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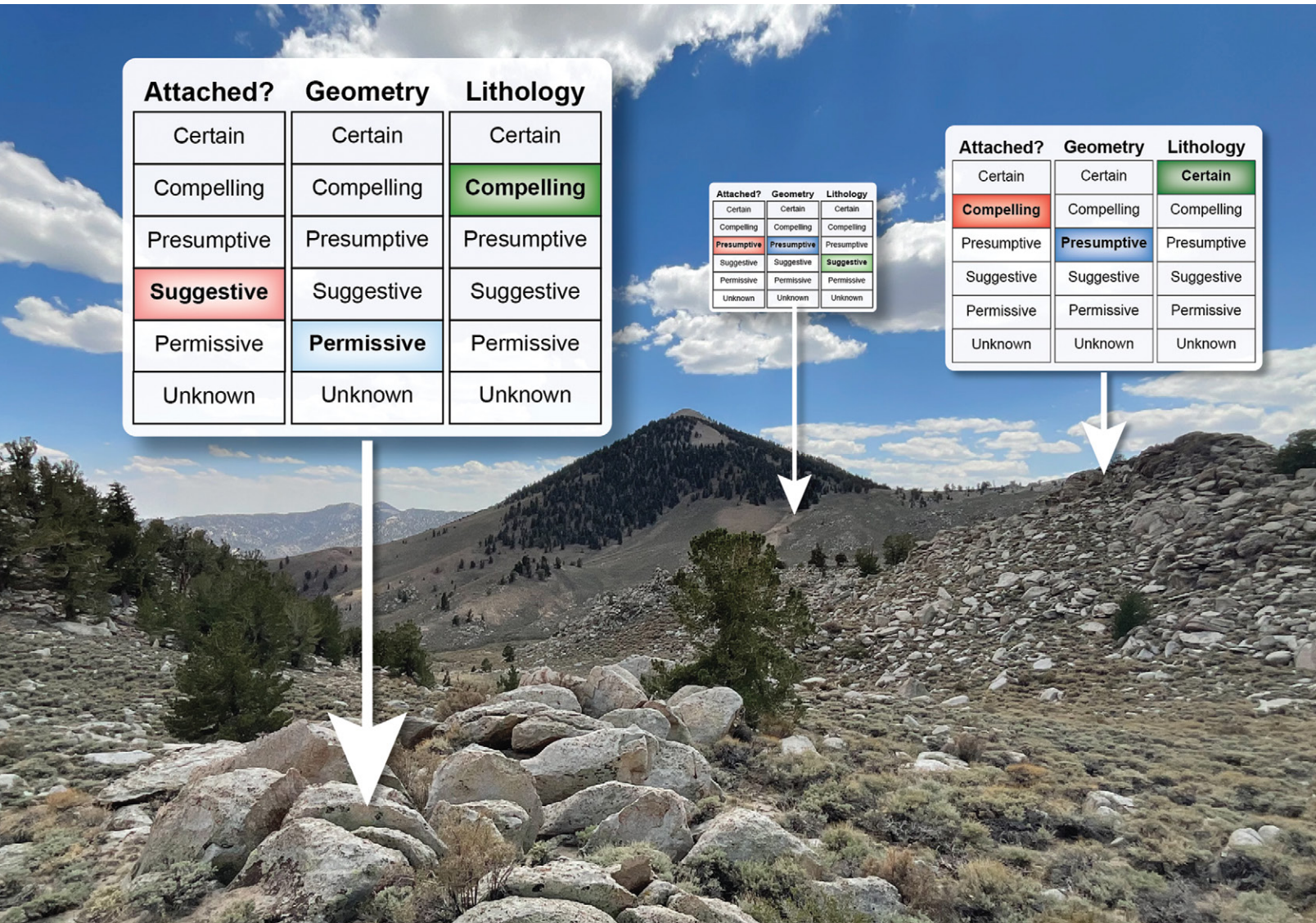
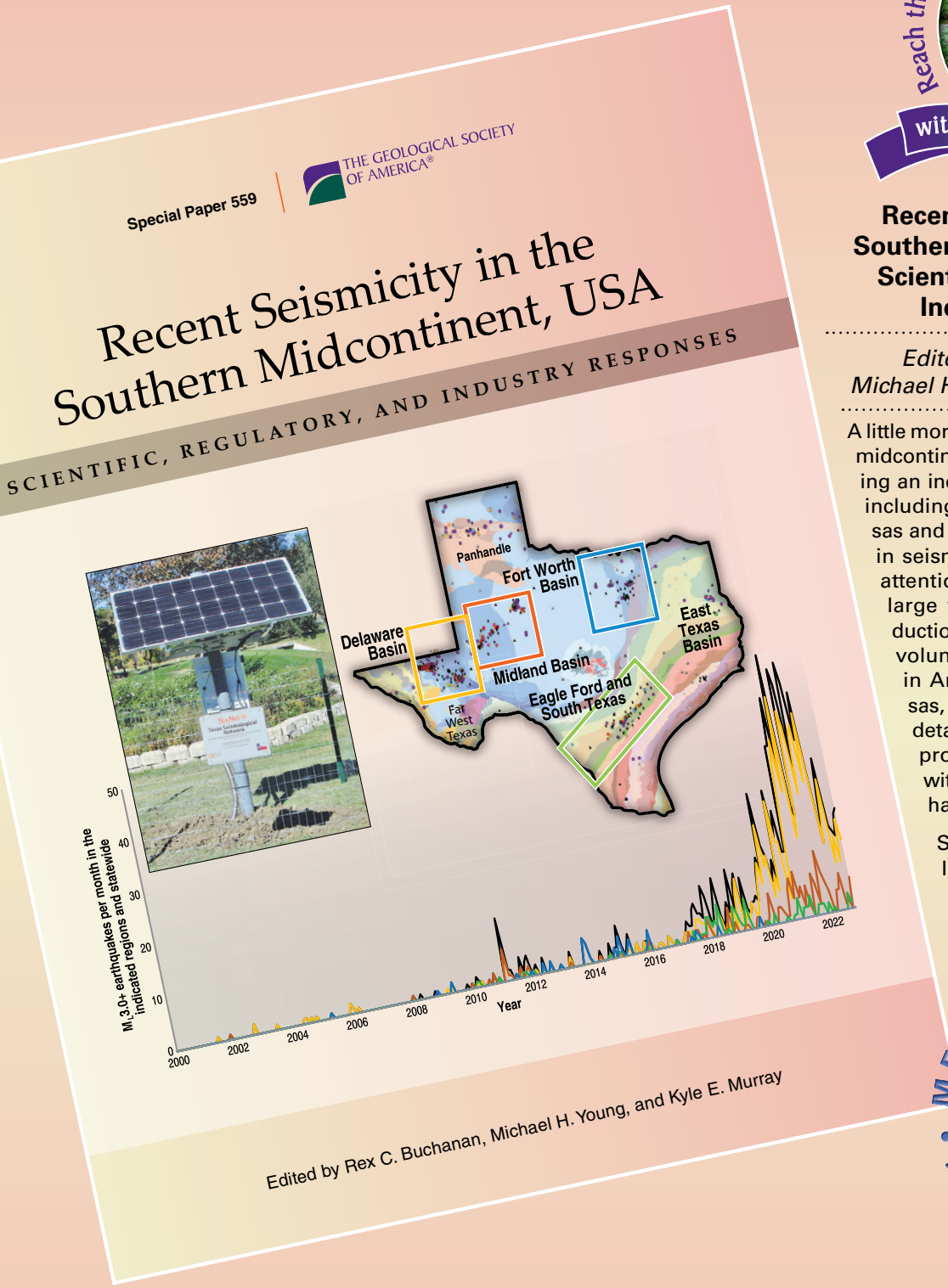
Improving the Practice of Geology through Explicit Inclusion of Scientific Uncertainty for Data and Models





Recent Seismicity in the Southern Midcontinent, USA: Scientific, Regulatory, and Industry Responses

Edited by Rex C. Buchanan, Michael H. Young, and Kyle E. Murray

A little more than a decade ago, the southern midcontinent of the U.S. began experiencing an increasing number of earthquakes, including several large events in Arkansas and then Oklahoma. As that increase in seismicity spread to multiple states, attention focused on how disposal of large volumes of brine from oil production could trigger earthquakes. This volume examines that phenomenon in Arkansas, Oklahoma, Texas, Kansas, Colorado, and New Mexico, and details the regulatory response to it, providing a case study in dealing with an unexpected natural resource hazard.

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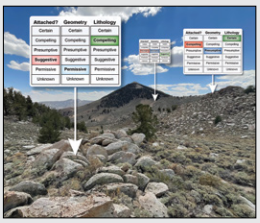
SCIENCE



Cover: Field photograph from the Sage Hen Flat area, eastern California, USA. Columns show a six-point uncertainty scale — with divisions of no evidence, permissive, suggestive, presumptive, compelling, and certain — as applied to three different observations (attachedness, geometry, and lithology) that geologists make at each outcrop. See related article, p. 4–9.

GSA CONNECTS 2023

GSA NEWS

Improving the Practice of Geology through Explicit Inclusion of Scientific Uncertainty for Data and Models

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ABSTRACT

The field of geology is poised to make a fundamental transition in the quality, character, and types of science that are possible for practitioners. Geologists are developing data systems—consistent with their workflow—to digitally collect, store, and share data. Separately, geologists and cognitive scientists have been working together to develop tools that can characterize the level of uncertainty of both data and models. The transformational change comes from the simultaneous combination of these two approaches: digital data systems designed to capture and convey scientific uncertainty. This approach promotes better data collection practice, improves reproducibility, and increases trust in community-based digital data. We applied these methods—attending to uncertainty and its incorporation into digital repositories—to the Sage Hen Flat pluton in eastern California, USA, where two published maps provide different interpretations. Incorporating uncertainty into our workflow, from field data collection to publication, allows us to move beyond binary choices (e.g., is this data/model right or wrong?) to a more nuanced view (e.g., what is my level of uncertainty about the data/model?) that is shareable with the larger community.

INTRODUCTION

G.K. Gilbert's 1886 article, "The Inculcation of the Scientific Method by Example," introduced the protocol of using multiple working hypotheses when conducting geological fieldwork. Gilbert recognized the need for an explicit statement and consideration of alternative models in order to mitigate biases that arise from human reasoning. Humans infer causes to explain their observations about the world. Once a sufficient (or even convenient) explanation is available, that explanation tends to be favored over others; subsequent, inconsistent observations are frequently disregarded. This tendency is referred to as "confirmation bias," and it is one of many cognitive biases that affect human judgment. Gilbert's fundamental contribution was in recognizing—nearly 100 years before the formal study of decision biases—that scientific observation was vulnerable to the same reasoning pitfalls. In short, he realized that doing better science requires not only taking advantage of the mind's strengths but also supporting its weaknesses. If one accepts that the mind plays a role in both data collection and interpretation, then it follows that knowing something about how the mind operates will result in better science.

Cognitive science has addressed the mind's struggle with multiple competing hypotheses and the human tendency to filter data at both conscious and unconscious levels. One of the most effective methods developed to reduce bias is to structure the environment of inquiry to "nudge" people toward more nuanced conclusions. For example, a particularly powerful workflow was demonstrated within geoscience practice wherein all reasonable interpretations are explicitly articulated prior to deciding which is the most reasonable (Bond et al., 2008; Alcalde et al., 2017). This approach is a recent example of utilizing Gilbert's multiple working hypothesis methodology. But, as a community, we can move beyond the need to de-bias our approaches and develop workflows that support nuanced data collection and model articulation. A workflow to enhance field-based geologic practice, built from cognitive science principles and designed to support the mind, has become possible with an unexpected ally: digital database systems.

Digital database systems are now available for field-based geology (e.g., StraboSpot; Walker et al., 2019). Access to basic digital database systems enables researchers to record nuance-rich and contextual information regarding individual outcrops, with the added benefit of improved data sharing with the larger community. These systems are integral to designing new workflows that take advantage of strengths and support areas of weakness in the human mind.

This article highlights how the simultaneous use of cognitive science principles and digital data systems allow us to fundamentally improve field geology through the characterization and capturing of the uncertainty of both data and models. Geologists already know that uncertainty information is useful, which is why digital systems for seismic interpretation have worked to incorporate uncertainty judgments (Leahy and Skorstad, 2013) and why geologists already capture this information for some features (e.g., dotted versus dashed versus solid contacts on maps). We introduce a system for capturing uncertainty across a broad range of geological features. Then we show how these rankings can be incorporated and used in a digital data system. Finally, we demonstrate the utility of this approach by applying it to geological mapping in the Sage Hen Flat pluton in eastern California, where two published

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maps provide different interpretations of the same geology. We show that mapping with the explicit use of uncertainty rankings allows the community to more directly evaluate published data and models with nuanced interpretation.

CHARACTERIZING UNCERTAINTY

As noted by R. Allmendinger (pers. commun., 2013): "Geophysicists collect data then filter; Geologists must filter reality, then collect data." Considering the case of field-based geology, the filtering is both perceptual (and likely to be unconscious) and cognitive (and therefore more likely to be conscious and strategic). Unconscious filtering is seen, for example, in the diagrams labeled "what a geologist sees" in S. Marshak's physical geology textbook (Marshak, 2009), where extraneous vegetation and cover are ignored. Experience allows experts to disembed key features and thereby visually focus attention on subtle geological patterns (Hanawalt, 1942; Kastens and Ishikawa, 2006; Reynolds, 2012). Conscious filtering is more complex. Geologists continuously make a series of decisions in the field: What data do I collect, where should I collect it, and is it worth collecting? All these decisions are susceptible to bias. Thus, much of the field data in publications is heavily filtered before being made available to peer-reviewers and readers.

What geologists call "data" or an observation is not, strictly speaking, a property of the world that is visible to everyone. Rather, field data are the accumulated balance of evidence for a claim about a property of the world. Although geologists might object to this characterization, the geologist authors of this article have been convinced by our cognitive scientist colleagues that it is true. For example, consider a geologist who wonders whether to record a measurement because that person is uncertain if a rock is fully attached to the underlying bedrock. In such a situation, the geologist must decide based on the balance of evidence for or against this rock's "attachedness." In the discipline's current working approach, a geologist will either take and report the measurement or not: It is a binary choice. The quality of the evidence is lost, as is all the potentially valuable data that was overlooked because the quality was under the threshold to collect and/or report. When we talk about data uncertainty, these are the types of issues that we are considering.

In the system we propose, there is a six-point scale to characterize uncertainty in data (recorded observations) (Fig. 1). The scale ranges from **no evidence** to **certain,** with four broad categories in between, from low to high: **permissive, suggestive, presumptive, compelling.** These terms are chosen to reflect the judged likelihood that an observation reflects the true state of the world (respectively, less than 25% chance, 25%–50%, 50%–75%, and greater than 75%). For data, it is possible to be completely uncertain (**no evidence**) or to have such compelling evidence that the data is essentially **certain.** The scale is designed to leverage humans' strengths in making stable judgments about mental states when using a consistent scale with a limited set of categories (Preston and Colman, 2000).

Data quality is a combination of the variability in the world (e.g., local heterogeneity in a surface orientation or diagenetic changes to minerals) and variability due to the mind (e.g., visual skill in identifying the "representative" plane of a feature to record). The two sources of variability are inherently intertwined, as one's confidence in recording a feature accurately will be inversely proportional to the observed variability of the feature in the locale. Humans can reliably estimate their relative uncertainty and thus accuracy of decisions (Maniscalco and Lau, 2012). In present practice, some of these quality judgments are recorded, such as in a field notebook, but not as part of the community record. Consequently, most quality judgments are lost, including those where no data were recorded at all, as when a geologist bypasses an outcrop looking for a better-quality one.

Models are necessarily uncertain, and the same ranking system is applicable to them (**permissive, suggestive, presumptive, compelling**; Fig. 1). As an end member, models can be *incorrect* if there is evidence to refute a model (e.g., flat Earth model) or *unsupported* if there is no data to support a model. Likewise, no scientifically interesting models ever attain the status of *certain*. All models are uncertain because they: (1) contain untested or contested assumptions; (2) have many parts for which each part may introduce some type of uncertainty; (3) contain parts that have nonlinear effects on inferred consequences from observations; and (4) cannot incorporate data that are yet to be obtained. Because of these limitations, models are generally less certain than the relevant data for which they account.

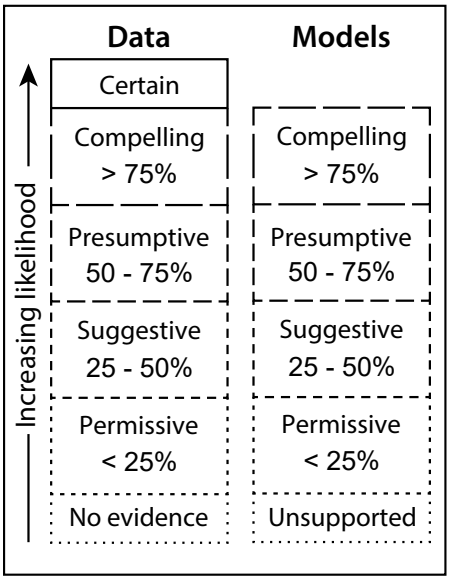

Figure 1. The uncertainty scale for geological data and models. The categories are linked to estimates of statistical likelihood, from low to high, of *permissive* (less than 25% chance), *suggestive* (25%–50%), *presumptive* (50%–75%), *compelling* (75%–99%), and *certain* (100%). Data can be categorized as *no evidence* or *certain*. In contrast, it is not possible for a model to be *certain*. Further, models can be *unsupported*. It is possible for both data and models to be *incorrect*.

UNCERTAINTY AND BEDROCK MAPPING

To characterize and store data uncertainty information, it is necessary to clearly specify the different aspects of the data that could be uncertain. First and foremost, this characterization must be streamlined into field protocols. Because field time is valuable and limited, uncertainty information will not be collected unless it requires minimal time expenditure. Second, the specific observations, to which uncertainty is assigned, depend on the map type. Bedrock mapping, for example, requires the determination of whether the rock at Earth's surface is directly connected to, and thus is representative of, the rocks below the surface at that location (*attachedness*). For comparison, attachedness for surficial mapping is less critical; attachedness has no relevance for a landslide deposit. Thus, while the identical scale (no evidence, permissive, suggestive, presumptive, compelling, certain) is useable for all maps, the observations to which they pertain may vary.

In this contribution, we concentrate on bedrock mapping. We introduce four basic observations that geologists are likely to encounter at an individual outcrop: (1) attachedness, (2) lithological correlation, (3) 3D geometry, and (4) kinematics. As

noted, each of these observations requires an inference, and the inference improves with experience. *Attachedness* is discussed above. *Lithological correlation* is the determination of whether a particular rock belongs to a larger group of rocks (e.g., a named formation). We expect the majority of uncertainty will be due to challenges inherent in evaluating nuances in rock properties to correlate to a known unit and explicitly recognize that a professional geologist will be able to determine rock type at any outcrop (e.g., granitoid), although ambiguities in rock type (e.g., tonalite vs. granodiorite) can also be reflected in this category. *Three-dimensional geometry* describes how accurately one can quantify the internal spatial features of an outcrop. An example of 3D geometry is the determination of strike and dip of bedding, which is measurable to approximately ±3° for both measurements given the natural variability of rock. However, there are multiple cases where one is not certain of the 3D geometry, such as non-planar bedding measurements (e.g., cross bedding). *Kinematics* is an interpretation of movement associated with the rock. Kinematics could include primary (e.g., paleocurrents) or secondary (e.g., fault offset) features.

We identified these four aspects of an outcrop to retain potentially valuable information in one aspect (e.g., lithology) that might have been lost due to uncertainty in some other feature (e.g., attachedness). The features are not completely independent. For example, a low certainty ranking for attachedness would necessarily indicate that the geometry is unlikely to reflect the orientation of the underlying rocks. However, some features are more independent. For example, lithology can be accessed independent of attachedness or geometry, and conversely geometry and kinematics can be observed compellingly in some cases even when the lithologic unit is uncertain.

AN EXAMPLE OF BETTER GEOLOGY ENABLED: SAGE HEN FLAT PLUTON, CALIFORNIA

Background

We provide an example of the use of uncertainty scales from the Sage Hen Flat pluton in the White-Inyo mountains of eastern California. The plutonic bodies of the White-Inyo range intrude into a nearly continuous section of exposed Late Precambrian–Paleozoic strata that are weakly metamorphosed and deformed by multiple generations of Paleozoic folding (e.g., Stevens et al., 1997). However, the Late Jurassic Sage Hen Flat pluton is unique among these intrusions because its emplacement does not disrupt any of the regional structural trends (Morgan et al., 2000).

The relevance of the Sage Hen Flat pluton for our study is that there are two geological maps—both done by professional geologists with significant mapping experience—that disagree in both map pattern and cross section (Figs. 2 and 3). The Ernst and Hall (1987; afterward E&H) map was part of a regional map of the White Mountains. The Bilodeau and Nelson (1993; afterward B&N) map focused solely on the Sage Hen Flat pluton. For our purposes, the geological maps are models based on data. There are places where the data are clearly distinguished from inferences: the strike-and-dip symbols, solid contacts between units, etc. The cross sections are models and are necessarily more speculative than the geological maps because of the lack of sub-surface information.

The difference between the geological maps is most prominent in the northwestern corner of the pluton, which is highlighted in Figure 3. The E&H map interprets the local geology as recording a fault contact between

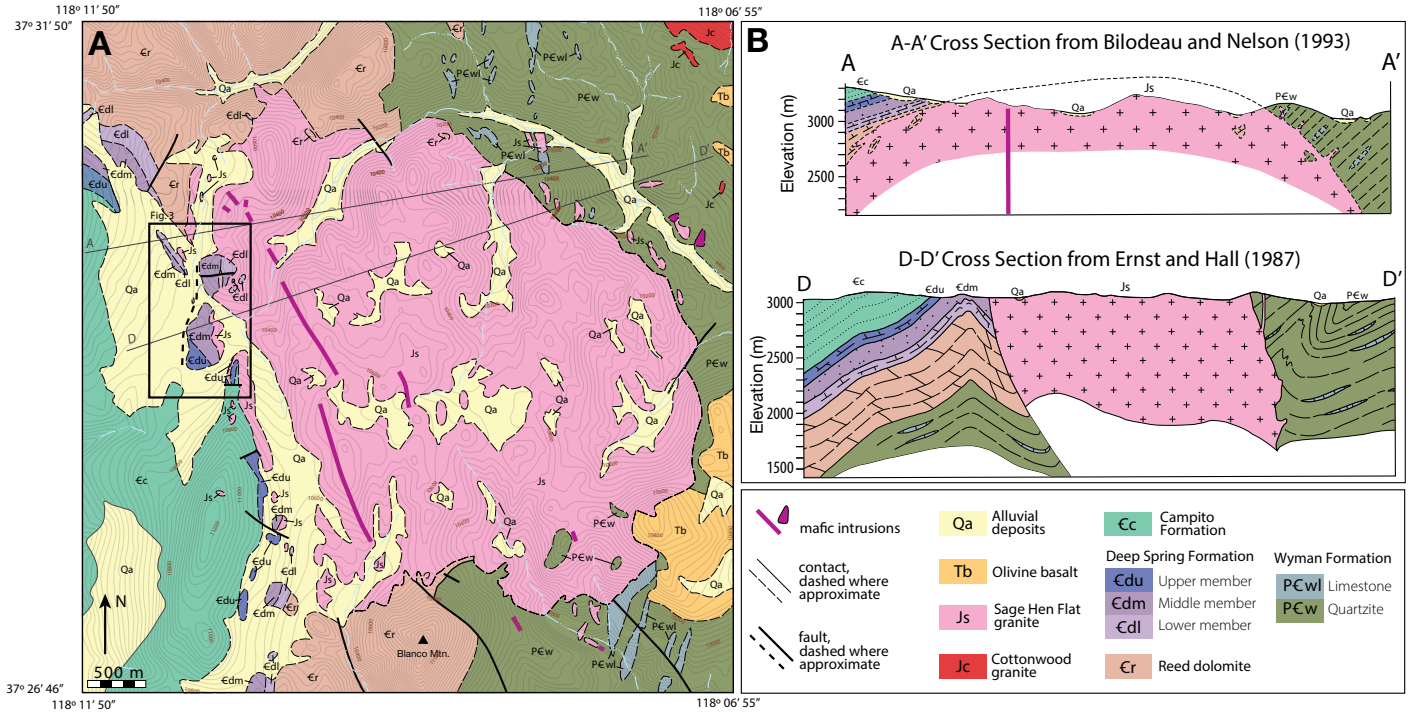

Figure 2. (A) Geological map (modified from Bilodeau and Nelson, 1993) and two different cross sections depicting different models for the regional geology. The Bilodeau and Nelson (1993) cross section (B, line A–A') indicates an intrusive contact for the Sage Hen Flat pluton. The Ernst and Hall (1987) cross section (B, line D–D') depicts the western edge of the Sage Hen Flat pluton as a faulted contact. The box on the geological map (A) shows the location of Figure 3. Both cross sections lines (A–A' and D-D') cross the area shown in Figure 3.

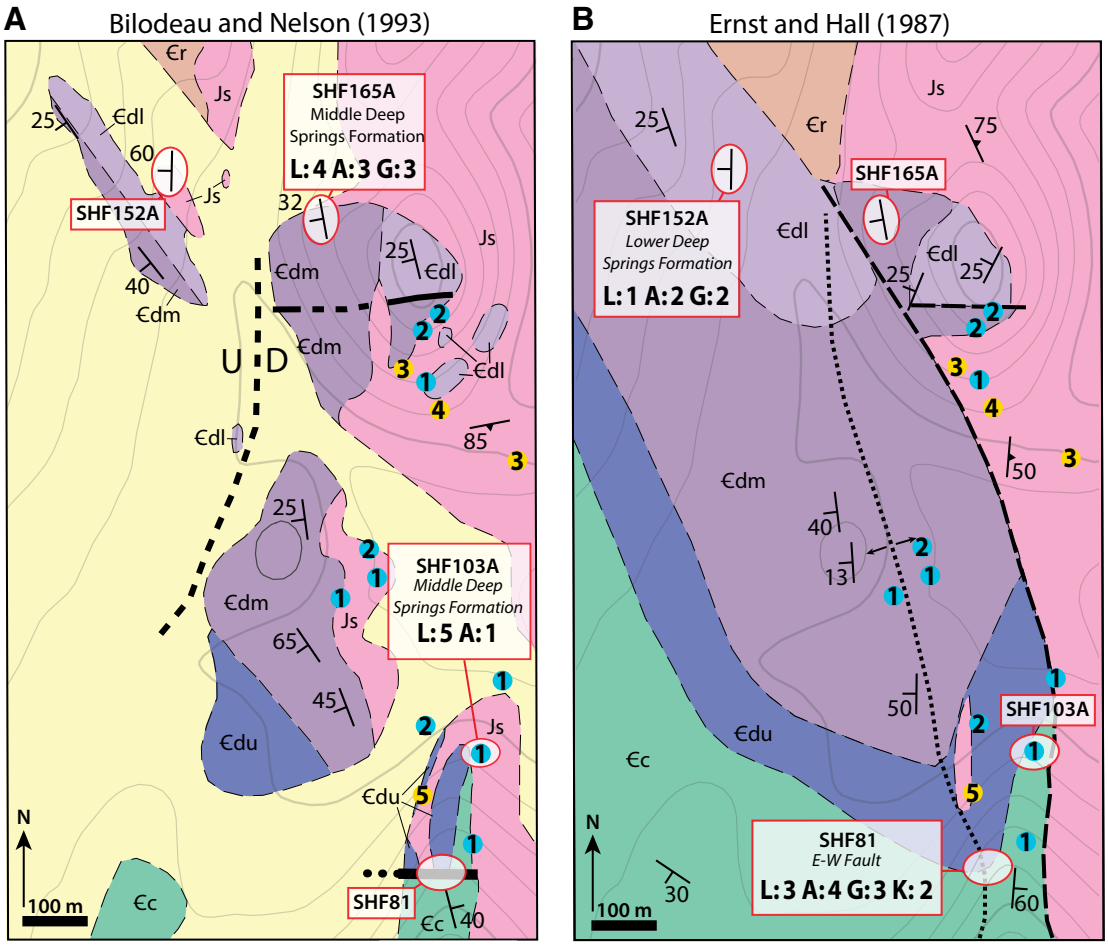

Figure 3. Geological maps of the northwest corner of the Sage Hen Flat pluton extracted from the geological map of (A) Bilodeau and Nelson (1993) and (B) Ernst and Hall (1987). The circled numbers show the location and attachedness values (blue = 1, 2; yellow = 3–5) for granitic outcrops discussed in the text. These data are part of the public "Sage_Hen_Flat_Tikoffetal" project on StraboSpot.org. L—lithology; A—attachedness; G—geometry; K—kinematics. See Figure 2 for legend.

Sage Hen Flat granite and country rock on the western margin of the pluton. The B&N map indicates that the plutonic contact on the western margin is intrusive. We focused our efforts in this location to investigate the interplay of data and model uncertainty, reasoning that the likely cause of the model uncertainty—as indicated by their disagreement—was data uncertainty.

Application of the Uncertainty Scales

The existence of two differing models for the geometry and origin of some features is not unique in geology, but it is particularly well illustrated in the case of the Sage Hen Flat pluton. We remapped the pluton in the summers of 2019 and 2021 in order to construct and then utilize uncertainty scales that are applicable to field geology. The data were recorded in the StraboSpot system with the uncertainty values noted. The publicly available full data set contains 461 stations with notes on the geological features, associated uncertainty, and photographs ("Sage_Hen_Flat_Tikoffetal" project on StraboSpot.org). Uncertainty for attachedness and lithology were collected on the 0–5 scale outlined above. Geometry information was collected in those cases in which: (1) attachedness was 2/5 or higher, and (2) a bedding or foliation was possible to measure. Kinematics were only noted in a few locations where kinematic features, in this case fault traces, were present.

Our intention is not to find that one mapping team is wrong and one is right. Rather, our objectives are to (1) understand what data drove the previous interpretations; and (2) demonstrate that showing uncertainty allows geologists to make an informed judgment.

Station SHF165A (Fig. 3) shows a location for which there is agreement between B&N, E&H, and our data. We are explicit in our evaluation of attachedness, lithology, and geometry: A practitioner can determine how much to trust our data. In contrast, we interpret that if B&N or E&H took a measurement, they likely did so only in cases for which attachedness was presumptive (3/5) or higher.

For Station SHF152 (Fig. 3), the B&N and E&H maps are in conflict. Our data suggest that B&N is incorrect in mapping it as a granite: The outcrop is a carbonate, although it is bleached, potentially by fluids expelled from the nearby Sage Hen Flat pluton. The E&H map indicates that the outcrop is the Reed (dolomite) Formation. We are less certain, because of the metasomatic alteration, but assign this outcrop to the Deep Springs Formation (1/5). If the B&N *data* are incorrect, does it alter their *model* for the margin of the pluton? In our opinion, the answer is no. It is relatively uncritical if this outcrop consists of granite or carbonate with respect to their model of an intrusive contact.

The more interesting case are the outcrops of Sage Hen Flat granite (Fig. 3): Blue circles show location of outcrops with low attachedness rankings (1/5 or 2/5), whereas yellow circles distinguish outcrops with high-attachedness rankings (3/5 or higher). Note that both maps are consistent with our high attachedness ranking outcrops. The difference is that there are numerous low-attachedness ranking outcrops that are consistent with the B&N map but not the E&H map (Fig. 3). Outcrop 103A (Fig. 3) shows one such example; although attachedness is low, most geologists would likely interpret that these rocks are nearly in place, as there is no reasonable process that could have moved them from elsewhere. We now ask the critical question of the E&H map: Do the incorrect *data* alter their *model* for the margin of the pluton? The answer, for us, is yes. The existence of abundant granite outcrops west of their interpreted fault—where no granites should outcrop—suggests that the model has more uncertainty than that of B&N.

At Station SFH081 (Fig. 3), the Lower Deep Springs Formation strikes into the Campito Formation, and both units display similar bedding orientations. A fault is shown on the B&N map but not on the E&H map. We judge the presence of this fault to be compelling (4/5). In this case, we can also investigate the kinematics. There is not an exposed fault surface with slickensides, and the movement cannot be resolved by stratigraphic offset. Geometrically, the fault movement could be N-side-down, dextral, or some combination. We rank the kinematics as suggestive (2/5) and, similar to B&N, would not indicate fault movement using a symbol on the map.

DISCUSSION

Data Uncertainty

Our uncertainty evaluations at the northwestern corner of the Sage Hen Flat pluton provide more robust field data than previously available. Geologists are already making these types of evaluations, but they are not doing it systematically, using a shared vocabulary, or storing the evaluations in a format that other geologists can access.

In our opinion, the data we present are more useful than the data that B&N and E&H provided, largely because our data collection system includes uncertainty. The advantages of our approach are (1) we have created methods to record the data that are accessible, so the community—including geologists who have not physically been there—can evaluate it and offer alternative geological inferences; (2) the collected data are nuanced, which allows all interested members of the community to consider how much to rely on a specific measurement; (3) we collected more data because we had a digital system that allowed us to collect it quickly; (4) the data are less filtered, as we were willing to collect low-certainty data because we could identify it as such; and (5) the need to explicitly evaluate uncertainty at every station motivated us to evaluate each outcrop independently, which reduces bias by reducing the influence of preconceptions (about the adjacent outcrops, regional geology, existing models, etc.).

Model Uncertainty

Our approach allows us to make better models through (1) the use of shared language to characterize the quality of the *model*; (2) the use of more robust field *data* (more data, stored in an accessible way, with quality evaluations); and (3) the ability to more closely link the quality of the *data* to the quality of the *model*. We apply these concepts to the two models for the western margin of the Sage Hen Flat pluton: (1) a faulted contact (E&H; Fig. 2B), and (2) an intrusive contact (B&N; Fig. 2B).

Prior to spending time in the field, we evaluated both the E&H and B&N models as "suggestive." Having collected data in this area, we promote the B&N model to "presumptive" and keep the E&H model as "suggestive." The data that we collected that are not consistent with the B&N model (e.g., SHF152A; Fig. 3) are nevertheless consistent with the processes interpreted in their cross section. In contrast, some of our data do not support the E&H model; the granitic outcrops with low attachedness rankings in the southern part of the area shown in Figure 3 are inconsistent with a faulted contact. Thus, although the E&H model remains suggestive (in the 25%–50% likely category), it is less likely than the B&N model. We note that in any field area, a compelling or even presumptive model may not exist, because the nature of the outcrop quality or the complexity of the region does not allow the true relationships to be discerned.

Our assessment applies only to a small area (Fig. 3) of the E&H and B&N maps, but illustrates a structured way to engage in assessments of model certainty. In particular, it addresses where models are uncertain and the level of that uncertainty. A critical point is that we are not trying to determine which model is correct: Our evaluation is more nuanced than one model is right and the other one is wrong. In large part, both models are well supported by high-certainty field data. It is unclear that additional geological mapping, by itself, would further adjudicate between the existing models.

Data Uncertainty and Model Uncertainty Interaction

Data uncertainties interact with the model uncertainties in a variety of different ways. The influence of data uncertainty on model generation is clear. All scientists likely recognize that one's interpretation can only be as good as one's data. For a sparse data set from an area where exposures are limited, model uncertainty is closely tied to the underlying data uncertainty. Thus, compelling models are made with consistent, compelling data. In contrast, permissive models are made with either consistent permissive data or a mix of inconsistent suggestive, presumptive, and compelling data. As data sets get larger, these relationships change. For example, a large number of consistent, permissive data could support a suggestive (or more certain) model. These relations can be developed statistically in the future as the community develops its facility with digital methods.

Most geologists engage in model comparison, but they are not doing it explicitly or consistently when collecting data. Model uncertainty guides data collection in areas where data can distinguish between different models. For this reason, we focused our work on the northwestern corner of the Sage Hen Flat pluton, where there was a clear need to collect unbiased data in order to evaluate competing models. Note the similarity of our approach to that of Gilbert (1886). The use of model uncertainty produces the same cognitive advantages as Gilbert's idea of multiple working hypotheses, particularly in debiasing of data collection.

We argue that we can make a fundamental improvement to the approach of Gilbert by focusing on data rather than models. This approach is facilitated by the use of digital data systems coupled with a workflow informed by cognitive science. In the absence of digital tools, people reason using models because there is no effective way for the mind to keep track of *all* of the data and its attendant uncertainties. Digital data systems offload this cognitive burden, which in turn can improve estimates of

relative model certainty. This process encourages data collection—particularly of unexpected features and/or low-certainty data—that can provide new model insights and transform practice. Marginal data in bulk can provide better estimators than sparse data to refine spatial and non-spatial interpretations. Data analytics developed for field-collected data uncertainty could prove to be a key for developing robust quality control and quality assurance for digital data systems.

Recording geologists' uncertainty allows transparent connections between uncertainty in data and the uncertainty in models. One can produce better models because one can evaluate the quality of the data upon which the model is built. Critically, the geologists who have used the uncertainty scales in the field do not find them cumbersome or overly time consuming. The use of uncertainty simultaneously could increase a scientist's trust of data types outside of their expertise as they could rely on the evaluation of uncertainty by others. Communicating the uncertainty in data and models may reduce the barriers to model revision or replacement and speed the advance of science.

Future Work

The presented workflow provides one possible approach for geologists to capture and communicate uncertainty in data and models. Although it is not meant to be prescriptive, it exhibits important attributes for gathering uncertainty information for field practitioners: (1) it does not interfere with workflow, (2) it facilitates transparent data collection, (3) it captures uncertainty about a manageable number of categories, and (4) the results are replicable and psychologically meaningful. These guidelines may be useful to other communities using field-based data that adopt the collection of uncertainty data to support their research needs.

This contribution aims to improve the quality of field-based geologic information through the explicit communication of uncertainty and the manner in which that uncertainty is communicated. There are, however, other discussions that need to be held at a community level. For example, practitioners in bedrock mapping may want to develop new conventions for visually communicating uncertainty. It may be time—with cognitive scientists involved in the process—to update how we record, represent, and communicate geologic information.

CONCLUSIONS

It is generally recognized that science and society are undergoing a digital revolution. The geological community has the opportunity to adapt best practices of the past to the emerging new workflows that result from the ability to operate digitally. We propose the systematic use of uncertainty scales when collecting digital field data and developing models, which are easily recorded by digital technologies, as better science practice.

We applied the use of uncertainty scales to bedrock mapping at the Sage Hen Flat pluton in eastern California, where different data resulted in different models for the regional geology. New data was collected in the area of most divergence between the two geological maps. The purpose of our evaluation was to show how data that contain uncertainty estimates provide a fundamentally better record of geological field data, can adjudicate between different models, and can guide future research. The language associated with the data and model uncertainties can also allow nuanced (e.g., non-binary) decisions and facilitate productive communication between researchers.

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Robert Dott provided a version of an "evidence meter," which he modified from an earlier effort by Preston Cloud. S. Morgan, M. St. Blanquat, R. Law, A. Glazner, and J. Bartley all provided data and/or information about the Sage Hen Flat pluton. J. Newman and J.D. Walker are thanked for multiple conversations about how to incorporate uncertainty into StraboSpot. The concept for the map comparison in Figure 3 came from an informal student presentation by L.D. Wilson, J.D. Higdon, and J.A. Davidson (from A. Glazner, pers. commun., 2022). Reviews by Steve Reynolds and two anonymous reviewers helped us improve the manuscript. This work was supported by the National Science Foundation under Grant NSF DUE 1839705 (TS) and 1839730 (BT), and NSF EarthCube 192973 (BT).

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Manuscript accepted 1 April 2023

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STUDENT/EARLY CAREER PROFESSIONAL TRAVEL GRANTS

You still have time to apply for grants. Various groups are offering grants to help defray your costs for registration, field trips, travel, etc., for GSA Connects 2023. Check the website at **community.geosociety.org/gsa2023/connect/student-ecp/travel-grants** for application and deadline information. Note: Eligibility criteria and deadline dates vary by grant. The deadline to apply for the GSA Student Travel Grant is **11:59 p.m. MDT on 13 Sept.**

STUDENT VOLUNTEERS

The Student Volunteer Program will open in August. Earn complimentary registration when you volunteer to work for at least ten hours, plus get an insider's view of the meeting.

Please wait until you have signed up as a volunteer to register for the meeting, unless you want to reserve a space in a Field Trip or Short Course. Detailed information can be found at **community.geosociety.org/gsa2023/registration/volunteers.**

2023 Michel T. Halbouty Distinguished Lecture

Susan L. Brantley, "How Fracking Affects Our Water"

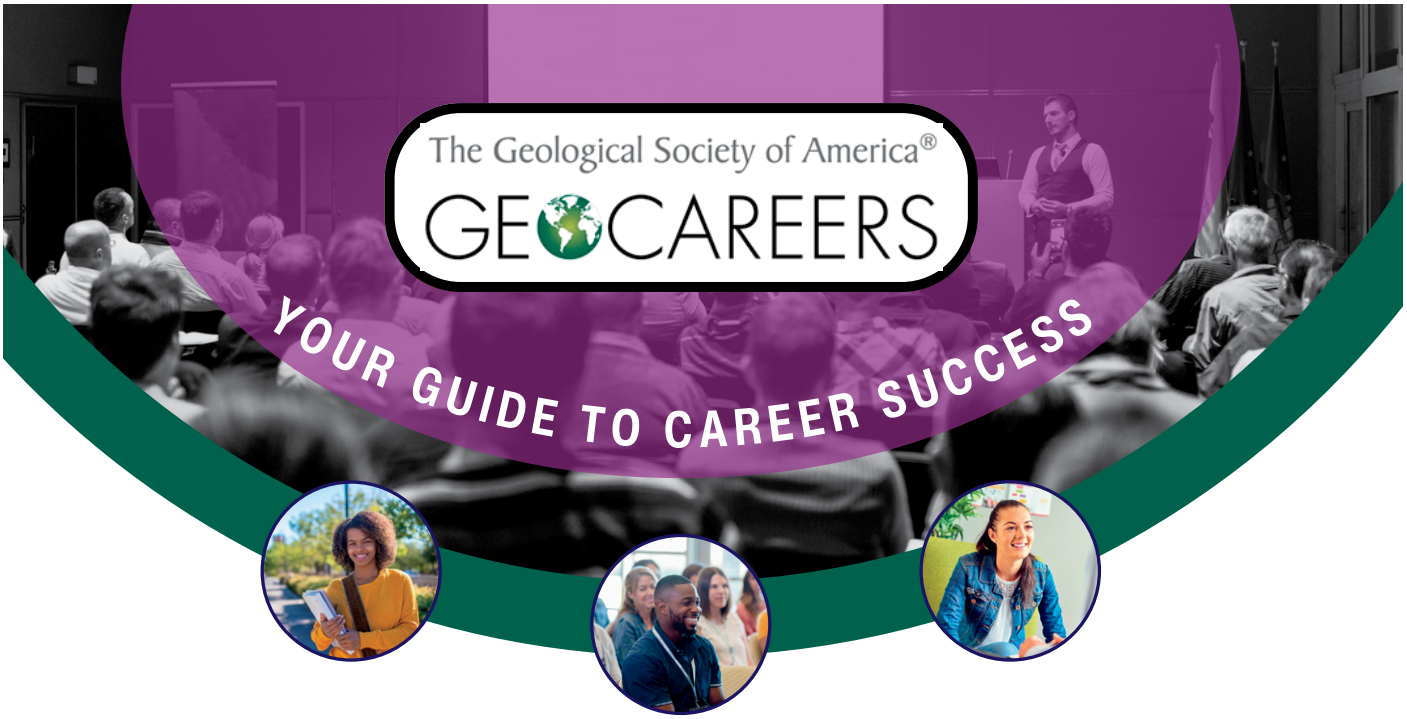
Tues., 17 Oct. 12:15–1:15 p.m.

"Fracking" of horizontal layers of shale at great depths has ushered in a new era of energy development in the USA. At the same time, shale-gas development has impacted water quality in some locations. In the mid-2000s, public outcry about "fracking" and water quality reached a fever pitch. Today, the pushback continues but is more muted. In this talk I will look at what has been learned over the last two decades about water impacts related to shale gas development (including fracking), with emphasis on both geospatial analysis as well as case studies. Much of this talk will focus on Pennsylvania, a state with the longest history of commercial oil extraction in the world, but some observations will also be made about the national situation. Government, universities, and private industry must work more closely with communities to document impacts and understand case examples of water contamination. Only with such approaches will geologists and hydrogeochemists enable the public to make educated decisions about the "social license" for the industry at the same time that our practitioners learn to understand the public's viewpoint on this distributed industry.

Noon Time Lecture

Richard Alley, "Sea-level Rise: The Solid and the Scary"

Mon., 16 Oct., 12:15–1:15 p.m.



Geocareers Center
15–18 October

Career Presentations	Résumé Review Clinic	Drop-In Mentoring
Early Career Professional Coffee	Navigating a Professional Meeting	Women in Geology Program
Networking Event	Geology Club Meet Up	View Job Postings

Geocareers Day
15 October

Career Workshop	Mentoring Roundtables	Panel Lunch

Talk with organizations and company representatives at their booths!

WANT TO MAKE A DIFFERENCE... *MENTOR!*

"The value in mentoring is seeing the talent and ability in someone who doesn't necessarily see it in themselves, and together figuring out how to reach that potential."
- Kalan Briggs, Michigan Department of Environment, Great Lakes,and Energy

Please visit: community.geosociety.org/gsa2023/geocareers & www.geosociety.org/mentors

CALL FOR PHOTOS

Pardee Session Spotlight on Positive, Diverse Female Role Models

GSA and the Association for Women Geoscientists are looking for photos of women working in the field, classroom, office, lab, or at home, to showcase as part of their Pardee Keynote Symposia at GSA Connects 2023. The goal is to demonstrate that there are diverse females working in the geosciences worldwide and to illustrate to the next generation the depth and breadth of female geologists.

The photos will be shown in the session "P2. Spotlight on Positive and Diverse Female Role Models," which will be held at GSA Connects 2023 in Pittsburgh, Pennsylvania, on Mon., 16 Oct., from 1:30–5:30 p.m. (and will be live streamed).

To be a part of this endeavor, please email:

- Two .jpg photos of YOU at work (500 px L x 500 px W) cropped to a square to diverse.geos2023@gmail.com.
- Name the files using first_last.jpg (example Abigail_burt.jpg).
- Include your name, occupation, employer, and location in the email.

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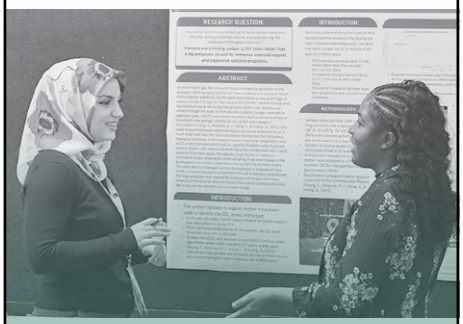

GSA Connects 2023 will broaden your perspectives and enhance your career. There's no better venue to:

- Have stimulating conversations about your research;
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- Find collaborators and inspiration for your next project;
- Enhance and develop your professional skills.

Themes:
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Climate and Energy Transition

Abstracts Deadline: 25 July

Submit at:
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2023 GSA Medal & Award Recipients

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PRESIDENT'S MEDAL OF THE GEOLOGICAL SOCIETY OF AMERICA
Jamil Bey, UrbanKind Institute

ARTHUR L. DAY MEDAL
Isabel P. Montañez, University of California, Davis

YOUNG SCIENTIST (DONATH) MEDAL AWARD
Andrew Zuza, University of Nevada–Reno

GSA PUBLIC SERVICE AWARD
Nick Zentner, Central Washington University

RANDOLPH W. "BILL" AND CECILE T. BROMERY AWARD
Karen Chin, University of Colorado Boulder

DORIS M. CURTIS OUTSTANDING WOMAN IN SCIENCE AWARD
Kelsey Moore, Johns Hopkins University

GSA FLORENCE BASCOM GEOLOGIC MAPPING AWARD
M. Jerry Bartholomew, University of Memphis
Giorgio Vittorio Dal Piaz, University of Padova, Italy

GSA HONORARY FELLOW AWARDS
Jacques Schott, CNRS Toulouse
Shucheng Xie, China University of Geosciences–Wuhan

2023 GSA Division Primary and International Awards

GILBERT H. CADY AWARD
Energy Geology Division
Shifeng Dai, China University of Mining and Technology, Beijing

EDWARD B. BURWELL, JR., AWARD
Environmental and Engineering Geology Division
Syed Hasan, University of Missouri–Kansas City
Hasan, S.E., 2022, *Introduction to Waste Management:* A Textbook, 1st Edition: New York, John Wiley & Sons, 464 p.

RIP RAPP ARCHAEOLOGICAL GEOLOGY AWARD
Geoarchaeology Division
Arlene Rosen, University of Texas

DISTINGUISHED CAREER AWARD
Geobiology and Geomicrobiology Division
Gabriela Mangano, University of Saskatchewan

M. LEE ALLISON AWARD FOR GEOINFORMATICS
Geoinformatics and Data Science Division
Simon Goring, University of Wisconsin

MERITORIOUS SERVICE AWARD
Geology and Health Division
Jean Morrison, United States Geological Survey

GEORGE P. WOOLLARD AWARD
Geophysics and Geodynamics Division
Mian Liu, University of Missouri

BIGGS EARTH SCIENCE TEACHING AWARD
Geoscience Education Division
Glenn Dolphin, University of Calgary

MARY C. RABBITT HISTORY AND PHILOSOPHY OF GEOLOGY AWARD
History and Philosophy of Geology Division
Claudine Cohen, L'École des Hautes Études en Sciences, Paris

O.E. MEINZER AWARD
Hydrogeology Division
Jiu J. Jiao, University of Hong Kong

ISRAEL C. RUSSELL AWARD
Limnogeology Division
Donald T. Rodbell, Union College

DISTINGUISHED GEOLOGIC CAREER AWARD
Mineralogy, Geochemistry, Petrology, Volcanology Division
Katharine V. Cashman, University of Bristol

G.K. GILBERT AWARD
Planetary Division
Candice Hansen-Koharcheck, Planetary Science Institute

KIRK BRYAN AWARD
Quaternary Geology and Geomorphology Division
Simon L. Pendleton, Woods Hole Oceanographic Institution
Pendleton, S.L., et al., 2019, "Rapidly receding Arctic Canada glaciers revealing landscapes continuously ice-covered for more than 40,000 years:" Nature Communications , v. 10, 445, https://doi.org/10.1038/s41467-019-08307-w.

LAURENCE L. SLOSS AWARD
Sedimentary Division
Nicholas Christie-Blick, Lamont-Doherty Earth Observatory

CAREER CONTRIBUTION AWARD
Structural Geology & Tectonics Division
John Platt, University of Southern California

INTERNATIONAL DISTINGUISHED CAREER AWARD
International Committee
Cecilia M. McHugh, Queens College, CUNY

JAMES B. THOMPSON, JR., DISTINGUISHED INTERNATIONAL LECTURESHIP
International Committee
Mary S. Hubbard, Montana State University

❖

Awardees will be recognized at the 2023 Presidential Address and Awards Ceremony in Pittsburgh on Sunday, 15 October.

❖

Cole Award

W. STORRS COLE RESEARCH AWARD

Simon F. Mitchell, The University of the West Indies at Mona, Jamaica, will be awarded US$8,650 from the W. Storrs Cole Fund for the research project "*Revision of the Larger Benthic Foraminifera from the Cenozoic described by Cole*."

Simon Mitchell will be honored at the Cushman Foundation for Foraminiferal Research Awards Ceremony on 18 October and at the GSA Presidential Address and Awards Ceremony on 15 October at GSA Connects 2023 in Pittsburgh, Pennsylvania, USA.

GSA FOUNDATION

John C. Frye Memorial Award in Environmental Geology

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

Editors and contributing authors will be recognized at GSA Connects 2023 in Pittsburgh, Pennsylvania, for their outstanding publication by The New Mexico Bureau of Geology and Mineral Resources Bulletin 164 entitled *Climate Change in New Mexico over the Next 50 Years: Impacts on Water Resources*.

Editors and contributing authors in alphabetical order: **Craig D. Allen, Paul W. Bauer, David DuBois, Nelia W. Dunbar, David S. Gutzler, Michael D. Harvey, J. Phillip King, Leslie D. McFadden, Kristin S. Pearthree, Fred M. Phillips, Bruce M. Thomson, and Anne C. Tillery.**

AASG Association of American State Geologists

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2023 J. David Lowell Field Camp Scholarship Recipients

These 20 undergraduate students will each be awarded US$2,000 and a new Blue Standard Transit to attend the summer field camp of their choice based on diversity, economic need, and merit. Congratulations to all of the recipients in 2023!

Alexandria Bradley, Arkansas Tech University
Teagan Duenkel, Florida Atlantic University
Christine Anderson, Sonoma State University
Hannah Bartlett, Schoolcraft College
Seth Brown, Naugatuck Valley Community College
Rebecca Buwalda, University of Miami
Sydney Cloutier, University of Miami
Megan Garrett, Oklahoma State University
Oddisey Knox, University of Arizona
Paul Odewale, Federal University of Technology Akure
Audrey Topp, University of Nevada, Reno
Leo Zook, University of Colorado Boulder
Trey Adams, Georgia Southern University
Caleb DeAbreu, University of Arkansas at Little Rock
Kyle King, Northern Illinois University
Ruby Parcells, University of Georgia
Bjorn Springer, University of Houston
Emily Williams, University of South Carolina
Autumn Arnold, Georgia Southern University
Nicole Guthrie, University of Idaho

GSA FOUNDATION

BRUNTON

2023 GSA Fellows

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 other GSA members 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 GSA Connects 2023. We invite you to read some of what their nominators had to say:

❖

Charles F.T. Andrus (University of Alabama): C. Fred T. Andrus is an outstanding geoarcheologist, educator, and community member as evidenced by his meaningful contributions to paleoclimate and archeological research, mentorship of students, and efforts at GSA meetings and committees. —David P. Gillikin

Jennifer G. Blank (NASA Ames/Blue Marble Space): Jennifer Blank's scientific achievements include research and discoveries in astrobiology and in generation of prebiotic materials from cometary impacts on planetary bodies. She actively trains and mentors a diverse cohort of international geoscientists and has expertise in administration of multidisciplinary national and international geoscience programs. —Joan Florsheim

Brenda B. Bowen (University of Utah): Brenda B. Bowen has made outstanding contributions in the area of public awareness of geology, educating various communities about environmental change due to both natural and anthropogenic causes in salt lakes and desert landscapes, with the aim of understanding geological processes and achieving sustainable land management. —Kathleen Counter Benison

Andrea E. Brookfield (University of Kansas): For her exemplary service in multiple roles, over many years, to the GSA Hydrogeology Division and for sustained efforts in graduate and undergraduate student mentoring. —Benjamin Jay Rostron

Matthew E. Brueseke (Kansas State University): Matthew Brueseke is recognized for the breadth of his accomplishments as an outstanding teacher and mentor; a leader in service to GSA and the profession; and a renowned researcher who integrates field and lab methods with quantitative analysis to address problems in igneous petrology, volcanology, geochemistry, petrogenesis, and tectonics. —Pamela D. Kempton

Keith A. Brugger (University of Minnesota): Keith Brugger has devoted his career as a geoscientist to bridging knowledge between the study of modern glaciers and the geologic record of past glaciation and attendant climate change. He has significantly advanced scientific understanding in these two areas while creating outstanding opportunities for undergraduates to engage in research. —Benjamin J.C. Laabs

John Cottle (University of California): John M. Cottle has made spectacular scientific achievements in the development of novel laser ablation inductively coupled mass spectrometry and its application to plate tectonics; trained and mentored a cadre of young geoscientists; and made lasting contributions to the administration of geoscience programs and professional organizations. —Bradley R. Hacker

Peter J. Fawcett (University of New Mexico): Peter J. Fawcett combines international field work, "big data," and extensive modeling to make fundamental discoveries about Earth-surface processes, climate history, and hydrological processes affecting society today, while providing strong academic leadership and promoting diversity. —Richard B. Alley

Sanjeev Gupta (Imperial College, University London): Sanjeev Gupta is a renowned sedimentary geologist. His 110+ publications focus on river deltas on Earth and Mars, and the megaflood origin of the Dover Straits. Gupta is a crucial member of NASA's Mars rover teams, helping maximize their productivity by coordinating the needs of science, engineering, and management. —Allan H. Treiman

❖

"a dedicated educator and mentor, and champion of a diverse geoscience workforce"

❖

David J. Hart (Wisconsin Geological and Natural History Survey): We recognize Dave Hart for outstanding and sustained contributions to promote public awareness of geology. Hart's engaging and approachable style underlies his success in support of science-based natural resource management in Wisconsin. His career achievements exemplify excellence in public service. —Madeline B. Gotkowitz

Philip H. Heckel (University of Iowa): Philip Heckel has made enormous contributions to our understanding of sedimentary processes and cyclic deposition in mixed siliciclastic-carbonate systems. He has expertise in carbonate petrology, early diagenesis, and conodont biostratigraphy. Above all, he is the master of Pennsylvanian cyclothems in the North American Midcontinent and a leader in the chronostratigraphy of Carboniferous rocks globally. —Thomas J. Algeo

Gregory L. Hempen (EcoBlast, LC): Greg Hempen has had a distinguished career as an applied geophysicist. He proved how less commonly used geophysical methods could aid site characterization, hazard mitigation, environmental protection, and research. He was the 2013 GSA-AEG Jahns Distinguished Lecturer, giving more than 100 lectures across the United States. —John H. Peck

Thomas A. Hickson (University of St. Thomas): Thomas Hickson is a passionate and effective teacher who provides outstanding learning opportunities at the university and national levels. His pedagogical contributions to the geoscience community in sedimentology are exceptional. At University of St. Thomas, he helped create the Environmental Science Program and Department of Earth, Environment, and Society.—Kevin Theissen

Laszlo P. Kestay (United States Geological Survey): Laszlo Kestay, an excellent field geologist and modeler, has a sustained record of achievement in understanding planetary volcanism on Earth, Mars, and Io. He also was the Science Center Director for the USGS Astrogeology team from 2012–2018, advancing information and data access and promoting diversity and inclusion.—Alfred S. McEwen

❖

"an exceptional teacher and mentor of both graduate and undergraduate students"

❖

Yvette D. Kuiper (Colorado School of Mines): I nominate Yvette Kuiper for an outstanding career of achievement in the area of structural geology and tectonics. Her impactful work, in a range of orogenic settings, has utilized an array of techniques. Additionally, she has an excellent record of sustained GSA engagement and in undergraduate and graduate teaching. —J. Christopher Hepburn

Benjamin J.C. Laabs (North Dakota State University): Ben Laabs has made innovations in understanding chronology and climate forcing of Western U.S. glaciation using cosmogenic dating and numerical modeling, and in archiving, assessing, and sharing cosmogenic data. He has made exceptional contributions to GSA meetings, field trips, and leadership, publishing in and editing GSA journals, and early-career mentoring. —Eric M. Leonard

Megan Elwood Madden (University of Oklahoma): Megan Elwood Madden is an outstanding planetary geochemist who investigates thermodynamics and kinetics of chemical weathering processes on Mars and Earth, and gas hydrate formation and dissociation processes to understand gas clathrates in planetary systems. She is a dedicated educator and mentor, and champion of a diverse geoscience workforce. —Gerilyn Soreghan

Elizabeth A. McClellan (Radford University): Elizabeth McClellan, Professor of Geology at Radford University, is recognized for outstanding training of students in mineralogy, petrology, structural geology, and geologic mapping; exceptional mentoring of students in field-based research projects; commitment to enhancing diversity in geosciences; and long-term service to the Southeastern Section of the Geological Society of America. —Madeline E. Schreiber

Jennifer M.K. O'Keefe (Morehead State University): Jennifer O'Keefe has made fundamental contributions to coal geology, palynology, and terrestrial paleoecology. Her pioneering work on fungal palynology and paleoecology gives us a new tool to understand fungal decomposition in terrestrial ecosystems through deep time. Her service as Chair of GSA's Energy Division and President of AASP is meritorious. —Anne Raymond

Michael E. Oskin (University of California): Michael Oskin is nominated for his scientific contributions that address outstanding questions in tectonics, neotectonics, paleoseismology, and geomorphology; for leadership in coordinating the recovery of perishable post-earthquake geologic data; and for the development of computational tools that fostered the application of high-resolution topographic datasets to studies of natural hazards. —Nathan A. Niemi

Susannah M. Porter (University of California, Santa Barbara): Susannah Porter's contributions to the geoscience community, including GSA, are impressive and wide ranging. She drives research at the cutting edge and does it in a respectful, inclusive manner. This research has already, and surely will continue, to be impactful, just as will her influence among younger scientists, including her advisees and undergraduate students. —Carol M. Dehler

Sarah M. Principato (Gettysburg College): Sarah Principato's multitude of exceptional accomplishments in student training and mentorship alone is worthy of recognition with GSA Fellowship. These achievements also speak to her effectiveness in leading academic programs that promote geosciences, and she has a strong record of professional service through organization and participation in GSA meetings. —Joseph Licciardi

Michael J. Retelle (Bates College): Michael J. Retelle has mentored over 100 undergraduate students with geology honors theses at Bates College in Maine, with over half continuing for graduate degrees and ten of them now serving as deans, research scientists, or Quaternary geology faculty at academic institutions. —P. Thompson Davis

Christie D. Rowe (McGill University): Christie Rowe is nominated for her ground-breaking contributions to understanding earthquakes and the dynamics of subduction systems through novel observations of the geologic record; for outstanding and selfless mentoring of numerous young scientists; and for her continuing service to GSA. —Darrel S. Cowan

James M. Russell (Brown University): James M. Russell is a global leader in the fields of tropical paleoclimatology, paleolimnology, and organic geochemistry. He has been an exemplary teacher and mentor. And, he has contributed significantly to the mission of GSA as the founding Chair of the Continental Scientific Drilling Division. —Paul A. Baker

❖

"drives research at the cutting edge and does it in a respectful, inclusive manner"

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Scott W. Starratt (United States Geological Survey): Scott Starratt is deserving of GSA Fellow under the Professional Organizations category by serving as an officer in Marine and Coastal Geoscience (2022–present) and Limnogeology (2015–2018) Divisions, Joint Technical Committee representative (2016–present); technical session convener (12 consecutive years); short course convener; and GSA Special Paper editor. —Jeffrey R. Knott

Wanda J. Taylor (University of Nevada, Las Vegas): Wanda Taylor is a field-based structural geologist who studies faults and their tectonic significance. The implications of her work range from seismic hazards in Las Vegas to the evolution of southwestern Laurentia. She is an exceptional teacher and mentor of both graduate and undergraduate students, particularly in the field. —Patricia H. Cashman

Jeffrey H. Tepper (University of Puget Sound): Jeffrey H. Tepper is a distinguished teacher, trainer, and mentor of undergraduates. Jeff has made over 60 presentations at GSA meetings since 1985. Undergraduates were first authors on 33 of these GSA abstracts. Jeff brings awareness of geosciences to our community and has made significant contributions to understanding Cascades arc magmatism from slab rollback and breakoff in the Pacific Northwest. —Nazrul I. Khandaker

❖

"a passionate and effective teacher who provides outstanding learning opportunities at the university and national levels"

❖

Jennifer Margaret Wenner (University of Wisconsin): For her exemplary mentoring of geoscience students, her development of educational tools for the training of geoscientists, her leadership in the National Association of Geoscience Teachers, and her outstanding service as Program Director in the Division of Earth Sciences at the National Science Foundation. —Elizabeth W. Boyer

Rebecca M.E. Williams (Planetary Science Institute): Becky Williams is nominated because of her keen ability to find interesting questions, her capacity for critical thinking, her knack for conducting field campaigns at sites on Earth that are directly applicable to Mars, and to develop coherent, robust hypotheses that stand the test of time. Becky's field studies integrate sedimentological, topographic, and climatic datasets to investigate sediment transport, deposition, and landscape evolution. Becky has a record of publications and sustained participation in GSA meetings, including a GSA field guide for exhumed fluvial landforms in east-central Utah which is widely used in college/university field trips. —Catherine Weitz

Sharon A. Wilson Purdy (Smithsonian Institution): Sharon Wilson Purdy's accomplishments and service are the markers of a leader in planetary geosciences. Her achievements have proven her expertise in Martian fluvial geomorphology, orbital and landed missions, detailed geologic mapping, and field analog research. Purdy's fundraising efforts enhanced the Planetary Geology Division's ability to support students. —Emily S. Martin

Danielle Y. Wyrick (Southwest Research Institute): Danielle Wyrick is nominated for Fellowship in the Geological Society of America, due to her excellent and continuing service to GSA, for her training and mentoring of young geoscientists, and for her exemplary scientific achievements. She has been active in GSA Planetary Geology Division leadership and on GSA committees. —Debra Buczkowski

Meet Your Fiscal Year 2024 Officers & Councilors

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Topeka, Kansas, USA

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India Institute of Technology–Kharagpur (ITT KGP)
West Bengal, India

Term: July 2021–June 2025

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Sedimentary Geology Consultants
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Donna M. Jurdy
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Evanston, Illinois, USA

Term: July 2022–June 2026

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Laramie, Wyoming, USA

Kathleen DeGraaff Surpless
(Sections Liaison)
Trinity University, San Antonio, Texas, USA

NEWLY ELECTED
Term: July 2023–June 2027

Craig H. Jones
University of Colorado
Boulder, Colorado, USA

Patricia Persaud
Louisiana State University
Baton Rouge, Louisiana, USA

Nicholas P. Lang
(Divisions Liaison)
NASA Planetary Science Div.
Mercyhurst University
Erie, Pennsylvania, USA

GSA STUDENT ADVISORY COUNCIL CHAIR
Miguel Valencia
Florida International University
Miami, Florida, USA

25-Year 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.

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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, go to https://rock.geosociety.org/membership/50YearFellows.asp. Asterisks (*) indicate GSA Fellows.

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The following new members joined between 5 August 2022 and 13 March 2023 and were approved by GSA Council at its spring meeting.

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Christopher Baiyegunhi
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Tripti Bhattacharya
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Mark Zellman
Nate Zielinski

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Brian Kessler
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Margaret Elizabeth Maenner
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Mollie McCormick
Jenine McCutcheon
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Nurana Ismayilova
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Anne Joseph
Brody Joy
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Olive Latham
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Levi Lee
Jessica Lefors
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Yvonne Leon
Jonathan Leonard
Gunner Leone
Hui Li
Pei Li
Rui Li
Shihan Li
Yushan Li
Sydney Licata
Janey Lienau
Ya-Shien Lin
Juan-Eduardo Linares-Perez
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In Memoriam

The Society notes with regret the deaths of the following members (notifications received between 22 December 2022 and 17 April 2023). Memorials to deceased members are published open access at **www.geosociety.org/memorials.** Visit that page for links to information on how to honor someone with a memorial.

Frederick B. Bodholt
Missoula, Montana, USA
Date notified: 24 February 2023

John Dallas Bredehoeft
Sausalito, California, USA
Date notified: 20 January 2023

B. Neil Church
Victoria, BC, Canada
Date notified: 31 January 2023

Oscar J. Ferrians, Jr.
Moses Lake, Washington, USA
Date notified: 9 March 2023

Robert E. Garrison
Santa Cruz, California, USA
Date notified: 3 February 2023

Robert C. Greene
Alexandria, Ohio, USA
Date notified: 28 February 2023

Steven A. Hauck
Cleveland, Ohio, USA
Date notified: 24 February 2023

Earl R. Hoskins
Bryan, Texas, USA
Date notified: 28 February 2023

Harold A. Hubbard
Sacramento, California, USA
Date notified: 24 February 2023

R. David Matthews
Ann Arbor, Michigan, USA
Date notified: 24 February 2023

John R. McGinley, Jr.
Tulsa, Oklahoma, USA
Date notified: 24 February 2023

James C. Ratte
Centennial, Colorado, USA
Date notified: 31 January 2023

Jason B. Saleeby
Scotts Mills, Orgeon, USA
Date notified: 19 January 2023

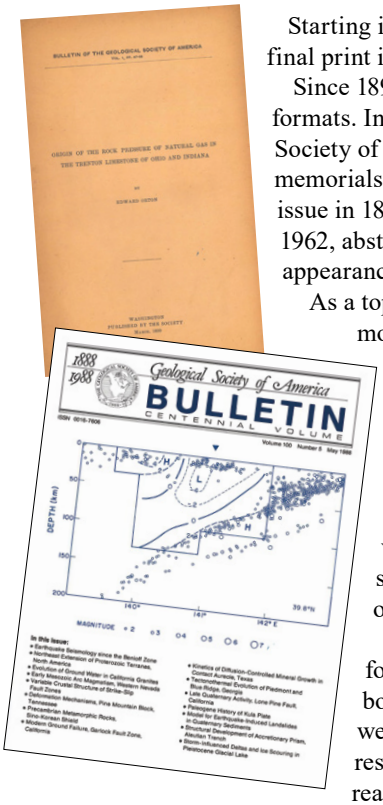
Ronald Z. Shmerling
Newbury Park, California, USA
Date notified: 24 February 2023

Edgar W. Spencer
Lexington, Virginia, USA
Date notified: 1 March 2023

Alistair R. Turner
Littleton, Colorado, USA
Date notified: 7 February 2023

Nels B. Vollo
Kamloops, BC, Canada
Date notified: 30 January 2023

Change Is Coming to *GSA Bulletin*



Starting in January 2024, *GSA Bulletin* will be published online only. The final print issue will be mailed in November 2023.

Since 1890, *GSA Bulletin* has served many roles and appeared in varied formats. In addition to being the flagship research journal of the Geological Society of America (GSA), the Society's meeting proceedings, abstracts, and memorials to deceased members were published in the journal from its first issue in 1890 until 1932. Proceedings reappeared in *GSA Bulletin* in 1961 and 1962, abstracts returned from 1938 to 1960, and memorials again made a brief appearance in 1962.

As a top-rated journal that publishes peer-reviewed, data-rich, longer, and more detailed papers, *GSA Bulletin* has been popular with authors and readers for many years. To provide more space for these longer papers, the size of the journal grew from 6 × 9 to 8½ × 11 inches in 1974. Then, as the number of published papers increased, only summaries of articles appeared in print from 1979 to 1981, while full articles were published on microfiche, which seemed a promising format at that time. Microfiche lost momentum and ultimately made viewing and copying articles more difficult, so *GSA Bulletin* was soon back to publishing in print only until 1999, when the entirety of GSA Publications began appearing online.

In 1999, GSA Council funded the scanning of the print archives for *Geology*, *GSA Bulletin* (including the microfiche content), and the books series. It took several years to complete, but when the archives were available online, *GSA Bulletin* in particular enjoyed new life as researchers took advantage of easy access to the older papers, and readership soared.

Now, over 20 years later, individual subscriptions to printed journals have declined, more and more readers have moved to accessing articles online only, the lag time between accepted papers being published online and appearing in print has grown by months, and printing and shipping costs have skyrocketed (both financially and environmentally). To address these changes and to continue providing the best service and value to authors and readers, GSA has decided to cease printing the journal. Although the format is changing once again to keep up with the times, rest assured that *GSA Bulletin*'s quality and impact on geoscience research will be preserved, and the journal will continue to thrive well into the future.

Etheldred Benett (1776–1845): The Lady was a Geologist

Renee M. Clary, *Department of Geosciences, Mississippi State University*

Our efforts to build a geoscience culture of inclusion have sparked renewed interest in the women in the early history of geology, such as Mary Anning (1799–1847). Not allowed in professional societies, these women found unique ways to contribute. Some participated as wives and collaborators alongside their professional geologist husbands. Still others collected fossils or illustrated geology texts. Unfortunately, many women geologists remain hidden from history. Etheldred Benett (1776–1845) is one of them. Not only was she an early geological participant who preceded Mary Anning, but she may be the first woman to name fossil taxa, construct a stratigraphic column, and publish a fossil monograph.

Oil portrait of Etheldred Benett as a young woman. (Photograph by Renee M. Clary; used with the kind permission of Sir Henry Rumbold.)

A PRIVILEGED UPBRINGING AND EARLY INTEREST IN GEOLOGY

Etheldred Benett, the namesake of her paternal grandmother, was born in Wiltshire, England, in 1776, the daughter of Thomas Benett of Pythouse, a country gentleman whose family had profited as clothiers and in farming (Moody, 2005). Etheldred grew up in a privileged household and likely was privately educated.

Her older brother, John, became heir to the estate in 1797 following the death of their father, and in 1801, he married Lucy Lambert. He renovated and expanded Pythouse for his own family, and Etheldred and her sister Anna Maria moved to the Norton Bavant manor house, where Etheldred, who never married, resided throughout her life. As ladies of independent wealth, the sisters could follow their interests. In her correspondence[1], Etheldred commented on her servants and her numerous travels that included extended stays in London and along England's southern coast.

Lucy Lambert Benett's half-brother, the renowned botanist Alymer Bourke Lambert (1761–1842), may have inspired and cultivated Etheldred's interest in fossils (Burek, 2001). By early 1810, Etheldred was sending fossil specimens to naturalist James Sowerby (1757–1822), author of *The Mineral Conchology of Great Britain* (1812–[1846]). Sowerby referenced Benett several times in the first volume, such as her observations on collecting conditions, and her extraordinary, rare, and "uncommonly perfect" fossil specimens (p. 141). Sowerby also characterized her as an "indefatigable collector … whose desire [was] to assist science and give information" (p. 222). The specimen *Trochus Benettiae* (p. 224), named in her honor, provides further evidence of Benett's participation and esteem in the geological community. Benett's fossil specimens were useful in several volumes of *The Mineral Conchology* (i.e., 2–5, 7), the latter volumes published by Sowerby's sons after he had passed.

In July 1813, Gideon Mantell (1790–1852) wrote to Etheldred Benett, "under the kind recommendation of Mr. Lambert," to request Benett's observations of the fossils around Norton house, since he thought them analogous to those in his area of Lewes. Their correspondence continued steadily for 30 years and included not only fossil discussions and sketches, but also displayed a familiarity and friendship with inclusion of current politics and their personal health issues. Mantell repeatedly asked Benett to produce a comparison of Wiltshire and Sussex fossils for him, which she procrastinated and eventually declined to do. Benett appeared confident in her skills and challenged some of Mantell's fossil interpretations. Upon learning of her death, Mantell sorrowfully noted the passing "of my much valued correspondent and excellent woman" in a 29 January 1845 journal entry.

STRATIGRAPHICAL SKILLS AND CHICKSGROVE QUARRY

Benett had good working knowledge of stratigraphical principles. She was familiar with William Smith's (1769–1839) work, though she seemed skeptical of some of it. In 1817, she wrote to Mantell that, with regards to Smith's *Stratigraphical System*, "If any Geological friends form a good opinion of it, I shall buy it, but not else, as I do not like his other work!" Benett also noted in her 1831 book that "The Chalk Marl, which is so local as to have been altogether unnoticed by Mr. Wm. Smith, is exceedingly well defined at Norton Bavent, at Bishopstrow, and at Stourton" (p. iii). Her detailed observations contradicted what Smith had previously reported.

[1]The Hugh S. Torrens Archive in the History of Science Collections at University of Oklahoma includes copies of Benett's extensive correspondence, as well as sketches, books, and notes assembled by Torrens during his multi-year research on her. Unless otherwise specified, all quotes originate from letters and notes in the University of Oklahoma Hugh S. Torrens Archive. The original Mantell documents are housed in the Alexander Turnbull Library, Wellington, New Zealand, while Woodward correspondence is archived in Norwich Castle Museum, England. My research in the History of Science Collections at the University of Oklahoma was supported by an Andrew W. Mellon Travel Fellowship.

Etheldred Benett's collection included arrangements of small fossils, and she may have been among the first to sieve for microfossils. (Academy of Natural Sciences at Drexel University; photograph by Renee M. Clary.)

In 1815, Benett determined the stratigraphy of Upper Chicksgrove Quarry and sent the section to the Geological Society, London. She sent a corrected section the next year. In 1816, Sowerby reproduced her section in *The Mineral Conchology* (volume 2, p. 58–59), but he did so without Benett's knowledge—and without crediting her (Torrens, 1994). Benett's opinion of Sowerby's actions is clear in an 1816 letter to Mantell, "You have doubtless seen my section of Chicksgrove Quarry as Mr. Sowerby has publish'd it; which he did without my knowledge and without my seeing his observations on it, some of which I think is erroneous, and I am much vex'd that it should have been so publish'd; I shall therefore take an opportunity of sending you a copy of my own section as I otherwise intended doing."

AN EXTRAORDINARY COLLECTION OF FOSSILS

Etheldred Benett amassed a large collection of fossils. Though she personally collected some, she also purchased fossils from numerous individuals who resided in multiple locations. At least one of her collectors was a woman. In 1819, she confirmed, in a letter to Mantell, that she was buying in bulk, "I am obliged to buy masses to get those which I want. I have purchased more than a thousand specimens since my return from London." Benett examined, labeled, arranged, and sometimes sketched her fossils, and dispersed duplicates to her geological friends and professional societies—both in England and beyond. She also loaned her personal specimens to notable geologists, including Sowerby, Mantell, Greenough, and Murchison, who used them in their own publications. Upon Benett's death, Dr. Thomas Bellerby Wilson (1807–1865) purchased most of her collection and donated it to the Academy of Natural Sciences in Philadelphia, Pennsylvania, USA. There, some of Benett's carefully arranged fossil assemblages hint that she may have been one of the first people to sieve for microfossils (Torrens, 2004).

In March 1818, Benett informed Mantell that she had undertaken to write the *Geology of Wiltshire*. She eventually published the monograph in 1831, illustrated with E.D. Smith's lithographs. Benett's book documented her excellent taxonomic knowledge. She identified and named new species based on their external morphology (Spamer et al., 1989), after three scientific gentlemen whom she contacted failed to do so (Benett, 1831, p. iii). However, Benett also mentioned that her catalogue had been approved by Greenough and "will run no risk of being despised in the Geological World" (Benett, 1831, p. iii). Even after its publication, Benett continued to annotate the copies in her possession as new specimens and data became available.

RECOGNIZING ETHELDRED BENETT'S LEGACY

Benett referred to herself as a geologist on more than one occasion. In 1818, when Mantell considered abandoning a book project, she wrote to him that "we Geologists cannot give our consent" to his withholding the book. In 1821, she suggested that Mantell's specimens "deserve to be inspected by a better informed Geologist than myself." Alexander von Humboldt even sent a bust of himself to Benett in 1830 in appreciation of her scientific skills.

However, Benett was frustrated by her gender limitations. When she sent fossils to the Museum of St. Petersburg, Russia's Czar Alexander I conferred upon her the Honorary Doctor of Civil Law to Dominum Etheldredus Benett—presuming Benett was a male. She personally delivered her monograph to the British Museum, and later received a letter of thanks mailed to "Etheldred Benett, Esqre." Benett wrote to Samuel Woodward (1790–1838), "It is provoking that no one will believe that a Lady could write such a trifling thing."

Benett's specimens and knowledge were sought by male geologists, but women were not allowed to join and participate in professional scientific societies during her lifetime. Mantell's obituary of Benett acknowledged that geologists' fossil understanding was indebted to her, and Woodward (1907, p. 118) later referenced her "most distinguished of early *women-workers in geology*." However, Etheldred Benett should now be given her due. We should recognize her role as a *geologist*, and perhaps the first woman to name fossil species, construct a stratigraphic column, and publish a geological monograph.

FURTHER READING

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Draft Position Statement: Diversity in the Geosciences

GSA members are invited to submit comments regarding the following Draft Position Statement by 15 August. Go to **www.geosociety.org/PositionStatements** to learn more about the major revision to this statement and submit comments.

POSITION SUMMARY

The Geological Society of America (GSA) is committed to constructing an environment in which all can thrive by building an inclusive, equitable, and accessible professional community that engages diverse students, professional and academic geoscientists, and the communities they serve.

This position statement lays out actions that GSA is undertaking and recommending to institutions and geoscientists to support increased diversity in the geoscience community through cultural change, including (1) focus on diversity-driven demographic data collection, measurement, and reporting; (2) prioritize diversity in leadership and decision making; (3) focus on systemic change; and (4) engage, empower, and hold accountable the geoscience community.

CONCLUSIONS AND RECOMMENDATIONS

GSA is committed to fostering a geoscience community that reflects the diversity of our society. To achieve representative diversity in the geosciences, leaders and members of the geoscience community must model, and advocate for, equitable and inclusive practices.

GSA's vision defines diversity broadly to encompass all expressions of human identity and the full spectrum of personal, cultural, professional, and socioeconomic statuses. To disrupt structures of exclusion, GSA and geoscience organizations must adopt strategies that prioritize people from the most marginalized groups and focus on racial disparity. GSA recognizes that equality is not synonymous with equity. Therefore, striving towards a diverse community, GSA prioritizes inclusion to welcome members of historically underrepresented and the most marginalized groups.

Geoscientists within GSA and other organizations, whether they are professionally affiliated with academia, government, or industry, should collectively work to address issues related to diversity in the geosciences and in their home institutions. To do so, GSA recommends the following actions:

- **Focus on demographic data collection, measurement, accountability, and reporting.** GSA recommends adopting evidence-based strategies, transparency, and accountability in efforts to increase justice, equity, diversity, and inclusion. Organizations should track the implementation of actions in priority areas, to measure the impact on stakeholders and functions, and effectively communicate progress and adjustments in approach.
- **Prioritize diverse leadership and decision making.** GSA and geoscience organizations should prioritize diversity and equity throughout, especially in positions of power and leadership, decision making, and standard setting, including honorees, awardees, and in recruitment and hiring. As scientists and leaders bring their perspectives and identities to the decisions that determine the future of the community, those decision makers should reflect the diversity of the community itself.
- **Focus on systemic change.** GSA and geoscience organizations should weave justice, equity, diversity, and inclusion into the operations, policies, and norms associated with all governance, services, programs, activities, and events. GSA's initiatives such as On To the Future and Respectful, Inclusive Scientific Events (RISE) demonstrate programming that can contribute to systemic change and diminish barriers to career progression. An integrated approach will elevate the importance of this work and, coupled with the measurement and reporting focus described above, will enable ongoing monitoring to help ensure sustained, impactful change. Additionally, GSA views efforts toward diversity as an imperative and high-priority aspect of the leadership role (GSA Diversity Working Group, 2021).
- **Engage, empower, and hold accountable the geoscience community.** GSA and geoscience organizations must engage geoscientists to take ownership of this challenge of increasing diversity and understanding its value. GSA and geoscience organizations should provide practical guidance and engagement opportunities empowering geoscientists to contribute to systemic and cultural change that will foster a sense of belonging for all identity groups. The community must hold one another accountable through mechanisms such as GSA's Code of Conduct. Responsibility for this work must be shared without overburdening minoritized people through strategies such as self-education, staff training, and coleadership of projects (see resources list below) and valuing equity, diversity, and inclusion work in hiring, promotion, and tenure decisions (see Rewarding Professional Contributions in the Public Spheres position statement).

To attract and retain scientists in a healthy and supportive professional community, organizations and individuals must foster a culture of inclusion, and a sense of belonging for all.

RATIONALE

Geosciences are critical to society, now more than ever, as humanity faces urgent threats to biodiversity and the sustainability of civilizations. Yet, the current and future contributions of geosciences to society are limited by having one of the lowest diversities among science, technology, engineering, and mathematics (STEM) fields. Geoscience lags other disciplines with respect to racial and ethnic representation (Dutt, 2020; Bernard and Cooperdock, 2018; McDaris et al., 2018), and while white women have experienced gains, women geoscientists remain underrepresented in academia (Holmes and O'Connell, 2003) and continue to experience bias and harassment (St. John et al., 2003; Societies Consortium on Sexual Harassment in STEMM, 2020). Geoscientists face barriers based on race, gender, gender identity, sexuality, physical ability, neurological difference, citizenship, socioeconomic, and other factors, which are exacerbated in field settings (Olcott and Downen, 2020; Carabajal et al., 2017; Berhe et al., 2022). The exclusion of minoritized groups from scientific research, knowledge, and associated power harms our science and

is unethical (NASEM, 2020; Bhatti, 2019; Raja et al., 2022). The lack of diversity and inclusion places the future of the geoscience enterprise at risk.

Increasing diversity benefits such efforts by driving innovation (Nielsen et al., 2017; Hofstra et al., 2020); improving problem solving, research team productivity, and impact (Horowitz and Horowitz, 2007); benefiting geoscience education and public science literacy (Feinstein, 2010; Snow and Dibner, 2014); and increasing the relevance of science to marginalized populations (Dietze et al., 2019; Stewart and Valian, 2018) and expanding the workforce. With escalating climate and disaster hazards that continue to disproportionately impact the most marginalized populations, these benefits are vital to the ability of the geosciences to address the challenges of the future. Key examples are the emergent role that geoscientists can play in assessing disproportionate community impacts around earth science issues and environmental injustice, engaging local communities in the research process, and centering Indigenous knowledge in research and decision making.

OPPORTUNITIES FOR GSA AND ITS MEMBERS TO HELP IMPLEMENT RECOMMENDATIONS

To facilitate implementation of the goals of this Position Statement, GSA recommends the following actions to increase the involvement of geoscientists in local, regional, statewide, and federal diversity policy decisions:

- Engage in the work being done by geoscience-related organizations towards increasing diversity, such as, but not limited to:
  - 500 Queer Scientists
    https://500queerscientists.com
  - ADVANCEgeo
    https://serc.carleton.edu/advancegeo/index.html
  - American Indian Science and Engineering Society (AISES)
    https://www.aises.org/
  - Asian American and Pacific Islanders in Geoscience
    https://www.aapigeosci.org
  - Association for Women in Geoscience (AWG)
    https://www.awg.org/
  - Black in Marine Science
    https://www.blackinmarinescience.org
  - GeoLatinas
    https://geolatinas.org/
  - International Association for Geoscience Diversity (IAGD)
    https://theiagd.org/
  - National Association of Black Geoscientists (NABG)
    http://www.nabg-us.org/
  - Society for the Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS)
    https://www.sacnas.org/
  - Society of Latinxs/Hispanics in Earth and Space Science (SOLESS)
    https://ciresdiversity.colorado.edu/soless
  - The Geoscience Alliance
    https://geoscienceallianceorg/
  - Unlearning Racism in Geoscience (URGE)
    https://urgeoscience.org/
- Seek opportunities to effectively communicate the value of a diverse workforce and of implementing suitable diversity practices to all levels of government, to private industry, and to academia. Geoscientists are encouraged to work with the media in addressing critical diversity issues. Geoscientists who are engaged in diversity projects are encouraged to share their experiences.
- Participate in professional forums for community discussions on the importance of a diverse workforce and of implementing suitable diversity practices.
- Provide readily accessible print, web, and personnel resources to members that support geoscientists' communications with decision makers regarding the value of a diverse workforce and of implementing suitable diversity practices. Considerable expertise and resources are available to members through GSA's Geology and Public Policy Committee (GPPC) and GSA's Geology and Society Division, and these entities can assist with the development of relevant materials.
- Identify legislation that affects diversity and alert the GPPC, Geology and Society Division, and GSA's Associated Societies if action by the GSA membership and affiliated organizations can help to improve the basis for diversity decisions. The GPPC, Geology and Society Division, and Director of Geoscience Policy, working with GSA members, can also bring this Position Statement to the attention of lawmakers when legislation affects diversity.
- Raise awareness of diversity issues by publishing articles on diversity work and connections in geoscience.
- Draw upon the rich diversity of the geoscience community as a resource for individuals when selecting organizing committees, invited speakers, and nominees for offices and special prizes.
- Provide equitable compensation and support in these processes whenever possible.
- Continually practice strategies to increase diversity, cultural awareness, inclusive behavior, and bystander intervention.

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At the Intersection of Science and Policy

Hannah Palmer

As an earth and climate scientist and a Congressional Science Fellow, I continually find that the most pressing challenges, the most impactful questions, and the most innovative solutions occur at intersections. In science, research grows more interdisciplinary each day as it brings together toolsets, questions, and innovation from multiple fields to address grand challenges. In policy, challenges and solutions do not often fit neatly within a single committee jurisdiction or focus on a singular topic without impacting and influencing a web of policies. As the 2022–2023 Geological Society of America and U.S. Geological Survey Congressional Science Fellow, I serve in the Office of Senator Tammy Baldwin (D-WI), working on energy, environment, and agriculture policy and the many policy areas with which they intersect.

Challenges posed by the current climate crisis do not occur in isolation. As such, neither do solutions. Climate mitigation and adaptation policies intersect with health, finance, agriculture, housing, banking, energy, and much more. I began my fellowship shortly after the passage of the Inflation Reduction Act (IRA, H.R. 5376), which made the single largest investment in climate and energy in American history, enabling the United States to tackle the climate crisis, advance environmental justice, and promote domestic clean energy manufacturing. The IRA aims to reduce U.S. greenhouse gas emissions by 40% by 2030, compared to 2005 levels. Although this law was signed into law prior to the beginning of my fellowship, work on the IRA was far from over. A critical role of the U.S. Congress is conducting oversight of the Executive Branch and ensuring that laws are enacted in line with congressional intent. Put another way, Congress does not stop working on issues once they become law. Instead, congressional offices, including mine, work to ensure that federal programs and investments reach the American people. In my year as a fellow, this included interacting with agency staff and leaders, sharing opportunities for constituents to access federal programs, and engaging in discussions about novel climate and environmental policies to build on existing work.

When the public considers the role of geosciences in policy making, they may first think of natural hazards, climate change, and natural resources. Yet, during my year working on the Hill, I continually utilized my scientific expertise and geosciences background to evaluate and develop policy on another topic: agriculture. Geosciences intersect with multiple axes of agriculture and agriculture policy: The climate and hydrology of a region determine where certain crops and livestock thrive; atmospheric science informs the timing of planting and harvesting; topographic and landscape structures lay the foundation for growing regions; and soil characteristics can be the difference between feast and famine. Agriculture policy is a focal point of the current U.S. Congress as the Farm Bill is due for reauthorization. The Farm Bill is a broad, multiyear law that governs a wide array of agricultural and food programs. It provides an opportunity for policy makers to address agricultural and food issues comprehensively and periodically. This set the stage for multitudes of stakeholder group visits, member and staff conversations, bill drafts, committee meetings, and press on agriculture policy during my fellowship year. In my role as a fellow, I had the opportunity to meet with groups ranging from geographic information systems analysts for weather and hydrologic prediction to school nutrition advocates and from vegetable growers to environmental groups. Further, I contributed to multiple individual bills that are aimed for inclusion in the Farm Bill.

Through all of my experiences working on the Hill, one theme continued to empower and energize me each day: public service. In each meeting, phone call, quick hallway conversation, and draft legislation, a central question emerged: How will this serve the American people? In this question, I found the motivation for each project I worked on, and I was continually reminded of the key role of sciences, and of geosciences specifically, in public policy. Geoscience serves society by informing how, when, and where we farm, by illuminating the urgency of the climate crisis, and by defining the ground on which we stand. I challenge all geoscientists to ask this same question of their own work: How do the questions I pursue in the laboratory, model, field, or classroom serve society? Geoscience is more relevant today than ever, and through my fellowship experience, I have seen firsthand how the pursuit and communication of interdisciplinary science in service of the public are leveraged into drafting and enacting effective policy. In both science and policy, I find that we are best able to be innovative and effective by embracing complexity, leaning into the intersectionality of challenges, and genuinely collaborating.

The article was submitted for publication by Hannah M. Palmer, 2022–2023 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 No G23AP00241. 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. *Palmer works in the office of Senator Tammy Baldwin (D-WI) and can be contacted by e-mail at Hmpalmer@ucdavis.edu.*

A Lasting Impact

Consistent, reliable, long-term, stable, empowering, secure, greater impact—These are the qualities that make planned giving a steady source of support for the future of the geosciences. If these are qualities that you find compelling, then planned giving may be the right mechanism for your inclination to help.

Every year, the Geological Society of America Foundation (GSA Foundation) receives contributions that were established with intentional, forward-thinking generosity. They include gifts left in a will or trust, or named beneficiary gifts from a retirement account, life insurance policy, bank account, or donor-advised fund.

Planned givers join The *Pardee Legacy Circle*, which is named in honor of Joseph T. Pardee (1871–1960) in recognition of a $2.7 million bequest from the estate of Pardee's daughter, Mary Pardee Kelly (1905–1994). Joseph Pardee spent his entire career as a U.S. Geological Survey geologist in the Pacific Northwest and is best known for his work on Glacial Lake Missoula. Along with the Penrose bequest of nearly $4 million in 1931, Pardee's bequest helped shape GSA into the thriving organization of today. Both of these contributions continue to provide vital support for GSA, helping to sustain the Society and its impact on the geologic community many decades later.

While most bequests are not the scale of those left by Pardee and Penrose, planned gifts of all sizes are the pillars of support that allow us to implement special programs like GSA Cares, which provided assistance to student members early in the pandemic. They also help to sustain some of GSA's strategic programs. Today, the *Pardee Legacy Circle* comprises more than 50 active GSA members who have let us know about their gift plans. While it is beneficial for the GSA Foundation to be aware of these intended gifts, so that we can express our thanks and ensure that wishes are met, sometimes the planned gifts we receive are unexpected and demonstrate how deeply members have valued their society throughout their lifetimes.

If you would like to ensure that future generations benefit from your generosity, and that the geoscience community maintains support in critical times when the economy fluctuates and annual giving might dip, please visit **https://gsa-foundation.org/planned-giving/** to learn more or contact Debbie Marcinkowski at dmarcinkowski@geosociety.org or 303-357-1047. Your legacy makes a lasting difference.

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If you would like to include the Geological Society of America Foundation in your estate plans, please let us know so we can ensure that your intentions are accurately understood and documented. We would like to thank you for your generosity by including you in the Pardee Legacy Circle, the GSA Foundation's bequest and estate plan recognition society. Examples of planned gifts include:

- Gifts left in a will or trust
- Retirement or bank account named beneficiary gifts
- Life insurance policy beneficiary gifts
- Donor-advised funds

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