plates, and then print her thesis on Professor Harris's own printing press. Not many paleontologists have done that.

A legacy of her student days at Cornell University is the organization Sigma Delta Epsilon[4], which was founded at Cornell in 1921. At the time, it was the only national organization for women in science, and Katherine was one of the founders and later served as national president.

Katherine had intended to return to Washington State and resume her work with Dr. Weaver, but those plans changed. She had fallen in love with the Ithaca region and with a Cornell professor of rural education, Ephraim Laurence Palmer (1888–1970)[5]. They were married in 1921 while she was still a graduate student. The couple had two children: Laurence Van Winkle Palmer, born in 1923, and Richard Robin Palmer, born in 1930. However, tragedy stuck the family when Laurence, "Punky" as he was known, was stricken with a *Streptococcus* infection at age 4, which left him with severe arthritis and eventually took his life at the age of 17.

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[1] Although this was the proper terminology for this part of geologic time when Katherine was growing up, this has since been redefined as the Paleogene. To keep with current terminology, the term Paleogene will be used in place of Tertiary in the rest of the paper.

[2] For a complete bibliography for Katherine Palmer, see Caster (1983, p. 1142–1144).

[3] For details of Harris's life see Brice (1996).

[4] The formal founding name was Sigma Delta Epsilon Graduate Women's Scientific Fraternity. It is now known as Graduate Women in Science.

[5] For details of Dr. E. Laurence Palmer's life and work, see Pruitt (1963).

Paleontology class of G.D. Harris, ca. 1921: (left to right) Axel Olsson, Harris, Pearl Sheldon, Dr. Carlotta Maury, Katherine V.W. Palmer. Note: Dr. Maury, a former student, was visiting the campus to study the collections at the time the photograph was taken (courtesy of PRI).

LIFE AFTER GRADUATION

Upon graduation, Katherine received a Hecksher Fellowship (1925–1927) to continue her work with Professor Harris on Paleogene fossils. Several years later, she was present when Harris laid the cornerstone for the Paleontological Research Institution (PRI) in 1932; it was literally in the backyard of his home, just across the gorge from Cornell University. Katherine worked actively with PRI and served on its board of directors. During World War II, she was also a special lecturer in paleontology at Cornell University.

Though Katherine never had a full-time academic appointment, over the years she served as curator of collections and technical assistant at several universities and museums. Her long association with PRI gave her a professional base from which and through which she published much of her work.

She made many fossil-collecting trips over the years, often with Professor Harris, to Paleogene locations along the Eastern and Gulf Coasts of the U.S., and to Cuba in 1941 and 1947. She traveled as far away as New Zealand in 1947, although appendicitis and surgery delayed the trip, but only by a few days. In 1959, Katherine and several others made a collecting expedition to Panama. Sometimes a picture of a fossil she collected would end up on the annual PRI Christmas card.

Frequently she would become involved with projects that, though important to the field of paleontology, few workers would undertake, such as the fossil catalogues that she published. Later, a colleague would say of these works, "Such work [the catalogues] is perhaps our greatest drudgery and most thankless endeavor, yet when well done, far surpasses in general utility many a long monograph" (Caster, 1973).

DIRECTOR OF PRI

Due to Gilbert Harris's illness, and before his death on 4 December 1952, the board appointed Katherine director of PRI in April 1952. She was the logical successor as she had been associated with the institution right from the laying of the cornerstone some 20 years earlier. One of her main concerns as the new director was to find new quarters, for the little concrete block building in Harris' backyard was no longer adequate. Though it took over 10 years, she succeeded, and PRI moved to the west side of Cayuga Lake to the former International Order of Odd Fellows orphanage. The purchase was completed in 1968 and PRI began a new era[6].

As director of PRI, Katherine was responsible for PRI publications, which included both the *Bulletins of American Paleontology* (BAP), which Harris founded in 1895, and *Palæontographica Americana*, founded in 1916. And, yet, she also managed to continue her research work in paleontology and to care for her family. In addition, the Palmer family was well known for their gracious hospitality, often hosting visiting scholars of both geology and rural education from around the world. Ephraim L. Palmer died on 18 December 1970, and though her health slowly deteriorated during the 1970s, Katherine continued as director of PRI until 1978.

During the first 21 years as director of PRI, Katherine Palmer edited 137 numbers (28 volumes) of *BAP* and 20 numbers (4 volumes) of *Palæontographica Americana* as well as several books, guidebooks, and booklets. Over her productive career, she produced more than 70 paleobiologic papers, 17 of which are considered "… major works" (Caster, 1973). Some of them are quite massive; e.g., Palmer (1937 and 1946) and Palmer and Braun (1965–1966); just these three papers total more than 2,000 pages of paleontology.

Katherine Palmer's contributions to paleontology were officially recognized by several professional societies: She became a GSA Fellow (1935); received the award for "outstanding contributions to the study of Mollusca" from the Western Society of Malacologists (1974); received an honorary degree from Tulane University (1978); and was the first woman to be awarded the Paleontological Society Medal (1973).

Truly a pioneer in geology and especially in paleontology, Katherine Van Winkle Palmer died on 12 September 1982. Her last publication was a history of PRI. Fittingly, the second home of PRI, and now the administrative building, Palmer Hall, is named in her memory.

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I am indebted to the Paleontological Research Institution (PRI), Ithaca, New York, USA, for preserving the Palmer Archive, and to the director, Dr. Warren Allmon, for allowing me access to those files and reviewing an earlier version of this manuscript. Unless otherwise indicated, the material used in this presentation is from the Palmer or Harris Archives at PRI.

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[6] For more on the history of PRI, see Allmon (2007).

New Comment and Reply Published Online

COMMENT

Sigloch, K., and Mihalynuk, M.G., 2020, Comment on *GSA Today* article by Pavlis et al., 2019: “Subduction polarity in ancient arcs: A call to integrate geology and geophysics to decipher the Mesozoic tectonic history of the Northern Cordillera of North America”: *GSA Today*, v. 30, p. e47, https://doi.org/10.1130/GSATG431C.1.

REPLY

Pavlis, T.L, Amato, J.M., Trop, J.M., Ridgway, K.D., Roeske, S.M., and Gehrels, G.E., 2020, Subduction polarity in ancient arcs: A call to integrate geology and geophysics to decipher the Mesozoic tectonic history of the northern Cordillera of North America: REPLY: *GSA Today*, v. 30, p. e51, https://doi.org/10.1130/GSATG465Y.1.

Original Article:

Pavlis, T.L., Amato, J.M., Trop, J.M., Ridgway, K.D., Roeske, S.M., and Gehrels, G.E., 2019, Subduction polarity in ancient arcs: A call to integrate geology and geophysics to decipher the Mesozoic tectonic history of the northern Cordillera of North America: *GSA Today*, v. 29, p. 4–10, https://doi.org/10.1130/GSATG402A.1.

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. (Note: Combined March/April issue releases on March schedule.) Print ads will also appear on the Geoscience Job Board to coincide with the month of print issue. **Contact: advertising@geosociety.org,** +1-800-472-1988 ext. 1053, or +1-303-357-1053. Email correspondence should include complete contact information (including phone and mailing address). Rates are in U.S. dollars.

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Positions Open	$9.40	$9.35
Fellowship Opportunities	$9.35	$9.30
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First 25 lines	FREE	$5.00
Additional lines	$5.00	$5.00

POSITION OPEN

GIS Analyst, University of Idaho

Position Summary: Based in Moscow, Idaho, the GIS Analyst will support Idaho Geological Survey (IGS) staff in grant related responsibilities and research including database creation and management, digital cartography, and geologic mapping. This position works closely with the IGS Director, Digital Mapping Lab (DML) Manager and other mapping lab staff. The position reports to the DML Manager and requires the development, implementation, and maintenance of GIS and non-spatial databases.

The position is a one-year appointment funded by the USGS-STATEMAP 2020 grant. Ongoing employment will be contingent upon funding.

Principal duties are: (1) supporting agency projects through GIS and database design and creative problem solving; (2) creating computer programs and scripts to assist with GIS projects; (3) GIS and other data management and maintenance including migrating and converting databases as necessary; (4) modeling of GIS data sets; and (5) creation of geologic maps in both GIS and vector graphic software.

Posting Number: SP002514P

Open Until Filled: Yes

Special Instructions: Preferential review of applicants will begin July 25, 2020.

Certificates and licenses along with an example of geologic map and/or database that the applicant has produced are optional documents to upload as "other documents."

Background Check: Applicants who are selected as final possible candidates must be able to pass a criminal background check.

To apply, please visit: https://apptrkr.com/1940225

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Graduate Online GIS Certificates, Ohio University. GIS skills are now essential for geologists. If you are a recent college graduate or a working professional looking to acquire, or enhance your existing, proficiency in GIS, consider enrolling in a competitively priced, Ohio University Department of Geography online certificate program in Geospatial Information Science. These are fully online, three-course programs open to any individual who has an undergraduate degree (any major); GRE scores are not required for admission. With little or no previous experience in GIS, choose the certificate in GIS and Cartography (ND9984). For advancing existing GIS skills, select the Geospatial Analysis and Programming certificate (ND9985). The certificates are designed to be completed in one year. Start fall or spring semester for ND9984, and fall, spring, or summer for ND9985. See https://www.ohio.edu/cas/graduate/online-programs or contact Dr. Gaurav Sinha (sinhag@ohio.edu) for more information.

Ph.D. Research Opportunity: Phosphorus Environmental Biogeochemistry in Agricultural Watersheds, UW Madison. The UW Madison Department of Soil Science and Department of Environmental Engineering has four years of funding for a Ph.D. student interested in developing expertise in advanced chemical analytical methods, nutrient management in waterbodies and applying project results to real life wastewater management and nutrient trading scenarios. Partnering with existing research field trials, we will identify P compounds (speciation) and determine their bioavailability in field runoff using a variety traditional wet chemistry and advanced spectroscopic methods infrequently applied to agricultural systems (including synchrotron-based x-ray spectroscopic techniques and reverse phase ion-pair chromatography). We will then construct and test a model for particulate P bioavailability. This vital information will immediately inform Wisconsin and USDA nutrient management models. This work is important in the development of sustainable agricultural systems while protecting water supplies. It also has direct applicability to nutrient trading schemes involving utilities, municipal water systems, watershed protection agencies and farm management. The RA includes tuition waiver, health insurance and monthly stipend. The student will receive a joint Ph.D. from the UW Madison Soil Science and Environmental Engineering departments and be jointly advised by Dr. Francisco Arriaga and Dr. Matthew Ginder-Vogel. For more information contact Geoff Siemering, Department of Soil Science, gsiemering@wisc.edu.

Silence Comes at a Cost: Sexual Harassment Reporting in STEM

Maria Daniella Douglas and **Barbara C. Bruno**, Hawai'i Institute of Geophysics and Planetology, University of Hawai'i at Mānoa, Honolulu, Hawai'i, 96822,USA*

"In order to defeat the darkness, you must bring it into the light." —Seth Adam Smith, *Rip Van Winkle and the Pumpkin Lantern* (2016, p. 113)

Sexual harassment claims and their investigations bring unwanted attention to an ugly side of academia. Informing the public of these awful events can paint the institution in a poor light. Such reports can also empower other victims to come forward, potentially leading to more bad press for the school. So, many institutions are understandably loath to publicize the prevalence of sexual misconduct on their campuses. However, this silence comes at a cost, because it communicates that sexually harassing behavior is tolerated. In contrast, regularly informing campus communities of sexual harassment claims and their outcomes communicates intolerance, which can create a safer environment to study and work.

REPORTING COMMUNICATES INTOLERANCE

The National Academies of Sciences, Engineering, and Medicine (NASEM, 2018) recently published a report aimed at mitigating sexual harassment in higher education. The report states: "There is often a perceived tolerance for sexual harassment in academia, which is the most potent predictor of sexual harassment occurring in an organization… The evidence suggests that the workplace climate is seen as intolerant of sexual harassment when… the campus community is regularly informed about how the institution is handling/attending to claims" (p. 3).

This key recommendation suggests that institutions should regularly inform the campus community about the number and types of sexual harassment claims that have been reported, how these claims are being investigated, and their outcomes, including disciplinary measures taken. This creates the perception of sexual harassment intolerance, which is critically important in spreading awareness of resources for sexual harassment victims and preventing future incidents of harassment. These reports also hold the institutions accountable for protecting their students and employees and adhering to their own set policies and procedures.

However, no law requires universities to release such reports. The Clery Act (1990) requires U.S. colleges and universities to publish annual reports on campus crimes. Since many types of sexual harassment are not considered crimes, they are not included in the mandated Clery reports. Additionally, the Clery Act does not require reporting on the status of pending claims. Thus, Clery reports are a good first step, but fall well short of meeting the NASEM (2018) standard for sexual harassment reporting.

Similarly, many institutions conduct campus climate surveys, which are largely aimed at gathering anonymous data to inform policies regarding campus sexual misconduct (Association of American Universities, 2015). However, because these surveys are anonymous, institutions cannot properly investigate survey responses, let alone impose sanctions on perpetrators.

Last year, NASEM (2019) launched an Action Collaborative to address and prevent sexual harassment, in partnership with more than sixty higher education institutions and research organizations. The Action Collaborative may be the next big step in the battle against sexual harassment in higher education as it develops research-based policies and promising practices that promote a campus culture of civility and respect.

A LOOK AT THE TOP 100 GEOSCIENCE UNIVERSITIES

While there are no laws that require U.S. universities to publicly release annual reports on sexual harassment, NASEM (2018) strongly encourages them to do so. So, how many institutions are actually doing this? To find out, we searched the websites of the top 100 geoscience universities (Nature Index, 2019) to see how many had released at least one report since January 2019 that follows NASEM guidelines. Specifically, we looked for reports that included data on (1) the number of sexual harassment claims made against students and faculty; (2) their investigations and outcomes; and (3) sanctions taken on claims that were found to have cause.

Several search terms were used in addition to the name of the institution, including *sexual harassment*, *sexual misconduct*, *annual report*, and *Title IX*. If the report could not be found within 30 minutes of active searching, then the institution was determined not to have publicly released a report.

Of the top 100 geoscience universities in the U.S., we found only 26 to have released reports that met all three criteria (Table 1). An additional eight institutions released reports that met two of the three criteria; most of these did not describe the sanctions imposed (Table 2). Thus, two-thirds (66%) of the top 100 geoscience institutions fall considerably short of the NASEM (2018) recommendation.

In contrast, the vast majority (eight, or 80%) of the top ten geoscience institutions released detailed reports on sexual misconduct, and many announced the publication of these reports as an important step in promoting public safety and institutional accountability. Some of these schools noted an increase in sexual misconduct reporting

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TABLE 1. UNIVERSITIES AMONG THE TOP 100 U.S. GEOSCIENCE UNIVERSITIES THAT HAVE PUBLICLY RELEASED REPORTS ON SEXUAL MISCONDUCT THAT MEET THE NASEM (2018) CRITERIA

Ranking	Name of Institution
1	University of Colorado Boulder
5	Columbia University in the City of New York[AC]
6	The University of Texas at Austin
7	Yale University[AC]
8	Massachusetts Institute of Technology[AC]
9	Stanford University[AC]
10	University of California, Los Angeles[AC]
14	University of Michigan[AC]
18	University of California, Davis
19	Princeton University
20	University of California, Irvine
24	Cornell University[AC]
26	University of California, Santa Cruz[AC]
29	The University of Iowa
34	Johns Hopkins University[AC]
41	Purdue University[AC]
42	The University of Chicago[AC]
43	Brown University
49	Indiana University
54	University of Alaska Fairbanks[AC]
62	The University of North Carolina at Chapel Hill
70	The University of Tennessee, Knoxville[AC]
90	University of Missouri
93	Northwestern University[AC]
96	Rensselaer Polytechnic Institute
98	University of Rochester

AC—denotes schools that are NASEM 2019 Action Collaborative members.

TABLE 2. UNIVERSITIES AMONG THE TOP 100 U.S. GEOSCIENCE UNIVERSITIES THAT HAVE PUBLICLY RELEASED REPORTS ON SEXUAL MISCONDUCT THAT PARTIALLY ADDRESS THE NASEM (2018) CRITERIA

Ranking	Name of Institution
3	University of California, Berkeley[AC]
15	Harvard University[AC]
16	University of Maryland, College Park
31	Duke University[AC]
36	Virginia Polytechnic Institute and State University
39	University of California, Santa Barbara[AC]
51	Michigan State University[AC]
99	University of Montana

AC—denotes schools that are NASEM 2019 Action Collaborative members.

following the release of annual reports (e.g., Yale shared that their reported complaints had doubled), and this can draw unwanted media attention. However, such a reporting increase can and should be viewed positively, because greater awareness of resources and support for victims encourages reporting (Davila IV and Steinkamp, 2019). Similarly, Stanford provost Persis Drell shared, “It is also my hope that by making surveys and reports visible and accessible we will encourage anyone experiencing unwanted sexual conduct to come forward so that it can be addressed” (Drell, 2019).

Of the 60+ NASEM Action Collaborative institutions, 38 are among the top 100 geoscience universities. Of those 38, 19 have released detailed sexual misconduct reports since January 2019. Since joining the Action Collaborative, several universities have pledged to publish reports within the coming year.

A CALL TO ACTION

To prevent sexual harassment, higher education institutions must be perceived to be intolerant of such harassment. Informing the campus community of sexual harassment allegations, how these claims have been handled, and the outcomes of these claims clearly communicates that sexual harassment is not tolerated (NASEM, 2018). Such reports also hold universities accountable for upholding the policies they have put in place to protect their communities. We are therefore issuing a call to action for all universities, and particularly those 100 top geoscience universities, to follow the lead of the top ten geoscience universities and Action Collaborative members to produce such annual reports. The power is in the hands of the institution to pave the way for a future where fears of discrimination or harassment no longer impede success.

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GSA Update on Sexual Harassment Reporting

Maria Daniella Douglas and Barbara C. Bruno's article, "Silence Comes at a Cost: Sexual Harassment Reporting in STEM," (p. 24) reinforces GSA's conviction that universities, scientific societies, and other institutions need to be far more transparent about discrimination and harassment complaints and how they are handled. Staying silent about such issues is risky. It sends a message that inappropriate conduct is tolerated. This increases the likelihood of future misconduct and prevents talented geoscientists from achieving their full potential.

GSA is committed to fostering a culture of integrity, respect, and scientific excellence across the geosciences so scientists with diverse backgrounds and identities feel welcome and included. That is one of the reasons GSA established a new Code of Ethics and Professional Conduct in 2019. Under this policy, we spell out aspirational standards to guide our members. The Code of Ethics also includes specific mandatory standards of conduct that will not be tolerated, including discrimination, harassment, sexual harassment, bullying, and retaliation.

In the past year, GSA has received eight ethics complaints on topics ranging from sexual harassment at our members' home institutions to plagiarism. Thus far, the GSA Council—the Society's highest governing body—has found ethical misconduct in two of these cases and voted to impose stiff penalties, including revoking a member's status as a GSA Fellow and banning another member from GSA events for several years. Four of the six remaining cases are pending, and GSA closed the other two because there was insufficient evidence to support the allegations.

GSA will continue to take all ethics complaints seriously and impose sanctions against individuals who violate our policies. Being transparent about these efforts is critical. We also recognize the importance of playing a leadership role in driving positive culture change within the geoscience community. As a member of the Leadership Council of the Societies Consortium on Sexual Harassment in STEMM, we are actively exploring ways to improve our policies and practices. We also are working with a culture task force composed of members and other geoscientists to identify practical ways we can work together to make GSA events—and the broader geosciences community—more welcoming and inclusive for people of diverse identities.

— ***Nan Yale Stout,*** *GSA Ethics & Compliance Officer*

A Boost for the CURE: Improving Learning Outcomes with Curriculum-Based Undergraduate Research

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In a recent survey of geoscience employers, more than 75% of respondents indicated that the particular courses a job candidate had taken were less important predictors of workforce success than the development of problem-solving skills, competencies, and conceptual understanding (Summa et al., 2017). An effective pathway to develop these attributes is through participation in undergraduate research experiences (UREs), which are known to catalyze increases in conceptual understanding, confidence, and skills through the practice of scientific investigation (NASEM, 2017). Since many traditional UREs follow an apprentice-style approach via one-on-one mentoring, they are faculty intensive, often selective, and open to fewer students. Course-based UREs (CUREs) provide a mechanism to scale up participation and increase access by bringing collaborative research that generates new knowledge with broad relevance into the classroom (Auchincloss et al., 2014). However, the short-term nature of a CURE (NASEM, 2017) leaves little time for students to reflect upon alternative interpretations or revise hypotheses—two fundamental components of the process of science.

Time is a critical factor in the development of science skills and professional attitudes, because novice researchers become proficient at technical tasks through iterative data collection relatively rapidly, but it can take more than a year in a URE to develop confidence, perseverance, and a more holistic understanding of the nature of science (Thiry et al., 2012). How can a URE provide the benefit of time, while also increasing student access to research? In this contribution, we propose that it is possible to resolve this by extending a CURE across multiple required courses in a curriculum. This gives students the positive impact of a commitment that is sustained over time, reduces the bottleneck associated with apprentice-style UREs, and broadens academic and social inclusion by opening the doors of research to everyone.

A CURRICULUM-BASED UNDERGRADUATE RESEARCH EXPERIENCE

Our novel, multi-semester, curriculum-based undergraduate research experience (MS-CURE) is embedded in five semester-length courses across the core geology curriculum. The two-year sequence begins with a sophomore-level course in environmental and applied geology and continues through earth materials and minerals, structural geology, petrology, and our summer geology field camp. Research is spread across each course as: (1) writing assignments integrating traditional course topics with the URE; (2) components of endemic laboratory activities; and (3) short discussions (specific activities and learning goals are presented in Fig. S1[1]). Importantly, each student retains the same research project through the sequence so he/she/they can incrementally build a complex data set while progressively writing and revising a journal-style research paper at the same time as others in the class. The writing spans four courses, providing students space for metacognitive reflection from one course to another and time to mature in their understanding of the process of science. In order to scaffold the learning experience, students incrementally present results at a campus-wide poster forum during the second and fourth semesters.

The student research topics are multidisciplinary and focus on the petrology, geochemistry, and structural geology of a system of mid-crustal fault rocks in the Colorado Rockies. Although the research foci are based upon our departmental capabilities and research interests, the MS-CURE model is transferable to other research themes, course sequences, and durations. For example, an MS-CURE could be distributed across two or more courses with or without gaps and lead to senior independent research or a capstone course. Further, an MS-CURE could capitalize on local geologic, hydrologic, or environmental problems amenable to collaborative, long-term investigation.

In our MS-CURE, participants prepare thin sections from the field area and analyze them using petrographic methods and electron probe microanalysis across four consecutive campus-based courses. The URE concludes with original mapping at the field site during the summer field camp, in which the lab work is placed in a field context and samples for future cohorts are collected. This fosters continuity and establishes scientific communication and data sharing between past and future cohorts. Students are assigned samples from the same field site, but each student feels ownership of a unique set of data.

LEARNING GAINS

In order to evaluate learning gains and the effectiveness of the MS-CURE, two cohorts of students anonymously responded to a set of questions from the Undergraduate Research Student Self-Assessment (URSSA; Weston and Laursen, 2015) at the end of the five-course sequence. Both cohorts were taught by the same instructors (JLA and SCK), and an external evaluator (EGC) prompted students to respond to the URSSA on the basis of the embedded URE. We then compared pub-

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[1]Supplemental Material: MS-CURE research activities, learning goals, and rubric for student assessment. Please visit https://doi.org/10.1130/GSAT.S.12290381 to access the supplemental material, and contact editing@geosociety.org with any questions.

lished data (Thiry et al., 2012) from novice (≤1 year) and experienced (>1 year) undergraduate researchers to the MS-CURE students. Students in the comparison groups participated in apprentice-style UREs predominated by bioscience disciplines at two research-intensive universities. Those participants were competitively selected, received stipends, and had access to supplemental enrichment activities as part of their experience. Therefore, the comparison groups likely reflect best-case URE outcomes. In contrast, our MS-CURE reached a broad cross section of students who completed their research as part of graded, required courses that included other topics and exams and a higher student-faculty ratio, which can discourage interest in research (Auchincloss et al., 2014).

The comparative results show that the MS-CURE students experienced gains comparable to the experienced, apprentice-style URE students (Table 1). In the category of personal and professional gains, four of five items and the mean for the category show statistically significant gains between the novice URE comparison group and the MS-CURE group. This suggests that extended time helped the MS-CURE students to develop self-confidence in their ability to function as scientists. Alternatively, other factors, such as group interaction among the MS-CURE students, as well as with the instructors, fostered increased personal and professional gains. In the category of thinking and working like a scientist, the MS-CURE group showed high Likert scores that are similar to those of experienced students, although statistically indistinguishable from novice students. The highest gains were in perceived improvements in problem solving and probably reflect the real-world nature of the research project.

SYNERGISTIC BENEFITS

Students of lower socioeconomic status, first-generation students, and underrepresented groups often are unaware of the benefits of research and thus may not apply for competitive research opportunities (NASEM, 2017). Extending the traditional CURE into a curriculum-embedded experience provides an opportunity for all students in an academic major to have access to a more authentic research experience that can foster gains in confidence, comfort in working with others, and problem solving. These are examples of the types of changes to student learning that promote workforce preparedness (Summa et al., 2017). For students, the MS-CURE model supports enhancement of social diversity and thus levels the playing field for research access. For academic departments, student-focused research provides a central organizing theme for the curriculum and allows undergraduates and faculty to operate within a connected learning community.

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TABLE 1. MEANS FOR SURVEY ITEMS

URSSA survey items and category means. How much did you gain in the following areas as a result of your URE?*	**Novice** student comparison group† (*n* = 29)		**Experienced** comparison group† (*n* = 44)		**MS-CURE** students# (this study; *n* = 14)	
	Mean	(SD)	Mean	(SD)	Mean	(SD)
Personal/Professional Gains Category						
Confidence in my ability to do research	2.82	(1.10)	3.38	(0.68)	3.43§	(0.62)
Confidence in my ability to contribute to science	2.75	(1.00)	3.32	(0.78)	3.29§	(0.70)
Comfort discussing scientific concepts with my research mentor	3.18	(0.60)	3.40	(0.82)	3.36	(0.61)
Comfort discussing scientific concepts with other research students	2.85	(0.84)	3.45	(0.69)	3.64§	(0.48)
Comfort in working collaboratively with others	3.09	(0.70)	3.64	(0.57)	3.57§	(0.50)
Category Mean	**2.94**	**(0.85)**	**3.44**	**(0.71)**	**3.46§**	**(0.58)**
Thinking and Working Like a Scientist Category						
Understanding how to collect scientific data	3.40	(0.64)	3.61	(0.65)	3.57	(0.49)
Understanding how scientific research is done	3.43	(0.79)	3.71	(0.55)	3.71	(0.45)
Analyzing data for patterns	3.10	(0.76)	3.35	(0.79)	3.29	(0.59)
Interpreting results from analyzing scientific data	3.09	(0.86)	3.40	(0.74)	3.43	(0.49)
Problem solving in general	3.15	(0.77)	3.44	(0.76)	3.64§	(0.48)
Formulating a research question that can be answered with data	3.26	(0.75)	3.21	(0.93)	3.29	(0.70)
Identifying flaws in the interpretation of data	3.09	(0.76)	3.35	(0.83)	3.29	(0.70)
Figuring out the next steps in a research project	3.17	(0.79)	3.24	(0.88)	3.07	(0.70)
Category Mean	**3.21**	**(0.77)**	**3.41**	**(0.77)**	**3.41**	**(0.58)**

* Likert scale: 1 = no gain; 2 = a little gain; 3 = good gain; 4 = great gain.
† Comparison group data from Thiry et al. (2012).
# Demographics: 43% female, 14% minority, 36% 1st generation, 43% Pell, $\bar{x}$ GPA 3.03 (RGE 2.1–3.7), $\bar{x}$ GPA major 2.64 (RGE 2.0–3.6).
§ $P \leq 0.05$ determined from unequal variances *t*-test of novice student comparison group mean vs. MS-CURE mean.
SD—standard deviation; RGE—range; URE—undergraduate research experiences; URSSA—Undergraduate Research Student Self-Assessment.

A Tremendous Thanks to GSA Members, Sections, and Community

During an unprecedented time, the GSA Foundation Board of Trustees and the GSA Council undertook an unprecedented measure: the conception of GSA CARES, the GSA COVID-19 Assistance and Relief Effort for Students.

Both the Society and the Foundation committed US$50,000 to the effort, and the Foundation launched a funding campaign to match another US$50,000 in contributions. We want to give an extraordinary thank you to the GSA membership, particularly to our committed donors who continue providing the support allowing GSA to fund its programs. During this challenging time, many of you sprang into action to help students in need, with 300 gifts totaling more than US$80,000. Not only did each GSA Councilor, GSA Foundation Trustee, and GSA Foundation staff member make a gift, but GSA Sections contributed significantly, which unlocked an additional matching amount from the GSA Foundation to its original pledge. In all, we had US$188,000 to provide to students whose educational progress has been impacted by the pandemic.

This outpouring of support for GSA students during this time demonstrates the very heart and soul of the Society and our donor community. You have come together to show your care and interest in the wellbeing of our next generation of scientists, and your ongoing, generous contributions are making an immediate, direct impact. On behalf of the GSA Foundation Board of Trustees and staff, we commend you and we thank you. We are proud to work with and for you, in support of the future of the ever-vital geoscientists and the roles they will fill.

Thank You

for your support and generosity.

#GSACARES

GSA FOUNDATION

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2021 GSA Section Meetings

Northeastern

14–16 March
Connecticut Convention Center
Hartford, Connecticut
https://www.geosociety.org/ne-mtg

The skyline of Hartford, Connecticut, as seen from across the Connecticut River. Image by Jimaro Morales from Pixabay.

Southeastern

1–2 April
The Hotel at Auburn University
and Dixon Conference Center
Auburn, Alabama
https://www.geosociety.org/se-mtg

William J. Samford Hall, Auburn University. The George F. Landegger Collection of Alabama Photographs in Carol M. Highsmith's America, Library of Congress, Prints and Photographs Division.

Joint North-Central/South-Central

18–20 April
University Plaza Hotel
Springfield, Missouri
https://www.geosociety.org/nc-mtg

Downtown Springfield Park Central Square. Photo courtesy of the Springfield, Missouri, Convention and Visitors Bureau.

Cordilleran

12–14 May
Whitney Peak Hotel
Reno, Nevada
https://www.geosociety.org/cd-mtg

Volcanic geology of the Virginia Mountains, Nevada.
Photo courtesy of Dr. Philipp Ruprecht, UNR faculty member.

Rocky Mountain

25–27 May
Colorado State University
Ft. Collins, Colorado
https://www.geosociety.org/rm-mtg

Pineridge Natural Area. Image by Jan Alexander from Pixabay.