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# Answering Geosciences Research Questions at Global Scale via a Hybrid Machine–Human Learning Approach: A Case Study of the Link between Climate and Volcanism

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## SCIENCE



**Cover:** Quaternary volcano from the Puna Plateau, NW Argentina. Photo by Barbara Carrapa. See related article, p. 4–8.

## GSA NEWS

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# Answering Geosciences Research Questions at a Global Scale via a Hybrid Machine-Human Learning Approach: A Case Study of the Link between Climate and Volcanism

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## ABSTRACT

A common challenge in science is the human capability to evaluate the real impact of an observation and a data set. This is a complex task due to having only partial information and/or to the complexity of the problem, requiring different fields to be combined. In order to overcome these important limitations, we need to be able to review all the available data and interpretations. This would allow us to evaluate the global distribution of a specific process or phenomenon of interest. The increasing number of scientific publications prevents scientists from being able to keep up with all the available literature especially when scientific papers cross disciplines. These challenges prevent us from evaluating the global impact of a certain process and are particularly relevant today given the impact of our scientific assessment on one of the most pressing issues of our time, which is climate change and its impact on society. We present here an application of artificial intelligence to geosciences: We conduct a systematic analysis of geoscience literature through a hybrid machine-human approach. Such applications are more common in other fields such as biomedicine and are in their infancy in the geosciences because of various difficulties the machines encounter in parsing geologic literature. We describe here some of these limitations and how we overcame them. We then use the following case study as an example to test our approach: We ask whether climate is influenced by volcanism in the geologic past. Our case study results show, as expected, that most analyzed literature in this experiment conclude that volcanism influences climate change in deep time, but there is no complete consensus on this question. Similarly, any question of potential global significance, such as the impact of human activities on climate change, can be posed as an interrogating technique for our vast and fast-growing literature in the field of geosciences. Such an approach has the potential to be applied to a variety of complex problems, hence addressing some of the major limitations with cross-disciplinary research.

## INTRODUCTION

One of the cornerstone theories in natural sciences, Darwin's evolutionism, states that the evolution of flora and fauna in the geologic past goes through temporally determined and irreversible extinctions corroborated with the development of new species. That theory has been vetted by innumerable observations and stands today because of that. However, most potentially groundbreaking research questions in natural sciences have a difficult time being resolved at global scales because of the complexity of observations. In order to answer such questions at a global scale, we need to have a global review of the scientific literature. This task has turned into a near impossible challenge in recent years due to the vast amount of scientific data that have been published, which exceeds human capacity for processing and interpretation. This is particularly problematic in fields like geosciences that require the interpretation of data and research questions on a global scale and over large time intervals. Whereas data pertaining to a specific field (e.g., regional geology) of a particular area can still be tracked by the interested geologist (the number of papers is still within reach of human processing), the importance of so many global-scale multidisciplinary interpretations is difficult to evaluate. For example, did erosion of Earth's surface increase globally since the Pliocene as the result of increased climate variability (Zhang et al., 2001; Herman et al., 2013)? Was tectonics the cause of $CO_2$ drawdown and global cooling in the Cenozoic (e.g., Raymo and Ruddiman, 1992; Gernon et al., 2021)? Did Earth's surface topography affect biodiversity through time (Badgley et al., 2017)? These are just a couple of examples of far-reaching but hard-to-evaluate research questions in a science that increasingly requires ingestion of too much information at a global scale and that commonly needs to be placed into a complex deep time–space framework.

To address these issues, we built a hybrid machine-human approach for the systematic analysis of scientific discoveries in geosciences. The proposed approach employs machine reading to ingest publications at scale and aggregate scientific discoveries. These models allow scientists to attempt a wider understanding of science, which facilitates the identification of (apparent) contradictions in scientific findings, as well as "blank spaces" in the research landscape.

Note that approaches that summarize scientific work already exist, such as SCITE (https://scite.ai) and SCITLDR (https://scitldr.apps.allenai.org), both of which are trained on previously published papers. However, their goals are different from what we aimed to achieve in our study. SCITE

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analyzes the relationship between citations and their textual context (i.e., whether the citation is used in a positive way or negative way). SCITLDR is used to create a short summary of the given paper (without truly understanding what the underlying content means). Our work is complementary to these directions, because we aim for deeper language understanding. That is, the purpose of the proposed approach is to spatially and temporally contextualize a given geoscience research question and to identify whether the content of the papers analyzed supports or negates it.

For this purpose, we developed an application to geosciences to demonstrate the potential of our proposed approach to experiment with the limitations of this type of literature and how they can be overcome. The application investigates the research question of whether there is a causal relationship between volcanism and climate change in the geologic record as seen through the lens of published literature. Specifically, we ask whether volcanism influenced climate change in the deep time geologic archive. We selected this question because several geological studies seem to support this link (e.g., Lee and Dee, 2019). Our results indicate more variability on whether or not available studies on the subject actually support this research question.

## SYSTEMATIC MACHINE REVIEW OF GEOSCIENCE DATA

Since there was no pre-built corpus for this geosciences task, we extracted 1164 papers from the Web of Science website via the University of Arizona's library. These papers were selected because they contained keywords relevant to the research question at hand, such as *volcanism* or *magmatism*, and *climate change*. This was implemented as the Boolean query: (*volcanism* OR *magmatism)* AND "*climate change,*" where OR and AND are the disjunctive and conjunctive Boolean operators, and quotes indicate that the entire phrase must be present. This query extracted 1164 papers from the Web of Science. We then randomly chose 200 papers and extracted the abstract, introduction, and conclusion sections from each paper to be manually annotated with the information if they support or do not support the research question. Note that for this work we assume that the authors' data, interpretations, and conclusions are correct. The annotation task was conducted on FindingFive (https://www.findingfive.com), an online annotation platform. The papers were placed into one of four classes: SUPPORT, NEGATE, NEGATE&SUPPORT, and UNRELATED (see Table 1). The annotations for these four classes were collected by two of the coauthors of this effort, who are domain experts (i.e., geoscientists). The two annotators worked independently.

Next, we implemented a natural language processing (NLP) component for geosciences that extracts two types of information. First, we contextualized individual publications by extracting and normalizing the geospatial and temporal contexts addressed in these papers (e.g., *Pliocene*, *4 million years ago*, and *Bering Sea*). For example, *Tucson* and *Saguaro National Park* can be considered as the same geographic location (for the purposes of this analysis), even though they are described differently in text. To facilitate the consolidation of findings, we normalized the geospatial contexts to absolute latitude/longitude coordinates (see the next section for details). Similarly, temporal expressions such as *4 million years ago* were converted to geological eras or epochs (e.g., *Paleoproterozoic*) to have a better overall understanding of the relationship between volcanism and climate change on the geological time scale.

Second, we built a document classifier that is trained to determine whether any given paper supports the observation that "volcanism affected climate change," so that we could make a prediction on *new* papers. The results of these two components were aggregated into a publication knowledge base, which contains the publication itself, the prediction of our classifier (SUPPORT, NEGATE, NEGATE&SUPPORT, and UNRELATED—see Table 1 for details), the occurrence of geological eras and epochs (e.g., the frequency of *Pliocene* in a given paper), and the occurrence of geological locations (e.g., the frequency of *Africa* in a given paper). We used this knowledge base to visualize the evidence for the research question investigated on the world map to identify global temporal and geospatial patterns.

## THE HYBRID MACHINE-HUMAN APPROACH

Below, we detail the three key components of our hybrid machine-human approach in this experiment.

### Contextualizing Findings: Time and Site Identification

To analyze the relationship between volcanism and climate change at different times in the geological past and locations, we built a custom *Named Entity Recognizer* to extract spatial and temporal information from the analyzed text. Named entity recognition (NER) is a common NLP task that aims to identify named entities within the given text and classify or categorize those entities under various predefined classes. Our focus in this work is on the identification of locations and geological eras and epochs, which are necessary to contextualize the findings discussed in the papers.

Existing NER tools such as Stanford's CoreNLP (Manning et al., 2014) or spaCy (Honnibal and Montani, 2017) focus on generic locations, times, and dates rather than geoscience-specific ones. For example, when we fed the sample sentence "Clay mineral assemblages and crystallinities in sediments from IODP Site 1340 in the Bering Sea were analyzed in order to trace sediment sources and reconstruct the paleoclimatic history of the Bering Sea since Pliocene (the last 4.3 Ma)" into the Stanford CoreNLP NER, the result was:

*Clay mineral assemblages and crystallinities in sediments from IODP Site [1340] DATE in the [Bering Sea]LOCATION were analyzed in order to trace sediment sources and reconstruct the [paleoclimatic] MISC history of the [Bering Sea] LOCATION since Pliocene (the last [4.3] NUMBER Ma).*

Even though the Stanford CoreNLP NER correctly identified *Bering Sea* as a LOCATION, it did not recognize geo-sciences-specific expressions, and, further, it classified expressions into the incorrect

TABLE 1. NAMES AND DESCRIPTIONS OF THE LABELS USED DURING THE MACHINE CLASSIFICATION PROCESS*

| Classification label | Definition |
|---|---|
| Support | The given text supports the relationship between volcanism and climate change. |
| Negate | The given text negates the relationship between volcanism and climate change. |
| Negate&Support | The same overall text both supports and negates the relationship between volcanism and climate change, with different paragraphs discussing each relationship. |
| Unrelated | The given text is unrelated to the topic at hand, i.e., the relationship between volcanism and climate change. |

*See text footnote 1.

entity types. For example, *IODP Site 1340* (IODP stands for Integrated Ocean Discovery Program) refers to a certain location, but the recognizer identified only *1340*, and classified it incorrectly as a DATE. The recognizer missed the term *Pliocene*, which means "the geologic time scale that extends from 5.333 million to 2.58 million years B.P." *Ma* in geosciences articles usually means *million years ago*, but the CoreNLP NER did not identify it as TIME.

To recognize expressions that were not identified by CoreNLP or Spacy, we used the Odin event extraction framework and rule language (Valenzuela-Escárcega et al., 2016); henceforth, Odin), and added custom rules to capture geoscience-specific expressions. In particular, we developed rules to capture:

### Temporal Information

As mentioned, initially we utilized the named entity recognition tool in Stanford's CoreNLP (Manning et al., 2015); henceforth, CoreNLP) to identify time information. However, since CoreNLP was trained on general text data, it does not recognize geological temporal expressions, such as Paleocene or Jurassic. In addition, in geosciences papers, there were abbreviations such as *M.y.r.* and *M.a.*, which mean *millions of years* (duration), and *million years ago* (absolute time). Thus, we wrote custom rules to recognize geological temporal expressions and built a custom time normalizer to convert actual times (e.g., *170 M.y.r.*, or *1.5 million years ago*) to relevant geological time scale (e.g., *Jurassic*, *Quaternary*) (see supplemental document 1[1] for specific details on these rules).

### Site Information

Similar to temporal information, there were domain-specific spatial expressions that could not be captured by existing NERs such as Stanford's CoreNLP. Further, some of these expressions did not have any information about the actual locations that they indicate. Thus, we wrote scripts to extract spatial expressions, disambiguate geoscience-specific spatial expressions (e.g., *IODP Site U1360*), and normalize these expressions by aligning them with specific latitude-longitude bounding boxes that indicate the actual location of the corresponding spatial expressions on the world map (see supplemental document 2 [see footnote 1]).

## CLASSIFYING THE SUPPORT FOR THE RESEARCH QUESTION OF INTEREST

Even though these spatial and temporal expressions are important to contextualize the findings of a publication, they provide no information on our key research question: whether volcanism affected climate change. To make a prediction of whether the given paper supports or negates the relationship between volcanism and climate change, it is necessary to build a machine learning classifier that infers if the observation is supported (or not) from the text of these publications.

Among the wide variety of text classification methods, in this work we focused on four methods that have been shown to perform well for text classification, including "traditional" statistical methods as well as deep learning. To represent the traditional "camp," we used Support Vector Machines (Cortes and Vapnik, 1995) and Naïve-Bayes SVMs (NB-SVMs) (Wang and Manning, 2012). For the deep learning field, we implemented a Multi-Layer Perceptron (henceforth, MLP) that operates on the same features as the above SVM variants. Last, we implemented an ensemble strategy that combines the outputs of these three individual models.

To prevent the classifiers from overfitting on the training data, we used L2 regularization when training the statistical classifiers that support it (i.e., SVM, NB-SVM, and MLP classifiers). Intuitively, regularization aims to "zero out" the features that are not critical to the task, which reduces the potential of overfitting, or "hallucinating a classifier" (Domingos, 2015). All document classification routines are detailed in supplemental document 3 (see footnote 1).

### Data Annotation

Data annotation was performed via FindingFive. Two hundred papers were randomly chosen from the set of 1157 downloaded papers, and then title, abstract, introduction, conclusion/discussion sections of 200 papers were presented to the two

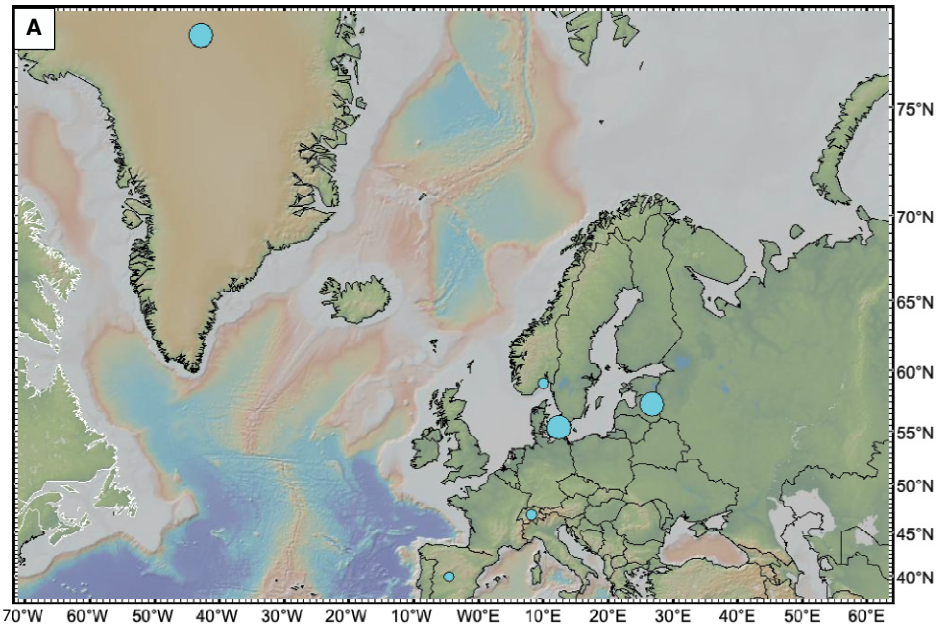


**Figure 1. (A) Topographic map of Europe with circles representing the most frequent location found in each paper where the relationship between volcanism and climate change has been tested during the Cenozoic. Light blue circles indicate the locations where the impact of volcanism on climate change was verified, and pink circles indicate the locations where previous research negated the relationship between volcanism and climate change. The size of the circles represents its frequency; i.e., the number of publications supporting it. (B) Topographic map of North America with circles representing the top three most frequent locations found in each paper where the relationship between volcanism and climate change has been tested during the Cenozoic. (C) Topographic map of northern Europe with circles representing the most frequent location found in each paper where the relationship between volcanism and climate change has been tested during the Phanerozoic. (D) Topographic map of Europe and Asia with circles representing the top three most frequent locations found in each paper where the relationship between volcanism and climate change has been tested during the Cenozoic.** **(*Continued on following page*.)**

[1]Supplemental Material. Supplemental Documents 1–3. Go to https://doi.org/10.1130/GSAT.S.20030015 to access the supplemental material; contact editing@geosociety.org with any questions.

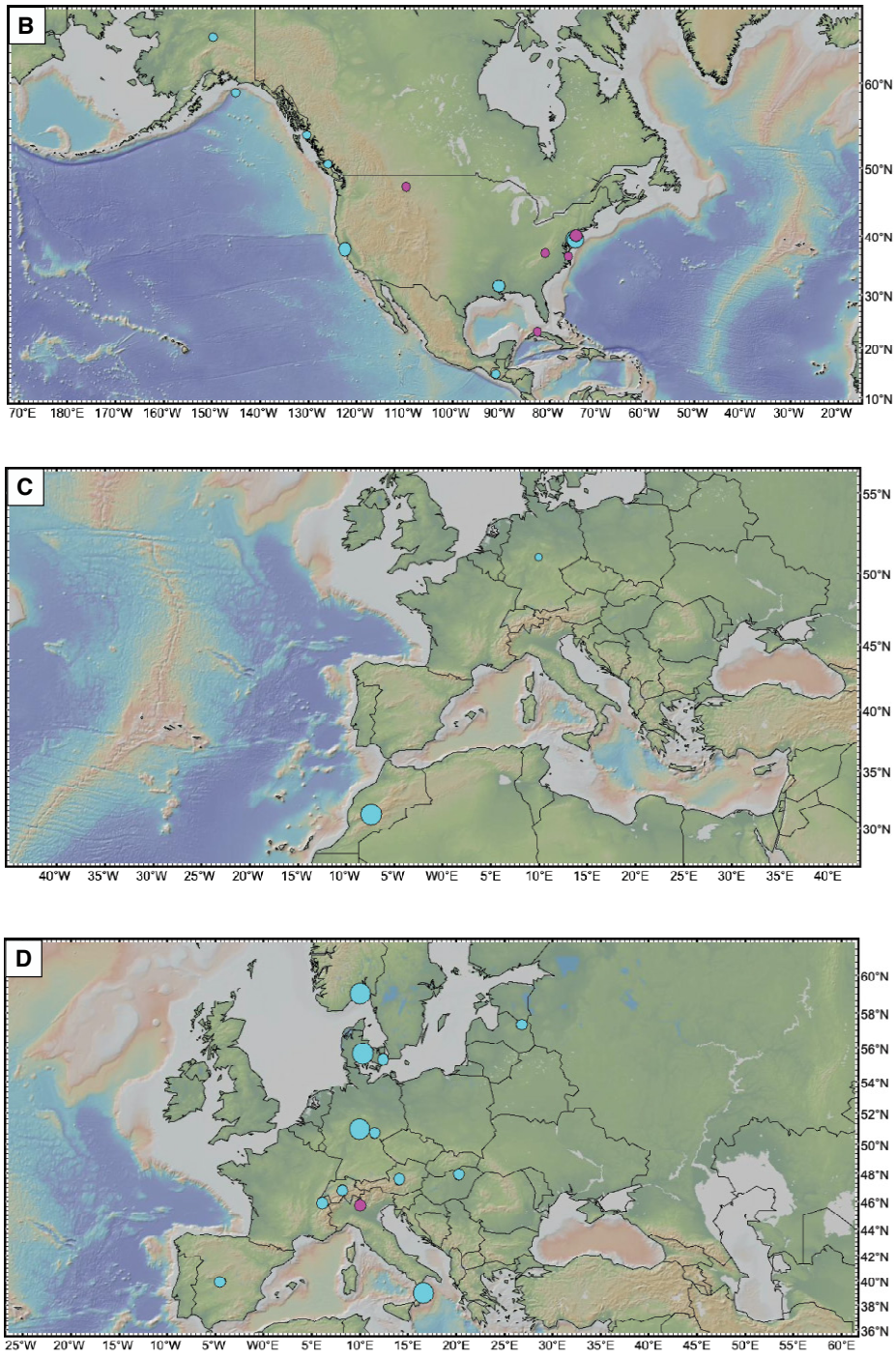


**Figure 1 (*continued from page 6*).**

annotators. After reading the provided text, the annotators determined whether the given paper supported or negated the relationship between volcanism and climate change. As a result, we produced 400 annotation results (200 papers × 2 annotators). All of 400 annotation results were used as a data set to train, validate, and evaluate the proposed system. Thus, even the disagreement between two annotators was used as data so that the proposed system could learn the ambiguity (see supplemental document 3). Before conducting the annotation session, authors discussed annotation criteria using papers that were *not* selected for annotation. To measure the agreement between annotators, Cohen's kappa score (Cohen, 1968) was measured. Cohen's kappa score is a commonly used metric to measure the agreement between two annotators. The Kappa result was 0.523, which showed moderate agreement between annotators (Landis and Koch, 1977). In other words, the two annotators somewhat agreed on whether a given paper supported or negated the observation that "volcanism affected the climate change." This "moderate" agreement is often found in this type of annotation task since the research question itself is quite complex and only part of the papers (e.g., abstract, introduction, conclusion) was provided to the annotators.

### *Classification of Results*

We evaluated the quality of the proposed classifiers that were trained on the annotations by comparing the micro-F1 score calculated using 10-fold cross validation. More formally, we collected the algorithm's predictions on each test partition, and calculated the micro-F1 score (see supplemental material, including a formal definition of these measures in document 3) from *all* these predictions.

In these experiments, we observed that the MLP classifier outperforms both the NB-SVM and SVM classifiers, and that the ensemble approach does not improve over the performance of the MLP method (see supplemental document 3 for all these results). Informed by these results, we used the MLP model to classify all the 957 remaining papers in the collected data set on whether they supported/negated or were unrelated to the research question at hand.

## Aggregation of Results for Visualization

With the two components described above that (a) place a scientific finding in its proper geospatial and temporal context, and (b) identify if publications support or negate the research question at hand, we can aggregate and visualize results at scale. To further simplify the visualizations, we used the *geopy* (https://pypi.org/project/geopy/) Python library to convert IODP sites to latitudes and longitudes, and we converted the identified specific geological periods and epochs into broader (larger time intervals) geological eras. For each paper analyzed, we used the most frequent top $k$ (where $k = 1$, or $k = 3$) spatial and temporal entities for context.

Figure 1 shows several visualizations of the results, with light blue indicating support for the observation that volcanism impacts climate change and pink negating the observation. The sizes of the circles were determined based on the number of papers that the classifier predicted the corresponding label (i.e., light blue for

SUPPORT, and pink for NEGATE). Figure 1A shows the most frequent locations during the Cenozoic in Europe, and Figure 1 shows the top three most frequent locations during the Cenozoic in North America. When manually inspecting the machine prediction results from the MLP model, the domain experts observed that 11 out of 17 data points within the North American continent were correctly identified and visualized on the world map. Out of the six errors, four data points were from simulation papers, and two data points were based on incorrect predictions by the MLP classifier, as identified by the domain experts. For example, one pink circle (i.e., the corresponding paper was classified as not supporting the observation that volcanism impacts climate change) was incorrectly predicted when the actual paper was unrelated with respect to this observation.

These figures immediately highlight several important observations:

- Our data processing reduces the search space by almost two orders of magnitude (from ~1,000 papers that are shallowly related to the topic of interest to 17 that validate/invalidate the current observation that volcanism affects climate change), while our visualizations allow the scientist to quickly draw important conclusions that would not be easily available otherwise. For example, our figures show that while the majority of publications support the hypothesis investigated that volcanism impacts climate change, not all do.
- Similarly, this bird's-eye-view of a scientific question allows one to quickly identify "blank spaces" in research, i.e., topics that are insufficiently investigated. For example, our visualizations show that while support for our research question is well represented for the North American continent, it is scarce in other continents.
- Further, this work allows one to identify (potential) contradictions in scientific findings quickly, which provides opportunities for better science. For example, Figure 1B shows apparent contradictions in findings from the East coast of the North American continent in the Cenozoic.
- Lastly, the fact that 11 out the 17 identified papers are correctly classified is not surprising considering that none of the automated components (i.e., the module that extracts temporal and spatial context, and the research question classifier) are perfect. However, this result emphasizes that the human/machine interaction must continue if this system is to be improved.

All in all, this experiment finds strong support in favor of feedbacks existing between volcanism and climate change. However, the precise correlation is not a simple one. Our literature parsing system suggests that we do not yet have a clear and complete understanding of how volcanic events affect climate change.

## CONCLUSIONS

The result of this preliminary work introduced a methodology to automatically provide a global review of the geoscientific literature and to evaluate the impact of specific research questions (i.e., understand if the question is [mostly] supported or rejected by the literature), in this case the causal relationship between volcanism and climate change. We show the promises and limitations of this approach to the geoscience literature with this admittedly simplistic example. This approach helps us process and interpret a large amount of published scientific papers, without the need for human annotators to invest time in reading and parsing all of the papers. In addition, with the visualization, researchers are able to investigate chronological changes in the relationship between volcanism and climate change. This approach could be expanded to any number of queries in the geoscience literature for the systematic analysis of various observations and ideas by examining a large body of previously published papers. Results can be further plotted on reconstructed various sample or study locations using paleogeographic maps.

It is vital to emphasize that the proposed methodology is hybrid, requiring direct collaboration between humans and machines. For example, geoscientists were required to provide training data for our research question classifier. Further, as discussed, our resulting classifier is only ~80% accurate, which means that, in order to improve it, it needs continuous feedback from the scientists using it. Longer term, we envision a community-wide effort in which such classifiers are created and deployed in the cloud to mine an arbitrary number of observations and are continuously improved over time by their human end users.

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# Upcoming Award Deadlines

For details, go to **www.geosociety.org/about-awards.**

Award nominations: Go to **www.geosociety.org/awardnoms.**

You can also email GSA Grants and Awards at **awards@geosociety.org.**

## 2023 GSA MEDALS AND AWARDS

**Nomination deadline:** 1 Feb. 2023

- Penrose Medal
- Day Medal
- Young Scientist Award (Donath Medal)
- GSA Public Service Award
- Randolph W. "Bill" and Cecile T. Bromery Award for Minorities
- GSA Distinguished Service Award
- Doris M. Curtis Outstanding Woman in Science Award
- GSA Florence Bascom Geologic Mapping Award
- Honorary Fellow

## JOHN C. FRYE ENVIRONMENTAL GEOLOGY AWARD

**Nomination deadline:** 31 Mar. 2023

In cooperation with the Association of American State Geologists and supported by endowment income from the GSA Foundation's John C. Frye Memorial Fund, GSA makes an annual award for the best paper on environmental geology published either by GSA or by a state geological survey. Learn more at **www.geosociety.org/GSA/About/awards/GSA/Awards/Frye.aspx.**

## 2023 POST-DOCTORAL RESEARCH AWARDS

**Application deadline:** 1 Feb. 2023

- The **Gladys W. Cole Memorial Research Award** for research on the geomorphology of semiarid and arid terrains in the United States and Mexico is awarded annually to a GSA member or Fellow between 30 and 65 years of age who has published one or more significant papers on geomorphology.
- The **W. Storrs Cole Memorial Research Award** for research on invertebrate micropaleontology is awarded annually to a GSA member or Fellow between 30 and 65 years of age who has published one or more significant papers on micropaleontology.

Learn more about these post-doc research awards at **www.geosociety.org/GSA/About/awards/GSA/grants/postdoc.aspx.**

## OTHER AWARDS

**Nomination deadline:** 1 Feb. 2023

Submit nominations for the following awards at **www.agiweb.org/direct/awards.html.**

- **AGI Medal in Memory of Ian Campbell** recognizes singular performance in and contribution to the profession of geology.
- **The AGI Marcus Milling Legendary Geoscientist Medal** is given to a recipient with consistent contributions of high-quality scientific achievements and service to the earth sciences having lasting historic value; who has been recognized for accomplishments in field(s) of expertise by professional societies, universities, or other organizations; and is a senior scientist nearing completion or has completed full-time regular employment.

For a listing of other national awards and links information and nomination forms, go to **www.geosociety.org/national-awards.**

THE GEOLOGICAL SOCIETY OF AMERICA®

# Mark Your Calendar for Meetings Closer to Home

## South-Central Section

13–14 March
Stillwater, Oklahoma, USA
*Todd Halihan, todd.halihan@okstate.edu*
**www.geosociety.org/sc-mtg**

Edmon Low Library, Oklahoma State University.
Photo credit: rseigler0 from Pixabay.

## Joint Southeastern & Northeastern Sections

17–19 March
Reston, Virginia, USA
*Arthur Merschat, amerschat@usgs.gov; Patrick Burkhart, patrick.burkhart@sru.edu*
**www.geosociety.org/se-mtg**

Reston Town Center water fountain.
Photo credit: J. Rodysill.

## North-Central Section

4–5 May
Grand Rapids, Michigan, USA
*Tara Kneeshaw, kneeshta@gvsu.edu; Ginny Peterson, petersvi@gvsu.edu*
**www.geosociety.org/nc-mtg**

L.V. Eberhard Center at GVSU. Photo credit: Amanda Pitts, University Communications, Grand Valley State University.

## Cordilleran Section

17–19 May
Reno, Nevada, USA
*Stacia Gordon, staciag@unr.edu*
**www.geosociety.org/cd-mtg**

Panorama from the Mono Lake South Tufa Area.
Photo credit: Dr. Philipp Ruprecht.

## Rocky Mountain Section

23–25 May
Fort Collins, Colorado, USA
*Rick Aster, rick.aster@colorado.edu*
**www.geosociety.org/rm-mtg**

Pineridge Natural Area.
Photo credit: Jan Alexander from Pixabay.

2023

# GSA Scientific Division Awards

*Congratulations to All 2022 GSA Division Award Recipients*

GSA's primary Division awards and the other Division awards presented at GSA Connects 2022 are listed below. Learn more about GSA's scientific Divisions at **www.geosociety.org/divisions.**

## ENERGY GEOLOGY DIVISION

*Gilbert H. Cady Award*
**Sue M. Rimmer,** College of Agriculture, Life and Physical Sciences-Geology, Southern Illinois University

*Antoinette Lierman Medlin Research Award*
No Award for 2022

*Curtis-Hedberg Award*
**Eve Sprunt**

## ENGINEERING AND ENVIRONMENTAL GEOLOGY DIVISION

*E.B. Burwell, Jr., Award*
**Stephen B. DeLong, Jordan A. Carey, Nicholas Pinter, Carol S. Prentice, Alexandra Pickering,** 2019, Analysis of Landslide Kinematics Using Multi-Temporal Unmanned Aerial Vehicle Imagery, La Honda, California: Environmental and Engineering Geoscience, v. 25, no. 4, p. 301–317.

*Distinguished Practice Award*
**Abdul Shakoor,** Kent State University

*Meritorious Service Award*
**Robert Mitchell,** Western Washington University

*Richard H. Jahns Distinguished Lecturer*
**Vincent S. Cronin,** Baylor University

*Roy J. Shlemon Scholarship Award*
**Cissy Mean,** Virginia Polytechnic Institute and State University
**Lauren Miller,** Colorado School of Mines

*Roy J. Shlemon Meeting Award*
**Miguel Valencia,** Florida International University

## GEOARCHAEOLOGY DIVISION

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*Claude C. Albritton, Jr., Memorial Student Research Award*
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**Alyssa Pietrazsek,** Leon H. Charney School of Marine Sciences, University of Haifa

## GEOBIOLOGY AND GEOMICROBIOLOGY DIVISION

*Outstanding Contributions in Geobiosciences Award—Pre-Tenure*
**John W. Valley,** University of Wisconsin

*Outstanding Contributions in Geobiosciences Award—Post-Tenure*
**Lidya Tarrhan,** Yale University

*Outstanding Contributions in Geobiosciences Award—Distinguished Career*
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## GEOINFORMATICS DIVISION

*M. Lee Alison Award for Geoinformatics*
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## GEOLOGY AND SOCIETY DIVISION

*E-an Zen Fund Geoscience Outreach Grant*
**Muhammad Qasim Mahmood,** University of Prince Edward Island
**Angelique Rosamarin,** University of Miami

## GEOPHYSICS DIVISION

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*Pellas-Ryder Award*
**Sarah S. Sutton,** University of Arizona

## QUATERNARY GEOLOGY AND GEOMORPHOLOGY DIVISION

*Kirk Bryan Award for Research Excellence*
**Timothy Beach,** The University of Texas, for Beach, T., et al., 2019, Ancient Maya wetland fields revealed under tropical forest canopy from laser scanning and multiproxy evidence: Proceedings of the National Academy of Sciences, v. 116, no. 43, p. 21,469–21,477.

*Distinguished Career Award*
**Dorothy J. Merritts,** Franklin & Marshall College

*Farouk El-Baz Award for Desert Research*
**Ronald Amundson,** University of California, Berkley

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*Outstanding Publication Award*
**Lars N. Hansen, David L. Kohlstedt, Mark E. Zimmerman,** University of Minnesota

## OTHER AWARDS PRESENTED AT THE MEETING

## CUSHMAN FOUNDATION

*W. Storrs Cole Memorial Research Award*
**Peter van Hengstrum,** Texas A&M University

## AMERICAN GEOSCIENCES INSTITUTE

*AGI Medal in Memory of Ian Campbell*
**Jean M. Bahr,** University of Wisconsin

## ASSOCIATION OF AMERICAN STATE GEOLOGISTS

*John C. Frye Memorial Award*
**David J. Hart and Anna C. Fehling,** Potential effects of climate change on stream temperature in the Marengo River head-waters: Wisconsin Geological and Natural History Bulletin, v. 115, 74 p.

# Thank You 2022 GeoCorps™ America Supporters

GeoCorps provides paid, short-term geoscience opportunities that encourage participants to develop professionally by engaging in the science and stewardship of public lands. We sincerely thank the program's participants, mentors, partners, and donors for their outstanding contributions in 2022. The GeoCorps program is a partnership between the USDA Forest Service, Bureau of Land Management, Actalent, Inc., and GSA. Prospective participants can review and apply for summer 2023 GeoCorps projects beginning in early December 2022.

**www.geosociety.org/geocorps**

**Clockwise from above: Caroline Vickery, in a soil pit dug for pedon description, Superior National Forest. Grace Fleszewski and Salmon-Challis National Forest, examining kasparite mineral with Brian Valle at a drilling inspection site. Elise Chan recording observations at a debris flow on the Flathead National Forest. Kevin Liow crawling through a tight squeeze in a cave that has a red arrow pointing at the crawl.**

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# Thank You National Park Service Scientists in Parks Supporters

The National Park Service (NPS) Scientists in Parks (SIP) program provides immersive, paid work experiences in natural resource fields so the next generation of park stewards—especially those underrepresented in science—have a unique opportunity to work on important real-world projects while building professional experience and a life-long connection to America's national parks. Prospective participants can review and apply for summer 2023 SIP Intern projects beginning in early December 2022.

**www.geosociety.org/sip**

**Clockwise from top left: Abigail Gonzalez assisting with Red Knot Surveys and Piping Plover Monitoring in North Core Banks, Cape Lookout National Seashore. SIP Intern Esaac Mazengia reading out measurements while flow tracking in Kalapaupa National Historic Park. At the Shenandoah National Park media office, Hannah Prokop records audio description voiceover for a virtual program. Scott Kottkamp standing behind a cabinet drawer with numerous horse specimens arranged within it. This project is part of reorganizing the specimens primarily along taxonomic lines, and secondarily along catalog number, to make managing and utilizing the collections for research easier at Hagerman Fossil Beds National Monument.**


**2022 Partners include:**

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**Additional sources of funding include:** Alaska Geographic, Black Hills Parks and Forest Assoc., Devils Tower Natural History Assoc., Grand Canyon Conservancy, Great Basin National Park Foundation, NPS Intermountain Region, NPS Inventory and Monitoring Division, NPS Midwest Region, NPS Southeast Region, Rocky Mountain Conservancy, and Shenandoah National Park Trust.

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Point Reyes National Seashore
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Saint-Gaudens National Historical Park
Santa Monica Mountains National Recreation Area

# The Role of Outburst Floods in Earth and Planetary Evolution

**5–9 June 2023 | Grand Coulee, Washington, USA**
**www.geosociety.org/penrose**

## CONVENERS

**Tim Goudge,** University of Texas at Austin, Dept. of Geological Sciences, Austin, Texas, USA, tgoudge@jsg.utexas.edu
**Isaac Larsen,** University of Massachusetts, Dept. of Geosciences, Amherst, Massachusetts, USA, ilarsen@umass.edu
**Jim O'Connor,** U.S. Geological Survey, Geology, Minerals, Energy, and Geophysics Science Center, Portland, Oregon, USA, oconnor@usgs.gov
**Greta Wells,** University of Iceland, Institute of Earth Sciences, Reykjavík, Iceland, ghwells@hi.is

## SPONSORS

The Geological Society of America
National Science Foundation

## DESCRIPTION AND OBJECTIVES

The century following the start of the "Spokane Flood" debate has seen tremendous growth in the understanding of the significant role outburst floods have played in shaping the surfaces of Earth and Mars. Study of the geomorphology and hydrology of outburst floods has, in turn, generated hypotheses regarding the role such floods play in driving climate change and a greater recognition of the geohazards associated with outburst flooding. The objective of this Penrose Conference is to bring together a diverse community of scholars to discuss the current state of knowledge and chart the future of outburst flood science. The timing of the proposed conference in 2023 is also historically significant, as it marks the centennial anniversary of J Harlen Bretz's first publication on the Channeled Scabland.

## PRELIMINARY OUTLINE OF THEMATIC SESSIONS

**1. The Channeled Scabland and the Missoula Floods**

The Missoula Floods and the Channeled Scabland are a "Megaflood testing ground" for studies applicable throughout the solar system. It is here where Bretz's controversial and outrageous hypothesis for a flood origin of the Channeled Scabland brought huge ice-age outburst floods into the realm of modern Earth science. The Channeled Scabland continues to inspire geological analysis and modeling approaches, and this spectacular geographic area has long attracted attention, culturally and scientifically. This thematic session will explore the state of knowledge of the Channeled Scabland landscape and the Missoula floods, as well as the scientific controversies that have persisted for the past century and continue today.

**2. Outburst Floods—A Universal Process**

A wide range of geological processes lead to impoundment of water bodies that can then rapidly drain to cause large floods, ranging from tectonics to meteor impacts. Floods from ice-dammed, moraine-dammed, and landslide-dammed lakes can cause human catastrophes. Floods from constructed dams have also profoundly affected landscapes and people. Spectacular flood-carved landscapes on other planets, particularly Mars, owe to huge outburst floods. The diversity of settings, processes, and hazards results in a wide range of backgrounds, disciplines, and geographies represented by outburst flood researchers, including engineers, geomechanicists, glaciologists, volcanologists, geologists, geographers, hydrologists, and planetary scientists. This thematic session aims to search for commonalities and distinctions among outburst flood generation mechanisms and geomorphic consequences (across landscapes and planets), thereby enriching the perspective for the outburst flood research community.

**3. Mechanistic Understanding of Outburst Flood Processes—Flow, Erosion, and Deposition**

Outburst floods produce spectacular features—huge cataract complexes, eroded rock basins, streamlined landforms, and immense stratified deposits. Given the lack of in situ observations of ice-age and planetary megaflood processes, various methods have been used to address historical questions regarding flood magnitude, the number of floods, or the shear stresses generated by flooding, including empirical, stratigraphic, mechanistic, modeling, and physical experimentation. The development, refinement, and testing of mechanistic models have been key to advancing the overall understanding of how outburst floods drive the evolution of planetary surfaces. The objective of this thematic session is to generate discussion that charts a path for novel approaches for mechanistic understanding of the energetic and dynamic flows that produce outburst flood landforms.

**4. Broader Implications of Outburst Floods—Cultural Consequences and Hazards, Ocean Circulation and Climatic Systems, Ecosystems, and Landscape Evolution**

The hazards and impacts from outburst floods are immense, global, and diverse, begging several overarching questions. Are there specific geologic and climatologic settings that can condition such

**Aerial view downstream (south) of Dry Falls cataract complex, Grand Coulee, Washington, USA. The pair of giant cataracts at the head of lower Grand Coulee are 120 m deep and span 2 km in width. They formed via headward erosion during several Missoula floods. The planned conference venue, Camp Delany, sits at the foot of the left (eastern) amphitheater. Photograph by Bruce Bjornstad.**

hazards and preserve evidence of paleo-outburst floods? What are persistent cultural consequences of outburst floods, such as the landslide dam flood that has been attributed to marking the beginning of the Xia dynasty and onset of the Chinese Bronze Age? Can the formation of glacier dams and erosion by outburst floods influence long-term exhumation and geodynamics in uplifting mountains? More broadly, how do outburst floods affect landscapes on geologic time scales? Aside from landscape impacts, it is also important to consider climate impacts—Can large outburst floods trigger global or regional climate changes? This fourth thematic session will address these broad interdisciplinary questions, searching for directions of productive inquiry relevant to the culturally and scientifically important aspects of outburst floods.

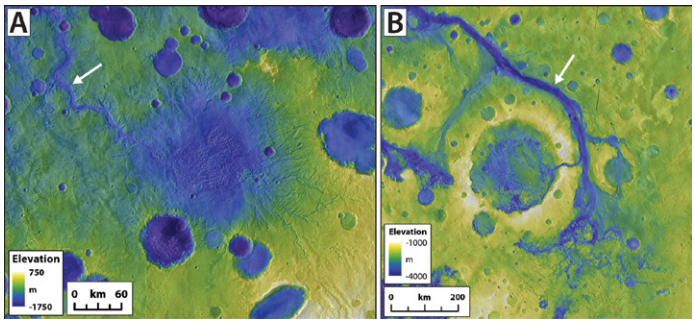
## PRELIMINARY AGENDA

The meeting will be held at Camp Delany, a facility within Sun Lakes–Dry Falls State Park, near Coulee City, Washington, USA. The conference venue is located within the plunge pool of the Grand Coulee cataract complex carved by the Missoula floods, providing a stunning location for inspiring conference discussion and two field excursions. The conference format will be a balance of oral presentations, poster presentations, evening plenary talks, and breakout discussions and will include mentoring opportunities for early-career scientists. All nights will be spent at Camp Delany, with shared bunkhouse or camping accommodations. A limited number of hotel rooms have been reserved in a nearby town for participants who require different lodging. Attendees will be expected to observe the GSA Code of Ethics & Professional Conduct throughout the meeting. The conference will follow the COVID-19 protocols that GSA has established for meetings and field trips.

Meeting participants who are arriving by air will be shuttled from Seattle-Tacoma International Airport to the conference venue on Sunday, 4 June. Day 1 of the conference on (5 June) will focus on the Channeled Scabland, setting the stage for a field trip on Day 2. The full-day tour of the Channeled Scabland and late Pleistocene outburst flood features will include inspection of several flow paths, evidence of ice dams and ice-dammed lake deposits, and a variety of erosional and depositional landforms. Day 3 will include multiple sessions focussing on different aspects of the universal nature of outburst floods. Day 4 will begin with a morning session focussed on outburst flood mechanics, followed by an afternoon field trip in Grand Coulee to extend the discussion of the origin of outburst flood erosional and depositional features. Finally, Day 5 will be dedicated to the broader societal and earth-system implications of outburst floods, followed by breakout discussion groups, where participants will summarize and record the key conference outcomes related to each theme. Those meeting participants who will be departing by air will be shuttled back to Seattle-Tacoma International Airport on Saturday, 10 June.

## ATTENDEES AND ESTIMATED COSTS

Thanks to the generous support of the sponsors, many of the meeting costs are covered. The registration fee is yet to be determined, but it will cover six nights of lodging, meals, transportation to/from Camp Delany, transportation for field trips, and facility usage. Participants will be expected to pay for travel expenses from their home to Seattle-Tacoma International Airport. However, we have funds allocated to support both the registration costs and the travel expenses of some participants, which will be prioritized toward individuals from groups underrepresented in the geosciences, as well as early-career and student participants. All participants will be expected to make their own travel arrangements to arrive at the Seattle-Tacoma International Airport on 4 June. Alternatively, attendees may choose to provide their own transportation to Camp Delany but will be expected to use conference-provided transportation during the meeting (i.e., for field trips).




**Examples of outburst flood features on Mars. (A) Loire Vallis (white arrow) carved by catastrophic lake breach flooding from the Parana basin. (B) Ares Vallis (white arrow) outflow channel carved by catastrophic release of overpressurized groundwater. Image credit: THEMIS (NASA/JPL-Caltech/Arizona State University) and MOLA (NASA/GSFC/MOLA Science Team), Timothy A. Goudge.**

## APPLICATIONS AND REGISTRATION

**Application deadline:** 27 Jan. 2023
**Acceptance notices:** 27 Feb. 2023
**Registration deadline:** 20 Mar. 2023

GSA and the meeting conveners are committed to fostering diversity, equity, inclusion, and belonging in the geoscience community. For this meeting we welcome and encourage applications from all gender identities, Black, Indigenous, Latinx, and People of Color, people with disabilities, LGBTQIA+ individuals, and other groups that are currently underrepresented within the earth-science community. We have dedicated funds to support conference participation for such individuals, as well as early-career researchers and students.

The conference will be limited to approximately 75 participants, and each participant will be expected to attend the full duration of the conference. To apply, please submit your application through the form on the meeting website:

**https://www.jsg.utexas.edu/penrose-2023/**

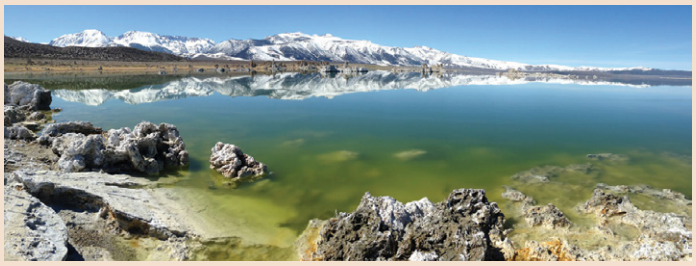
As part of the application, you will be asked to prepare a brief statement of your interests and relevance of your work to the conference themes (150 words max.), as well as a tentative title for a proposed presentation; every participant will be expected to present at the conference. Applicants will be notified regarding attendance and presentation format (oral or poster) by 27 Feb. 2023. Conference participants will be asked to submit full abstracts for presentations at the time of registration.

# Cordilleran Section

119th Annual Meeting of the Cordilleran Section, GSA

17–19 May 2023 | Reno, Nevada, USA

www.geosociety.org/cd-mtg



**Panorama from the Mono Lake South Tufa Area. Photo credit: Dr. Philipp Ruprecht.**

## LOCATION

The 2023 GSA Cordilleran Section Meeting will be held in Reno, Nevada, USA, a modern boomtown situated within the Basin and Range at the foot of the Sierra Nevada Batholith. Nevada, the Silver State, got its nickname from the historical Comstock Lode near Reno, and the state presently hosts world-class gold deposits in the Carlin trend. Reno and the surrounding high desert have much to offer in terms of exciting nearby geology: active faulting within the Walker Lane and Basin and Range, records for ancient glacial outburst floods and vast pluvial lakes, abundant evidence for extrusive and intrusive igneous activity, and windows into the deep crust within the Ruby Mountains and Snake Range metamorphic core complexes. In addition, with great and growing geothermal resources and the only domestic lithium deposits, Nevada is pushing the green-energy revolution! Reno offers affordable housing and abundant restaurants, bars, parks, and the Truckee River to relax in or by at the end of the day. The program includes a diverse range of technical sessions and field trips. We hope you can join us for an exciting meeting in Reno in May 2023!

## CALL FOR PAPERS

**Abstracts deadline:** 14 Feb. 2023
**Submit abstracts** online at www.geosociety.org/cd-mtg.
**Abstract submission fee:** GSA members: professionals, US$30; students, US$18; non-members: professionals, US$60; students, US$36. If you cannot submit an abstract online, please contact Heather Clark, +1-303-357-1018, hclark@geosociety.org.

## TECHNICAL PROGRAM

In addition to the following Theme Sessions, we are soliciting abstracts for general discipline sessions. For additional information, contact the Technical Session Co-Chairs: Andrew Zuza, azuza@unr.edu, and Mike Darin, mdarin@unr.edu.

### Symposium

P1. **The Changing Face of Paleontology: In Honor of the Career Contributions of Dr. Richard L. Squires.** Chris L. Bonds, CA-DWR-DRA, goldbondwater@gmail.com.

### Theme Sessions

T1. **Evolution of Transcrustal Cordilleran Arc Systems.** *Endorsed by GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division; GSA Structural Geology and Tectonics Division.* Katie Ardill, Texas Tech University, katie.ardill@gmail.com; Wenrong Cao, University of Nevada, Reno, wenrongc@unr.edu; Barbara Ratschbacher, University of California, Davis, bratschbacher@ucdavis.edu.

T2. **Drivers of Cordilleran Magmatic Processes and Geochemistry.** Juliet Ryan-Davis, Caltech, jrd@caltech.edu; Maddie Lewis, Purdue University, lewis622@purdue.edu; Penny Wieser, University of California, Berkeley, penny_wieser@berkeley.edu; Claire Bucholz, Caltech, cbucholz@caltech.edu.

T3. **Tectonic Processes along Subduction Zone Margins.** Cailey Condit, University of Washington, ccondit@uw.edu; Margo Odlum, University of Nevada, Las Vegas, margo.odlum@unlv.edu; Devon Orme, Montana State University, devon.orme@montana.edu.

T4. **Strike-Slip Faulting, Flower Structures, Plutons, and Tiltmeters: A Tribute to the Career of Arthur Sylvester.** *Endorsed by GSA Structural Geology and Tectonics Division.* Allen F. Glazner, University of North Carolina, afg@unc.edu; An Yin, University of California, Los Angeles, yin@epss.ucla.edu; Richard D. Law, Virginia Tech, rdlaw@vt.edu; Marc Mayes, Earth Research Institute, University of California, Santa Barbara, mmayes@sig-nal.org.

T5. **Temporal and Spatial Crustal Thickness Variations in the Mesozoic-Cenozoic North American Cordillera: Processes and Consequences.** Andrew Zuza, University of Nevada, Reno, azuza@unr.edu; Wenrong Cao, University of Nevada, Reno, wenrongc@unr.edu; Sean Long, Washington State University, sean.p.long@wsu.edu.

T6. **Late Jurassic to Eocene Tectonics of the North America Cordillera: Evolving and Emerging Models.** Basil Tikoff, University of Wisconsin, Madison, basil@geology.wisc.edu; Stacia Gordon, University of Nevada, Reno, staciag@unr.edu; Andy Barth, Indiana-Purdue University, ibsz100@iupui.edu; Cathy Busby, University of California, Davis, cjbusby@ucdavis.edu; Robinson Cecil, California State University, Northridge, robinson.cecil@csun.edu; Sarah Roeske, University of California, Davis, smroeske@ucdavis.edu; Michael Wells, University of Nevada, Las Vegas, michael.wells@unlv.edu.

T7. **Advancements in Central Sierra Nevada Structural Geology and Tectonics.** Allison Jones, Sierra College,

ajones124@sierracollege.edu; Kurtis Burmeister, California State University, Sacramento, k.burmeister@csus.edu.

T8. **At the Crossroads—Addressing Geological Questions and Complexities Near the Boundary of the Basin & Range, Cascadia, and/or Sierra Nevada Provinces.** Stephen M. Crabtree, University of Minnesota, Morris, crabt012@morris.umn.edu.

T9. **Paleo-, Archaeo-, and Rock-Magnetic Studies of Cordilleran Evolution and Geomagnetic Secular Variations of the Western United States.** Margaret S. Avery, U.S. Geological Survey, mavery@usgs.gov; Anthony Pivarunas, U.S. Geological Survey, apivarunas@usgs.gov; Shelby Jones, University of California, San Diego, and Center for New Mexico Archaeology, saj012@ucsd.edu.

T10. **Paleontologic Advances in the Cordilleran Region.** Paula Noble, University of Nevada, Reno, noblepj@unr.edu; Neil Kelley, Vanderbilt University, neil.kelleyca@gmail.com; Joshua Bonde, Nevada State Museum.

T11. **Glacier Change in the Western Cordillera.** Claire Todd, California State University, San Bernardino, claire.todd@csusb.edu.

T12. **A Multidisciplinary Effort to Better Understand Northern California's Clear Lake Volcanic Field.** Seth Burgess, U.S. Geological Survey, sburgess@usgs.gov; Dawnika Blatter, U.S. Geological Survey, dblatter@usgs.gov; Jessica Ball, U.S. Geological Survey, jlball@usgs.gov.

T13. **Interdisciplinary Insights into the Ecosystem, Paleoclimate, Volcanology, and Tectonic Framework of Mono Lake, California.** Lauren Harrison, U.S. Geological Survey, lnharrison@usgs.gov; Guleed Ali, Berkeley Geochronology Center, gali@bgc.org; Jared Peacock, U.S. Geological Survey, jpeacock@usgs.gov.

T14. **Nature of Magma Processes in Different Sized and Shaped Plutons.** *Endorsed by GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division.* Valbone Memeti, California State University, Fullerton, vmemeti@fullerton.edu; Cal Barnes, Texas Tech University, cal.barnes@ttu.edu; Jade Star Lackey, Pomona College, jadestar.lackey@pomona.edu; Joshua Schwartz, California State University, Northridge, joshua.schwartz@csun.edu.

T15. **Applied Geophysical Analysis of the Shallow Subsurface.** Daniel Sturmer, University of Cincinnati, Daniel.Sturmer@uc.edu; Seth Saltiel, University of Nevada, Reno, ssaltiel@unr.edu; Elnaz Seylabi, University of Nevada, Reno, elnaze@unr.edu; John Louie, Nevada Seismological Laboratory, University of Nevada, Reno, louie@unr.edu.

T16. **Getting Back into the Collections: Specimen-Based Paleontological Research.** Ashley Dineen, University of California Museum of Paleontology, aadineen@berkeley.edu; Patricia Holroyd, University of California Museum of Paleontology, pholroyd@berkeley.edu; Christina Garcia, California Academy of Sciences, cgarcia@calacademy.org.

T17. **Measuring and Projecting Geomorphic Responses to Modern Climate Change.** Jonathan Perkins, U.S. Geological Survey, jperkins@usgs.gov; Amy East, U.S. Geological Survey, aeast@usgs.gov.

T19. **General Contributions in Geomorphology.** Joel Scheingross, University of Nevada, Reno, jscheingross@unr.edu; Greg Stock, National Park Service, greg_stock@nps.gov; Erin Bray, San Francisco State University, ebray@sfsu.edu.

T20. **Time Scales of Deformation and Metamorphism.** Drew Levy, University of Nevada, Reno, drewlevy@nevada.unr.edu; Eirini Poulaki, University of Texas, Austin, eirini_poulaki@utexas.edu; Will Hoover, University of Washington, wfhoover@uw.edu.

T21. **Innovative and Novel Applications of GIS and Remote Sensing for Geologic Mapping, Geomorphology, Volcanology, and Other Fields.** Stephen M. Crabtree, University of Minnesota, Morris, crabt012@morris.umn.edu.

T22. **Integrated Geologic Maps and 3D Models in a Complex Non-Layered World.** *Endorsed by GSA Structural Geology and Tectonics Division; GSA Sedimentary Geology Division; GSA Hydrogeology Division; American Association of State Geologists.* Joseph Colgan, U.S. Geological Survey, jcolgan@usgs.gov; Donald Sweetkind, U.S. Geological Survey, dsweetkind@usgs.gov; Daven Quinn, University of Wisconsin, daven@davenquinn.com.

T23. **Hydrogeologic and Ecologic Monitoring and Assessment of Saline Lakes and Migratory Birds in the Great Basin.** *Endorsed by GSA Hydrogeology Division; GSA Soils and Soil Processes Division; GSA Geoinformatics and Data Science Division; GSA Environmental and Engineering Geology Division; GSA Geology and Society Division; GSA Limnogeology Division.* Rebecca J. Frus, Nevada Water Science Center, U.S. Geological Survey, rfrus@usgs.gov; Michael Casazza Western Ecological Research Center, U.S. Geological Survey, mike_casazza@usgs.gov; Garth Herring, Forest and Rangeland Ecosystem Science Center, U.S. Geological Survey, gherring@usgs.gov; Thomas Marston, Utah Water Science Center, U.S. Geological Survey, tmarston@usgs.gov; David O'Leary, Utah Water Science Center, U.S. Geological Survey, doleary@usgs.gov; Cory Overton, Western Ecological Research Center, U.S. Geological Survey, coverton@usgs.gov; Christine Rumsey, Utah Water Science Center, U.S. Geological Survey, crumsey@usgs.gov; Cassandra Smith, Oregon Water Science Center, U.S. Geological Survey, cassandrasmith@usgs.gov; Susan Kemp, Forest and Rangeland Ecosystem Science Center, U.S. Geological Survey, skemp@usgs.gov.

T24. **Geoscience and Hydrology of Your Federal and Other Public Lands: STEM Internships, Research, Science, Mapping, Resource Management, and Education**

**(Posters).** Matt Dawson, Geological Society of America, mdawson@geosociety.org.

T25. **Geomorphology and Public Policy in the 2020s: Earth-Surface Science in Service to Policymakers and Society.** Nicholas Pinter, University of California, Davis, npinter@ucdavis.edu; Kevin Schmidt, U.S. Geological Survey, kschmidt@usgs.gov; Joel Scheingross, University of Nevada, Reno, jscheingross@unr.edu.

T26. **Geoscience Education: Discovering New Tools and Adapting Old Ones in the Wake of COVID-19.** *Endorsed by GSA Geoscience Education Division*. Allison Jones, Sierra College, ajones124@sierracollege.edu; Kurtis Burmeister, California State University, Sacramento, k.burmeister@csus.edu.

T27. **From Online Expectations Back to In-Person Execution—Navigating New Teaching Norms in the "New Normal" Post-Pandemic World.** *Endorsed by GSA Geoscience Education Division.* Stephen M. Crabtree, University of Minnesota, Morris, crabt012@morris.umn.edu.

T28. **Entrepreneurship and Professional Innovation within the Geosciences.** Jennifer Wilson, Six Rivers Geosciences, jwilson@sixriversgeosciences.com.

T29. **Graduate Student Research (Posters).** Pooja Sheevam, University of Nevada, Reno, psheevam@nevada.unr.edu; Justin Toller, University of Nevada, Reno, jtoller@nevada.unr.edu.

T30. **Undergraduate Research (Posters).** *Endorsed by the Council on Undergraduate Research (CUR)–Geosciences Division.* Jeff Marshall, Cal Poly Pomona, marshall@cpp.edu.

## FIELD TRIPS

Trip registration opens in February 2023. For additional information, please contact the Field Trip co-chairs: Pat Cashman, patriciahcashman@gmail.com, Sue Cashman, smc1@humboldt.edu, and Harvey Kelsey, hmk1@humboldt.edu.

**Bodie and Aurora Mining Districts, Mono County California.** Gregg Wilkerson, California State University, Bakersfield, gwilkerson1@csub.edu. One day.

**Northern Sierra Nevada: Ophiolites and Blueschists to Active Tectonics and Geomorphology.** John Wakabayashi, California State University, Fresno, jwakabayashi@csufresno.edu; David Shimabukuro, California State University, Sacramento, dhs@csus.edu. Two days.

**Miocene Diatomite in Western Nevada—Climate and Tectonic Implications.** Michel Houseman, Imerys, mike.houseman@imerys.com; Bill Krebs, Subsurface Consultants, wnkrebs@hotmail.com. One day.

**Ammonites and Ichthyosaurs in Nevada's Triassic-Jurassic Seaway.** Montana Hodges, University of Nevada, Reno, montanahodges@unr.edu; Neil Kelley, Vanderbilt University, neil.p.kelley@vanderbilt.edu; Paula Noble, University of Nevada, Reno, noblepj@unr.edu. One day.

**Geology along the Yuba Pass and Highway 70 Corridors: A Complex History of Tectonics and Magmatism in the Northern Sierra Nevada.** Michelle A. Roberts, U.S. Geological Survey, roberts@usgs.gov; Vicki Langenheim, U.S. Geological Survey, zulanger@usgs.gov. One day.

**The Blast, The Quake, and the Bomb: An Accessible Tour of High-Energy Events in Western Nevada.** John Louie, University of Nevada, Reno, louie@unr.edu; Philipp Ruprecht, University of Nevada, Reno, pruprecht@unr.edu. One day.

**Northern Walker Lane Seismic Hazards and State Water Project Dams: Upper Feather River, California.** Chad W. Carlson, California Department of Water Resources, chad.carlson@water.ca.gov; Don F. Hoirup, California Department of Water Resources, don.hoirup@water.ca.gov; Christopher Hitchcock, InfraTerra Inc., chitchcock@infraterra.com. One day.

**The Transition from Walker Lane Transtension to Vertical-Axis Rotation Deformation Styles in Southern Oregon.** Andrew Meigs, Oregon State University, Andrew.Meigs@oregonstate.edu; Katherine Alexander, U.S. Geological Survey; Colin Amos, Western Washington University, amosc2@wwu.edu; Trevor Waldien, South Dakota School of Mines, trevor.waldien@sdsmt.edu. Three days.

**Emplacement of the Sage Hen Flat Pluton: Use of StraboSpot and Uncertainty Rankings.** Basil Tikoff, University of Wisconsin, Madison, basil@geology.wisc.edu; Sven Morgan, University of Michigan, Dearborn, svenmor@umich.edu; Ellen Nelson, University of Wisconsin, Madison, emnelson8@wisc.edu; Tim Shipley, Temple University, thomas.shipley@temple.edu. Two days.

**Tufa or Microbialites?** Russell Shapiro, California State University, Chico, rsshapiro@csuchico.edu; Tom Anderson, University of Nevada, Reno. One day.

**From Headwaters to The Terminal Basin: Tracking the Interrelated History of Lake Tahoe, The Truckee River, and Pyramid Lake.** Kenneth D. Adams, Desert Research Institute, kadams@dri.edu. One day.

## SHORT COURSES

Short course registration opens in February 2023. For additional information, please contact the short course chair: Rich Koehler, rkoehler@unr.edu.

**Solving Geomorphic Puzzles for Paleoflood Analyses: It's Just Water and Dirt, Right?** Keith Kelson, USACE National Paleoflood Lead, keith.i.kelson@usace.army.mil.

**Wilderness and Remote First Aid for Field Geologists.** Kurtis C. Burmeister, Sacramento State University, k.burmeister@csus.edu; Steve Skinner, Sacramento State University, steven.skinner@csus.edu.

**Basics of Electron Backscatter Diffraction (EBSD) Analysis Related to Structural and Petrochronology Studies.** Joel DesOrmeau, University of Nevada, Reno, jdesormeau@unr.edu; Zach Michels, University of Arizona, zacharymichels@arizona.edu; Drew Levy, University of Nevada, Reno, drewlevy@nevada.unr.edu.

## REGISTRATION

**Early registration deadline:** 10 April 2023
**Cancelation deadline:** 17 April 2023

Registration opens February 2023. For further information or if you need special accommodations, please contact the meeting general chair, Stacia Gordon, staciag@unr.edu.

## ACCOMMODATIONS

**Hotel registration deadline:** 24 April 2023

A block of rooms has been reserved at the Whitney Peak Hotel at 255 North Virginia Street, Reno, Nevada 89501, which is where the conference will be held. The meeting room rate is US$114 per night (single/double occupancy) plus tax. Make reservations going to https://res.windsurfercrs.com/ibe/details.aspx?hotelID=13492&lang=en-us&group=GSA-2023&hgID=0&currID=1&dt1=8535&nights=5&rooms=1&adults=1&child1=0&child2=0&child3=0&child4=0. Once on the website, add your check-in and check-out dates, and the conference rate will be applied to those dates. Alternatively, please call the direct sales line phone number at +1-775-398-5400 to make a reservation. When booking, make sure to use the group code of GSA-2023 to reserve at the meeting room rate.

## OPPORTUNITIES FOR STUDENTS AND EARLY-CAREER PROFESSIONALS

**Career Mentoring Luncheons**

Ask your career-related questions and learn about non-academic pathways in the geosciences while networking with professionals at the Roy J. Shlemon and John Mann Mentor Luncheons. GSA student members are welcome.

**Career Workshop Series**

This three-part series will feature career development planning, an exploration of geoscience job sectors, and information on best practices for crafting a résumé and cover letter. Non-technical skills and workforce statistics will be reviewed. The series will be led by workshop presenters and geoscientists. No registration is required, and everyone is welcome.

To learn more about mentors and career workshops, go to www.geosociety.org/mentors or contact Jennifer Nocerino at jnocerino@geosociety.org.

## ORGANIZING COMMITTEE

**Meeting General Chair:** Stacia Gordon, staciag@unr.edu
**Technical Session Co-Chairs:** Andrew Zuza, azuza@unr.edu; Mike Darin, mdarin@unr.edu
**Field Trip Co-Chairs:** Pat Cashman, patriciahcashman@gmail.com; Sue Cashman, smc1@humboldt.edu; Harvey Kelsey, hmk1@humboldt.edu
**Short Course Chair:** Rich Koehler, rkoehler@unr.edu
**Student Volunteer Chair:** Wenrong Cao, wenrongc@unr.edu
**Exhibits Chair:** Joel DesOrmeau, jdesormeau@unr.edu
**Sponsorship Chair:** John Louie, louie@seismo.unr.edu

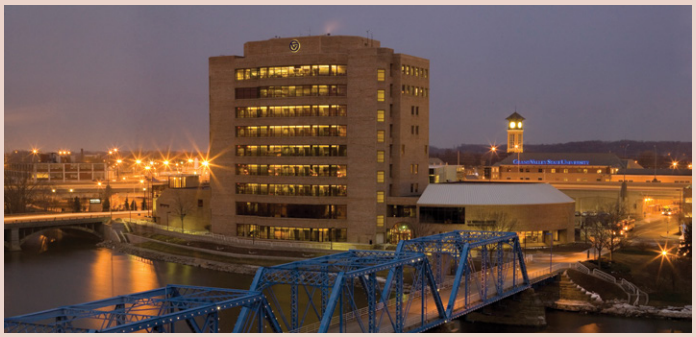
# North-Central Section

57th Annual Meeting of the North-Central Section, GSA

Grand Rapids, Michigan, USA | 4–5 May 2023

www.geosociety.org/nc-mtg

***A Meeting in the Mitten: Water, Rock, Wonderland***



**L.V. Eberhard Center at GVSU. Photo credit: Amanda Pitts, University Communications, Grand Valley State University.**

## LOCATION

Situated on the Grand River, just east of beautiful Lake Michigan, the city of Grand Rapids is home to approximately 600,000 people. In the Ottawa dialect, the Grand River is called Owashtanong, "Far-Flowing Water," a reflection on its length of 252 miles. Like the river, the history of the city is far reaching, is full of bends, has changed course several times, and its development has broadly impacted the region. Early on, the city was famous for its mile-long, 300-yard-wide, and 10-to-15-foot-tall rapids (which are soon to be restored!). Because the river allowed for the transportation of logs, mills and factories soon appeared, and Grand Rapids came to be called America's "Furniture City" thanks to the resultant production of fine wood furniture. More recently the city has been recognized as the center of office furniture manufacturing and the home of Gerald R. Ford, 38th President of the United States. Today, the city is well known as the home of the world's most attended public art event called ArtPrize, a Top 20 U.S. Foodie City, and, for 10 years running, recognized as Beer City USA! Geologically, Grand Rapids is centered in an elliptical, intracratonic structural basin overlying Precambrian crystalline basement and topped with glacially deposited unconsolidated material resulting in geologic formations that span more than 3.5 billion years. Added to the mix are an ancient failed mid-continental rift that includes important economic deposits and the unparalleled hydrologic system of the Great Lakes. This region is truly a water and rock wonderland. We are designing the 57th meeting of GSA's North-Central Section to be as diverse as the history of the region. The technical program, field trips, and short courses cover a range of topics, including coastal processes and landforms, critical minerals, magmatism and metamorphism, geomorphology and paleoclimate, geophysics, carbonate diagenesis, environmental geochemistry, undergraduate and graduate student–focused sessions, K–16 earth-science education, inclusivity and anti-racism in the geosciences, new technologies for mapping, karst of the Midwest, hydrologic processes and applications, geobiology, and advances in mineralogy and petrology. We invite you and your guests to join us for a *Meeting in the Mitten*, where we will gather in an engaging conference experience and take in the many offerings of this unique region.

## CALL FOR PAPERS

**Abstracts deadline:** 7 Feb. 2023
Submit online at **www.geosociety.org/nc-mtg**
**Abstract submission fee:** GSA members: professionals, US$30; students, US$18; non-members: professionals, US$60; students, US$36. If you cannot submit an abstract online, please contact Heather Clark, +1-303-357-1018, hclark@geosociety.org.

## TECHNICAL PROGRAM

For additional information, please contact the Technical Program chair, Kevin Mickus, kevinmickus@missouristate.edu.

T1. **Teaching Geoscience at 2YC: Working to Engage Students and Broaden Participation.** *Endorsed by GSA Geoscience Education Division.* Tari Noelani Mattox, Grand Rapids Community College, tmattox@grcc.edu; Andrea Bair, Delta College, andreabair@delta.edu.

T2. **Recent Advances in K–16 Geoscience Education.** *Endorsed by GSA Geoscience Education Division.* Steve Mattox, Grand Valley State University, mattoxs@gvsu.edu; Peter J. Voice, Western Michigan University, peter.voice@wmich.edu.

T3. **Building the High School to College Pipeline: Honoring the Career of Chris Bolhuis.** *Endorsed by GSA Geoscience Education Division.* Steve Mattox, Grand Valley State University, mattoxs@gvsu.edu; Jesse Reimink, Penn State University, jreimink@psu.edu.

T4. **From Online Expectations Back to In-Person Execution: Navigating New Teaching Norms in the "New Normal" Post-Pandemic World.** *Endorsed by GSA Geoscience Education Division.* Stephen M. Crabtree, University of Minnesota, Morris, crabt012@morris.umn.edu.

T5. **Teaching and Learning: Outdoors to Online.** *Endorsed by GSA Geoscience Education Division.* Kristen Foley, Western Michigan University, kristen.meade@wmich.edu; Heather Petcovic, Western Michigan University, heather.petcovic@wmich.edu.

T6. **In-Person Field Trips in A COVID-19 World: Best Practices, Best Places.** *Endorsed by GSA Geoscience Education Division.* Danita Brandt, Michigan State University, brandt@msu.edu; Michael Velbel, Michigan State University, velbel@msu.edu.

T7. **Unique Geology, New Insights, and Geoheritage of the Lake Superior Region.** Erika Vye, Great Lakes Research Center, Michigan Technical University, ecvye@mtu.edu; William I. Rose, Michigan Technological University, raman@mtu.edu; James DeGraff, Michigan Technological University, jmdegraf@mtu.edu.

T8. **Fostering a Diverse, Equal, Inclusive, and Anti-Racist Geoscience Community.** Ian Winkelstern, Grand Valley State University, winkelsi@gvsu.edu; Caitlin Callahan, Grand Valley State University, callahca@gvsu.edu; Amber Kumpf, Muskegon Community College, amber.kumpf@muskegoncc.edu; Stephen Mattox, Grand Valley State University, mattoxs@gvsu.edu; Tari Mattox, Grand Rapids Community College, tmattox@grcc.edu; Virginia Peterson, Grand Valley State University, petersvi@gvsu.edu.

T9. **Gender Identity and Geoscience: Recognizing the Challenges with Equity and Retention in Geoscience Employment.** Beth A. Johnson, University of Wisconsin, Oshkosh, Fox Cities Campus, johnsonba@uwosh.edu; Katherine Lewandowski, Eastern Illinois University, kjlewandowski@eiu.edu.

T10. **Impacts of Seasonality on Upper Midwest Geomorphology in a Changing Climate.** J. Elmo Rawling III, Wisconsin Geological and Natural History Survey, University of Wisconsin, Madison, elmo.rawling@wisc.edu; Lucas Zoet, University of Wisconsin, Madison, lzoet@wisc.edu; Ethan Theuerkauf, Michigan State University, theuerk5@msu.edu.

T11. **Recent Advances in Glacial Geology, Geomorphology, Sedimentology, and Chronology.** Randall Schaetzl, Michigan State University, soils@msu.edu; Timothy G. Fisher, University of Toledo, timothy.fisher@utoledo.edu; Patrick Colgan, Grand Valley State University, colganp@gvsu.edu.

T12. **The Grand River Past, Present, and Future.** Peter Wampler, Grand Valley State University, wamplerp@gvsu.edu; Kory Konsoer, Louisiana State University, kkonsoer@lsu.edu.

T13. **Processes and Landforms of Great Lakes Coasts.** Suzanne DeVries-Zimmerman, Hope College, zimmerman@hope.edu; Zoran Kilibarda, Indiana University Northwest, zkilibar@iun.edu.

T14. **Geobiology of the Great Lakes.** Cecilia Howard, University of Michigan, howardcm@umich.edu; Diana Velazquez, University of Michigan, dvelaz@umich.edu.

T15. **Recent Advances in Hydrogeology.** Peter Riemersma, Grand Valley State University, riemersp@gvsu.edu; Christopher A. Gellasch, Eastern Michigan University, chris.gellasch@emich.edu.

T16. **Geoscience and Hydrology of Your Federal and Other Public Lands: STEM Internships, Research, Science, Mapping, Resource Management, and Education.** Matt Dawson, Geological Society of America, mdawson@geosociety.org.

T17. **Karst of the Midwest—New Research and Future Challenges.** James Berglund, University of Wisconsin, Platteville, jameslberglund@gmail.com; Douglas Gouzie, Missouri State University, douglasgouzie@missouristate.edu.

T18. **Fate and Transport of PFAS in the Engineered and Natural Environment.** Donald M. Reeves, Western Michigan University, matt.reeves@wmu.edu; Daniel P. Cassidy, Western Michigan University, daniel.cassidy@wmu.edu; Richard R. Rediske, Annis Water Resources Institute, Grand Valley State University, redisker@gvsu.edu.

T19. **Aqueous and Environmental Geochemistry.** David T. Long, Michigan State University, long@msu.edu; W. Berry Lyons, The Ohio State University, lyons.142@osu.edu.

T20. **Climate Change Impacts on Carbon and Nutrient Cycling in Wetland Soils.** Ziming Yang, Oakland University, zimingyang@oakland.edu; Michael Philben, Hope College, philben@hope.edu.

T21. **Near Subsurface Microbiology: It's the Little Things That Count.** Edward Winner, RIP Group, ed@trapandtreat.com; Aaron Peacock, Microbac Laboratories, aaron.peacock@microbac.com.

T22. **If You Could Turn Back Time: An Open Session on Paleoclimatology of Any Sort.** Sierra V. Petersen, University of Michigan, sierravp@umich.edu; Allison N. Curley, ancurley@umich.edu.

T23. **Undergraduate and Graduate Geoscience Student Showcase.** Ken Brown, DePauw University, kennethbrown@depauw.edu; Claire McLeod, Miami University, mcleodcl@miamioh.edu; Robert Shuster, University of Nebraska, Omaha, rshuster@unomaha.edu.

T24. **Undergraduate Research Poster Session.** Robert Shuster, University of Nebraska, Omaha, rshuster@unomaha.edu; Ginny Peterson, Grand Valley State University, petersvi@gvsu.edu.

T25. **Future Directions in Mineralogy and Petrology: A Session for Undergraduate and Graduate Researchers.** Gary S. Michelfelder, Missouri State University, garymichelfelder@missouristate.edu; Sarah Brownlee, Wayne State University, sarah.brownlee@wayne.edu; Guilluame Girard, Northern Illinois University, ggirard@niu.edu; Elizabeth Kenderes, Indiana University, Bloomington, emkender@iu.edu; Claire McLeod, Miami University, mcleodcl@miamioh.edu.

T26. **The Stratigraphic Record of Syntectonic Sedimentation and Synsedimentary Deformation: Frameworks for Avoiding the Logical Fallacy of Begging the Question.** Kevin Ray Evans, Missouri State University, kevinevans@missouristate.edu.

T27. **Carbonate Formation and Diagenesis.** Ian Winkelstern, Grand Valley State University, winkelsi@gvsu.edu; Steven Kaczmarek, Western Michigan University, stephen.kaczmarek@wmich.edu; Ariel Martin, Western Michigan University, ariel.martin@wmich.edu.

T28. **Critical Minerals in North-Central United States: Exploration, Mining, and Processing**. Snehamoy Chatterjee, Michigan Technological University, schattel@mtu.edu; Tim Eisele, Michigan Technological University, tceisele@mtu.edu.

T29. **Reading the Record of Tectonic Processes through Diverse Investigations of Igneous and Metamorphic Rocks.** Robert Holder, University of Michigan, roholder@umich.edu; Hannah Blatchford, Eastern Michigan University, hblatchf@emich.edu.

T30. **Granites and Rhyolites as a Record of Crustal Magmatic Processes.** Gary S. Michelfelder, Missouri State University, garymichelfelder@missouristate.edu; Kenneth Brown, DePauw University, kennethbrown@depauw.edu.

T31. **The Origin of Compositional and Thermal Heterogeneity within Earth's Interior.** Allison Pease, Michigan State University, peaseall@msu.edu; Jiaxin Zhang, Michigan State University, zhang884@msu.edu; Meichen Liu, University of Michigan, meichenl@umich.edu; Yurong Zhang, Michigan State University, yurong@msu.edu.

T32. **Lithospheric and Crustal Studies of the Midcontinent Using Geophysics.** Kevin Mickus, Missouri State University, kevinmickus@missouristate.edu.

T33. **Advances in Geophysics for Shallow Subsurface Investigations.** Kennedy O. Doro, University of Toledo, Ohio, kennedy.doro@utoledo.edu; Kevin L. Mickus, Missouri State University, kevinmickus@missouristate.edu.

T34. **Innovative and Novel Applications of GIS and Remote Sensing for Geologic Mapping, Geomorphology, Volcanology, and Other Fields**. Stephen M. Crabtree, University of Minnesota, Morris, crabt012@morris.umn.edu.

T35. **Imaging the Subsurface.** Harry Jol, University of Wisconsin, Eau Claire, jolhm@uwec.edu.

## FIELD TRIPS

Trip registration opens in February 2023. For additional information, please contact the field trip co-chairs: Peter Wampler, wamplerp@gvsu.edu, Ed Hansen, hansen@hope.edu.

**Michigan Geological Repository for Research and Education (MGRRE) Tour—Michigan Subsurface Geology Using Borehole Core Samples.** Peter Voice, Western Michigan University, peter.voice@wmich.edu; William B. Harrison III, Western Michigan University, william.harrison_iii@wmich.edu; Jennifer Trout, Western Michigan University, jennifer.l.trout@wmich.edu; Robb Gillespie, Western Michigan University, robb.gillespie@wmich.edu.

**Tour of PFAS Disposal and Treatment Sites in Northern Kent County.** Richard Rediske, Grand Valley State University, redisker@gvsu.edu; Karen Vorce, Michigan Department of the Environment, Great Lakes, and Energy, vorcek@michigan.gov.

**Field Trip to the Bruce Dice Mineralogical Museum.** Deanna van Dijk, Calvin University, dvandijk@calvin.edu.

**Riverwalk Tour—Restoring the Rapids in Grand Rapids.** Wendy Ogilvie, Grand Valley Metro Council/Lower Grand River Organization of Watersheds, wendy.ogilvie@gvmc.org; Matt Chapman, Grand Rapids Whitewater, matt@grandrapidswhitewater.org; Michael Staal, City of Grand Rapids, mstaal@grand-rapids.mi.us.

**Mississippian Gypsum Mine Geology and Paleontology Field Trip.** John VanRegenmorter Grand Rapids Community College, johnvanregenmorter1@grcc.edu; Peter Wampler, Grand Valley State University, wamplerp@gvsu.edu.

**Collections Tour of the Grand Rapids Public Museum.** Cory Redman, Grand Rapids Public Museum, credman@grpm.org.

**Coastal Dunes of Southern Lake Michigan.** Suzanne DeVries-Zimmerman, Hope College, zimmerman@hope.edu; Erin Argyilan, Indiana University Northwest, eargyila@iun.edu; Todd Thompson, Indiana Geological and Water Survey, Indiana University, tthomps@indiana.edu.

**Geology, Age, and Shock Metamorphism of The Kentland, Indiana, Impact Structure.** John Weber, Grand Valley State University, weberj@gvsu.edu.

**Mid-Michigan's Outdoor Classroom: Pennsylvanian Marginal-Marine Strata at Grand Ledge, Michigan.** Danita Brandt, Michigan State University, brandt@msu.edu; Melinda Higley, Calvin University, mchigley@calvin.edu; Madeline Marshall, Albion College, mmarshall@albion.edu; Heather L. Petcovic, Western Michigan University, heather.petcovic@wmich.edu; Michael Velbel, Michigan State University, velbel@msu.edu; Peter J. Voice, Western Michigan University, peter.voice@wmich.edu; Ian Winkelstern, Grand Valley State University, winkelsi@gvsu.edu.

## SHORT COURSES

For additional information, please contact the short course leaders listed below.

**Practical High-Energy Injection in Overburden and Bedrock: Preparation, Tools, Design, Distribution, and Evaluation Illustrated by Case Studies**. Edward Winner, RPI Group, ed@trapandtreat.com.

**Stratigraphic Imaging of Geomorphic, Geologic, and Geoarchaeological Landscapes.** Harry Jol, University of Wisconsin, Eau Claire, jolhm@uwec.edu.

**Near Subsurface Microbiology: It's the Little Things That Count.** Edward Winner, RIP Group, ed@trapandtreat.com; Aaron Peacock, Microbac Laboratories, aaron.peacock@microbac.com.

## REGISTRATION

**Early registration deadline:** 27 March 2023
**Cancellation deadline:** 3 April 2023

Registration opens in February 2023. For further information or if you need special accommodations, please contact one of the general co-chairs, Tara Kneeshaw, kneeshta@gvsu.edu, or Ginny Peterson, petersvi@gvsu.edu.

## ACCOMODATIONS

**Hotel registration deadline:** 18 April 2023, 5 p.m. EST

A block of rooms has been reserved at two hotels in heart of downtown Grand Rapids within walking distance to the meeting venue.

**Courtyard by Marriott, Downtown Grand Rapids:** 11 Monroe Ave. NW, Grand Rapids, Michigan 49503. The meeting rate is US$149.00 per night plus tax for single/double/triple/quad occupancy. Reservations can be made by calling +1-616-242-6000. Reservations can also be made at https://book.passkey.com/e/50384970. Please be sure to identify yourself with the group code "GSA–North Central Section" and that you are attending the GSA North-Central Section Meeting.

**Holiday Inn Grand Rapids Downtown:** 310 Pearl Street NW, Grand Rapids, Michigan 49504. The meeting rate is US$125.00/night for one to two queen beds, single-quad occupancy; US$165.00/night for a king executive room (hospitality room) plus tax. Reservations can be made by calling +1-616-235-7611. Please be sure to identify yourself as attending the North-Central Section Geological Society of America meeting.

## OPPORTUNITIES FOR STUDENTS AND EARLY-CAREER PROFESSIONALS

**Career Mentoring Luncheons**

Ask your career-related questions and learn about non-academic pathways in the geosciences while networking with professionals at the Roy J. Shlemon and John Mann Mentor Luncheons. GSA student members are welcome.

**Career Workshop Series**

This three-part series will feature career development planning, an exploration of geoscience job sectors, and information on best practices for crafting a résumé and cover letter. Non-technical skills and workforce statistics will be reviewed. The series will be led by workshop presenters and geoscientists. No registration is required, and everyone is welcome.

To learn more about mentors and career workshops, go to www.geosociety.org/mentors or contact Jennifer Nocerino at jnocerino@geosociety.org.

## PROFESSIONALS

Interested in sharing information about your applied geoscience or hydrology career with students, or interested in earning continuing education credits (CEUs) or state continuing education clock hours (SCECHs) by attending the meeting? Being a mentor is a rewarding experience. To learn more about serving as a mentor at the North-Central Section Meeting, contact Jennifer Nocerino at jnocerino@geosociety.org.

The North-Central Section Meeting also offers an excellent opportunity to earn CEUs and SCECHs toward your continuing education requirements for your employer, K–12 school, or professional registration. Please check the meeting website after the meeting to download your certificate.

**DASH Around Downtown Grand Rapids**

Grand Rapids is equipped with a downtown area shuttle called DASH. It is a system of small buses that link downtown neighborhoods and destinations. This service is free and provides convenient connections to all parts of the urban core. For details and routes, go to https://downtowngr.org/get/dash.

## LOCAL COMMITTEE

**Meeting Co-Chairs:** Tara Kneeshaw, kneeshta@gvsu.edu; Ginny Peterson, petersvi@gvsu.edu
**Technical Program Chair:** Kevin Mickus, kevinmickus@missouristate.edu
**Field Trip Co-Chairs:** Peter Wampler, wamplerp@gvsu.edu; Ed Hansen, hansen@hope.edu
**Exhibits Chair:** Steve Mattox, mattoxs@gvsu.edu
**Budget/Finance Chair:** Ginny Peterson, petersvi@gvsu.edu
**Sponsorship Co-Chairs:** Peter Riemersma, riemersp@gvsu.edu; Ian Winkelstern, winkelsi@gvsu.edu
**Education Programs (K–12) Co-Chairs:** Caitlin Callahan, callahca@gvsu.edu; Steve Mattox, mattoxs@gvsu.edu

# Explorer of Mountains, Minerals, and Global Ecosystems: Alexander von Humboldt

***Michael T. May,*** *Western Kentucky University, Dept. of Earth, Environmental & Atmospheric Sciences, michael.may@wku.edu*

**Alexander von Humboldt circa 1806. Photo of a painting by Friedrich Georg Weitsch at the Old National Gallery in Berlin, Germany. Public domain.**

In a time of rapid climate change, earth scientists can learn from Alexander von Humboldt (1769–1859) as an immense contributor to geology and its complex of interacting spheres. His geological studies spanned decades and included minerals in mines, fossils and trace fossils, and erupting lava. Humboldt produced globally applicable maps by joining geological, botanical, and meteorological data that are invaluable to earth science and ecology. He is highly regarded because of his scientific expositions that resulted in publications, especially his magnum opus *Kosmos* (Cosmos, 1845), which incorporated myriad fields of study in his holistic view of nature.

Humboldt developed into a discoverer via his extensive excursions across Europe, into Asia, and to the Americas. For the latter, from 1799 to 1804, he documented a myriad of ecological zones via elevation and latitude changes, particularly focusing on plants. He also considered mineral associations, geomagnetism and gravity, mountain-building processes, volcanism, erosion of highlands, colonization of landscapes by plants, and defined global isotherms. Humboldt's notes and manuscripts, and particularly his *Cosmos*, serve as an invaluable baseline study for geologically instantaneous change brought on by humans.

Friedrich Wilhelm Heinrich Alexander, Freiherr (baron) von Humboldt, son of Alexander Georg von Humboldt and Maria Elizabeth Colomb, was born on 14 September 1769. From an early age he was influenced by his father and was collecting and cataloging treasures from the natural world. His father was an army officer who was part of a rich family with Pomeranian roots. Humboldt was baptized into the Lutheran faith, and his godfather, the Duke of Brunswick, was later to become King of Prussia.

Humboldt and his older brother Wilhelm became fatherless when they were 9 and 11 years old, respectively. It was their father who had the deepest emotional tie to his sons, and in contrast, their mother was somewhat aloof. She did provide them with good educations. Their tutors were "Enlightenment" thinkers, which aided development of intellectual prowess in the Humboldt brothers, but their pathways were somewhat different. Wilhelm (1767–1835) was to become widely known as the linguistically talented Prussian minister and philosopher, whereas Alexander gravitated to the world of natural science in "outdoor laboratories." Humboldt, in comparison to his bibliophile brother, was restless and later conveyed to Carl Freisleben that tutors doubted "whether even ordinary powers of intelligence would ever be developed in him" (Bruhns, 1873, v. 1, p. 31; Biermann, 1987, p. 50).

The aristocratic Humboldt family spent winters in Berlin and summers in their country estate, Schloss Tegel, located about ten miles (16 km) northwest of central Berlin. The countryside was a proving ground for Humboldt as he filled his pockets with insects, shells, and plants. His family did not think anything would come of this budding naturalist, dubbing him "the little apothecary." When Frederick the Great, the Prussian king, inquired of young Alexander if he was planning on a global conquest similar to his namesake, Alexander the Great, the youngster quipped "Yes, but with my head" (Walls, 2009, p. 15).

Humboldt's early years focused on nature, but his mother urged him to attend a university to become a civil servant. In 1787, he enrolled at the University of Frankfurt, studying finance courses in preparation for a political career. After six months, Humboldt moved on to Göttingen University where he studied natural science. While at Göttingen University, Humboldt was influenced by Georg Forster who sojourned with Captain Cook on his second voyage of discovery. Humboldt and Foster traveled throughout Europe, and in 1789 he had an opportunity to gaze upon the first-ever discovered fossil pterosaur skeleton. By 1790, Humboldt published *Mineralogical Observations of Some Basalts in the Rhine Basin*. His studies at Göttingen sparked further interests in mineralogy, so in 1791, Humboldt enrolled at the prestigious Freiberg School of Mines in Saxony. His mentor at Freiberg was Abraham Gottlob Werner (1749–1817). Under Werner's tutelage, Humboldt focused on minerals and mining. He worked underground in the mines by morning, took classes in the afternoon, and by evening he searched for plants to add to his collection.

The talented Humboldt prepared to become a scientific explorer by studying foreign languages and commerce at Hamburg, geology at Freiberg under Werner, anatomy at Jena under J.C. Loder, and astronomy and scientific instrumentation with F.X. von Zach and J.G. Köhler. He encountered several men at Freiberg who were important to his later career, including Andrès Manuel del Rio, who became director of the School of Mines established in Mexico and the discoverer of what would be called vanadium. Other Freiberg colleagues included Christian Leopold von Buch, a geologist who

defined the Jurassic and the *Kueper* or Upper Triassic, and Karl Freiesleben, who became Humboldt's tutor and close friend.

In 1792, Humboldt began working in Berlin as an assessor of mines. Here he continued his strong work ethic, being promoted and engaging in a number of diplomatic assignments. While he lived in Vienna from 1792–1797, he explored Italy and Switzerland. His descriptions of flora in the mines were published in *Florae Fribergensis Specimen* in 1793.

At age 27 Humboldt used his inheritance to begin his scientific expeditions. He first traveled with botanist Aime Bonpland (1773–1858) to Madrid to request special permission to explore South America. The king of Spain granted a permit and in the summer of 1799 he and Bonpland commenced their travels for five years in Central and South America, covering more than 6000 miles (9656 km) by foot, horseback, and by canoe. They climbed many mountain peaks, particularly near Quito, Ecuador, including most of the way up Chimborazo (20,702 feet or 6310 m)—standing for almost 30 years as the highest human ascent record. Humboldt's diary of Spanish America adventures, at over 4,000 pages, were seminal for his many published works, and he provided drawings such as of columnar basalts, mountains, and plants.

Some perhaps less known albeit important geology-related work of Humboldt beyond mines and minerals included his study of trace fossils such as the "hand-beast" footprint in Germany in 1833 (Knoll, 2009), vertebrate paleontology as is evidenced by his overseeing excavations near Bogota, Colombia (Bressen, 2014), and his assessment of manganese-dominated mineral coatings on rocks along cataracts of the Orinoco River that has been proven overall correct based on modern analytical results (Dorn et al., 2012). He also recognized the stratigraphic changes associated with rocks and coined the term "formation." Furthermore, he surmised that there must have been extinction events associated with life on Earth, which was not well accepted at the time.

Upon completion of the Spanish America expedition in 1804, Humboldt visited the United States and President Thomas Jefferson. Humboldt then went to Paris, residing there for 23 years, until 1827, publishing about 30 volumes chronicling the expeditions of the Americas. In order to make a living, he secured an advising role for the King of Prussia. His last big excursion was in 1829 to Russia, where he was the first to find diamonds outside of the tropics and where he started investigating geomagnetism. He later documented mineral associations such as gold, platinum, and diamonds. After returning to Germany, he became famous for his speeches and began work on *Cosmos*, publishing the first volume in 1845.

The zest that Humboldt had for exploring the world's awesome wonders was inspirational for his contemporaries (e.g., Simon Bolivar, Charles Darwin) and his students (e.g., Louis Agassiz and father of organic chemistry Justus von Liebig) but also for earth scientists since his death. Due to his comprehensive approach to documenting natural systems, Humboldt was probably one of the most influential to document Earth's interacting spheres—bio, litho, hydro, and atmos—as this is paramount for us not only to praise Earth but to preserve it. His spirit lives on to inspire us all to understand and value these interconnections inherent in modern geological sciences.


**Humboldt sketched this site in Mexico and published it in 1813. Public domain.**

## FURTHER READING


Becker, T.W., and Faccenna, C., 2019, The scientist who connected it all: Eos, v. 100, https://doi.org/10.1029/2019EO132583.

Biermann, K.R., editor, 1987, Alexander von Humboldt. Aus Meinem Leben Autobiographische Bekenntnisse: Munich, C.H. Beck, 228 p.

Bressen, D., 2014, Alexander von Humboldt and the hand-beast: Scientific American, 14 Sept. 2014, https://blogs.scientificamerican.com/history-of-geology/alexander-von-humboldt-and-the-hand-beast/ (accessed 9 May 2022).

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Dorn, R.I., Krinsley, D.H., and Ditto, J., 2012, Revisiting Alexander von Humboldt's Initiation of Rock Coating Research: The Journal of Geology, v. 120, no. 1, p. 1–14, http://www.jstor.org/stable/10.1086/662737 (accessed 9 May 2022).

Helferich, G., 2004, Humboldt's Cosmos, Alexander Humboldt and the Latin American Journey that Changed the way we see the world: Tantor eBooks, a division of Tantor Media Inc. (original and e-copyright 2011).

Knoll, F., 2009, Alexander von Humboldt and the hand-beast: A contribution to paleontology from the last universal scholar: Comptes Rendus Palevol, v. 8, p. 427–436, https://doi.org/10.1016/j.crpv.2008.12.001.

Walls, L.D., 2009, The passage to Cosmos, Alexander von Humboldt and the Shaping of America: Chicago and London, University of Chicago Press, 424 p.

Wulf, A., 2015, The Invention of Nature—Alexander Von Humboldt's New World: New York, Vintage Press, 496 p.

# Completion of the ST2B-2 (Subduction Top to Bottom 2) Themed Issue in *Geosphere*

***Gray E. Bebout,*** *Dept. of Earth and Environmental Sciences, Lehigh University, Bethlehem, Pennsylvania 18015, USA;* ***David W. Scholl,*** *Emeritus, U.S. Geological Survey, Menlo Park, California 94025, USA, and University of Alaska Fairbanks, Fairbanks, Alaska 99775, USA;* ***Robert J. Stern,*** *Dept. of Geosciences, University of Texas at Dallas, Richardson, Texas 75083, USA;* ***Laura M. Wallace,*** *University of Texas Institute for Geophysics, Austin, Texas 78758, USA, and GNS Science, Lower Hutt, New Zealand; and* ***Philippe Agard,*** *Sorbonne Université, CNRS-INSU, Institut des Sciences de la Terre Paris, ISTeP UMR 7193, 75005 Paris, France*


Over the past 25 years, tremendous advances have been made in our understanding of convergent plate margins. These advances have increasingly been made by highly multidisciplinary groups involving the fields of geophysics, petrology, geochemistry, and geodynamics, to a large extent made possible by NSF-funded initiatives like MARGINS, GeoPRISMS, and SZ4D. Understanding of the dynamics of subduction is particularly important for assessing earthquake, tsunami, and volcanic hazards. The scientific community, governments and the broader public increasingly recognize the need to assess hazards that subduction margins pose, especially to regions of high population densities around the Pacific and Indian Oceans (e.g., Japan, Indonesia, the Cascadia margin). As we've examined individual margins in greater detail and contrasted them with other margins, patterns have emerged that reveal some of the controls on convergent margin behavior and evolution. These include convergence rate and obliquity; age of incoming plate and the subduction zone itself; physical, thermal, and chemical state of the subducting oceanic lithosphere; presence of seamounts and other heterogeneities on the downgoing plate; the nature and thickness of subducting sediments; accretion versus erosion; and the composition and structure of the upper plate.

The "Subduction Top to Bottom" endeavor has fostered and highlighted multidisciplinary research on modern and ancient subduction margins, in part through sponsoring of sessions at recent conferences (AGU, GSA) but also through large publication projects. The first publication was inspired by the 1994 SUBCON held in Avalon, Santa Catalina Island, California, USA. The SUBCON meeting resulted in the publication of AGU Geophysical Monograph v. 96 (GM96), in which 35 papers provided a top-to-bottom survey of the state of knowledge of subduction dynamics, as of 1996. Much in the way of multidisciplinary research on subduction has since happened and, over the last five or so years, we sponsored an update, Subduction Top to Bottom 2 (ST2B-2).

Many will have noticed the ST2B-2 sessions run at AGU and GSA meetings over these years—together, these sessions have attracted 526 abstracts, and one session had 136 presentations! Particularly in the larger sessions (in both oral and poster venues), one could figuratively traverse a subduction zone system, from top to bottom, beginning on the seafloor, continuing through the forearc and subarc, and, in some cases, through to the base of the mantle where ancient subducted lithospheric slabs reside. Presentations were arranged by depth and process, not by approach or methods, and presenters often found themselves presenting adjacent to someone with a quite different but stimulating perspective. In recent years, ST2B has shifted focus to highlight particular depth-horizons or products of subduction margins, with a 2021 session "Focus on the Forearc" and a 2022 session "Origin and Evolution of Magmatic Arcs."

This brief note is to call attention to the now-completed Subduction Top to Bottom 2 (ST2B-2) Themed Issue in the all-online GSA journal *Geosphere*. This issue contains 74 papers, more than twice as many papers as GM96, and is published only electronically, thus with fewer constraints on length and format and the inclusion of color graphics and supplementary materials. Unlike the GM96 book project, these 74 papers appeared when-ready, without the need to await the full assembly of the volume, and some of the papers have been among the most-cited in *Geosphere* for several years running. The issue contains assessment of subduction from all perspectives, in many cases in multidisciplinary combinations of geological, geophysical, geochemical, and theoretical approaches.

Naturally, we begin on the seafloor, evaluating sedimentary and lithospheric inputs, outer-rise plate bending and related hydration, and incipient diagenesis and fluid release and flow. Papers on forearc regions provide syntheses of knowledge of what leads to rupture, including consideration of the roles of fluids and the processes leading to some particularly damaging earthquakes. For greater depths, an array of papers considers processes leading to the generation of magmatic arcs, including merging knowledge of arcs with that of metamorphic processes in deeply subducting oceanic slabs and sediments. Related to this, another set of papers considers the make-up of the subduction interface, in part as viewed from high- and ultrahigh-pressure metamorphic exposures.

We encourage you to check out the ST2B-2 Themed Issue in *Geosphere* and take a virtual spin through Earth's unique subduction zones, top-to-bottom!

**https://pubs.geoscienceworld.org/geosphere/pages/st2b2**

# GSA Reflection—My Professional Home

The Geological Society of America annual conferences have the warm atmosphere of a family reunion, paired with the cutting-edge science that forms the crux of my professional development each year. Nowhere else can an assortment of geological specialists, geoscience educators, science writers, and historians—some famously at the top of their fields, and more than a few international—build successful interdisciplinary collaborations within the span of a GSA topical session! Some of my most successful research endeavors and friendships originated and connect at the GSA annual conference crossroads.

Through the years, I have been honored to serve in various roles within the History and Philosophy of Geology Division, the GSA Education Committee, as a campus representative, as a reviewer and editor for GSA journals and books, and as a co-organizer and convener of topical sessions and Pardee Symposia on Geoheritage and the history of our science—from GSA's 125th anniversary to William Smith's mapping milestone bicentennial. Incidentally, it was at the 2015 William Smith bicentennial when I stumbled on the field excursion and broke five bones in my foot. My GSA family came to the rescue. YES, I finished the field trip (while in denial), and YES, my conference experience was made easy through the efforts of GSA staff and colleagues who came through with immediate and creative accommodations.

**Renee Clary, in the Dunn-Seiler Museum, Mississippi State University (photo by Athena Owen Nagel).**

I encourage all students and colleagues to join the GSA family. It is here you will find your place, scientifically and professionally. Welcome home!

**Renee M. Clary**
Professor of Geology and Director, Dunn-Seiler Museum
Department of Geosciences, Mississippi State University

# 2022–2023 GSA-USGS Congressional Science Fellow Announced

Hannah Palmer

GSA and the U.S. Geological Survey are pleased to announce that Dr. Hannah Palmer will serve as the 2022–2023 GSA-USGS Congressional Science Fellow. She will spend a year working in the office of Senator Tammy Baldwin (D-WI).

Palmer is a climate and environmental scientist dedicated to conducting science in service of the public and leveraging science to inform decision making. Her scientific research focuses on investigating the biogeochemistry of a changing world, impacts of environmental change on ecosystems, and human dimensions of global change.

Palmer earned her B.S. from the University of California, Los Angeles, in marine biology and her Ph.D. in earth and planetary sciences from the University of California, Davis. In her doctoral research, she utilized the paleorecord to understand biogeochemical and ecosystem change across systems and time scales. Specifically, she focused on investigating marine sediment records to understand oceanographic change and ecosystem responses to change through the past 12,000 years.

As a graduate student, she served as the University of California Center Sacramento Presidential Graduate Opportunities for Leadership Development Fellow, working with the California Council on Science and Technology to communicate up-to-date science on wildfire to state policymakers. Palmer also served as the co-director of the Santa Rosa Junior College–Bodega Marine Laboratory Internship Program in 2019–2020 during which she led a program to provide local community college students with opportunities for research experience and professional development.

Following her Ph.D., Palmer was awarded the University of California Chancellor's Postdoctoral Fellowship at the University of California, Merced. In this role, she investigated how wildfire severity impacts the biogeochemistry of landscapes following wildfire to both understand effects of modern fire as well as to improve how we understand wildfire in the past. Palmer recently served as an American Geophysical Union Thriving Earth Exchange Community Science Fellow in which she worked to connect scientists and community leaders to solve local challenges.

Palmer enjoys taking on new challenges as she has continually worked to build new collaborations, investigate diverse study systems, interact across organizations, and to link science and policy. When she is not working, she enjoys trail running, baking and eating delicious goods, jumping in the ocean, and spending time with friends, old and new. She is eager to learn from her experience as a Geological Society of America Congressional Science Fellow and to continue to work to bridge the gap between science and policy.

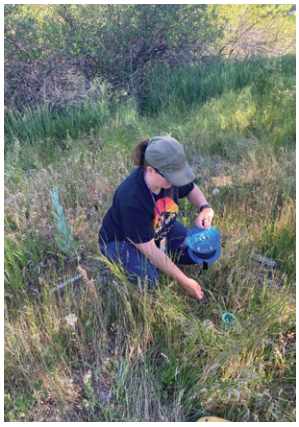
# Overcoming Challenges for a Life-Changing Experience

Unforgettable, pivotal, life-changing, crucial, invaluable, transformative—these are just a few of the words the 2022 J. David Lowell Field Camp Scholarship recipients used to describe their field-camp experiences.

Field camp can also be very challenging, said Benjamin Thomas: "Field camp was one of the most difficult experiences of my academic career, but also very rewarding. By the end of the final project the land did reveal its secrets and I was finally able to make sense of what I saw. While mapping was difficult and even frustrating at times, it was also one of the most enjoyable things I've done. I'm incredibly thankful to the GSA for the J. David Lowell Scholarship for making this experience possible."

Kitsel Lusted, whose field camp took her to the Juneau Icefield Research Program (JIRP), had to learn a completely new skillset. "I came into JIRP with no mountaineering experience, but by the end of the program, I felt comfortable telemark skiing in a white-out with a 40-pound pack on my back! Without the money I received from the J. David Lowell Field Camp Scholarship, I would not have been able to have this experience."

Elysia Viengkham felt the toll of the last two years of learning under COVID restrictions: "Heavy reliance on remote learning during the pandemic limited my hands-on exposure to minerals, rocks, and geology tools. Because of this lack of exposure, I was unsure of my ability to meet professional expectations as I ventured out into the geoscience community. Fortunately, with the support of GSA through the J. David Lowell Field Camp Scholarship, I was able to afford this crucial educational capstone."



Some faced extra challenges outside of the course itself, like Kristi Rasmussen. "Field camp requires a huge commitment for students to leave work, family, and home for long periods of time. As a non-traditional student, and a mother, the commitment was compounded. Receiving this scholarship is a great honor and gives financial peace of mind knowing that the cost of this course was covered."

Every one of this year's students persevered through their various hurdles and are better prepared to enter the geoscience community. Without the help of the J. David Lowell Field Camp Scholarship, these challenges would have been even greater and possibly insurmountable. Easton Hitchens said, "I am truly grateful for my selection for this award as it opened a door of opportunity that was previously shut. I hope this award continues to provide the same opportunity to other students as it did for me."

Thanks to your support, this year we were able to provide funding for a record 30 J. David Lowell Field Camp Scholarships, 10 more than when the program was solely funded by a corporate sponsor. With your help, lack of funding doesn't have to be an insurmountable challenge for students to participate in the life-changing experience of field camp.

Please consider making a gift today to the J. David Lowell Field Camp Scholarship at https://gsa-foundation.org/fund/field-camp-opportunities/. If you have any questions or would like to discuss ways to make an even greater impact, please contact Debbie Marcinkowski at dmarcinkowski@geosociety.org or +1-303-357-1047.

# Top Reasons to Join Scientific Divisions

## when you renew your 2023 GSA Membership

### Scientific Divisions...

- Provide an easy forum for members to network and collaborate with others in their discipline.
- Serve as the backbone of the GSA Annual Meeting (GSA Connects) technical program.
- Provide valuable information including news and opportunities through newsletters, websites, and emails.
- Recognize outstanding achievements within scientific disciplines.
- Provide opportunities for leadership, mentoring, and service.
- Offer research and travel grants.
- Help guide the Society.

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History and Philosophy of Geology
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Marine and Coastal Geoscience
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Student Members—US$2 each ... and join one for Free

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* Senior members may opt for dues waiver(s) or choose to financially support their Division(s).

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Bookmark the Geoscience Job Board at **www.geosociety.org/jobs** for up-to-the-minute job postings. Job Board ads may also appear in a corresponding monthly print issue of *GSA Today*. Send inquiries to advertising@geosociety.org, or call +1-800-427-1988 ext. 1053 or +1-303-357-1053.

## OPEN POSITIONS

### Brian J. Skinner Postdoctoral Fellowship, Yale University

The Department of Earth & Planetary Sciences (http://earth.yale.edu) announces a competition for the Brian J. Skinner Postdoctoral Fellowship. We welcome applicants with research interests across the full range of disciplines within Earth and planetary sciences, including studies of geophysics, planetary sciences, tectonics, oceans, atmosphere, climate dynamics, geochemistry, paleoclimatology, paleontology, geobiology, and the evolution of life. The Postdoctoral Associate position is awarded for one year, subject to renewal for a maximum of two years, providing a stipend ($63,000/yr) and research funds ($7,000/yr), plus health care benefits and some funds for relocation expenses. Applicants should contact a sponsor in the Department to discuss potential research projects, and then submit a short (2-3 page) statement of research interests and proposed research (including potential broader impacts), a curriculum vitae with a full list of publications, an endorsement letter (max 1 page) from the sponsoring faculty member, and names of three individuals who can provide confidential letters of reference. Broader impacts may include, for example, public education and outreach activities, impacts on diversity, equity, and inclusion, and other positive societal benefits. Applications should be submitted online at http://apply.interfolio.com/113647. The deadline for receipt of all application materials is December 15, 2022, and successful candidates are expected to begin their program at Yale between July 1 and December 31, 2023. Applicants should have a recent (within three years at the time of application) Ph.D. or should be a 2023-degree candidate, and they need to have documentation of degree completion by the time they start. Yale University is an Affirmative Action/Equal Opportunity employer. Yale values diversity among its students, staff, and faculty and strongly welcomes applications from women, persons with disabilities, protected veterans, and underrepresented minorities.

### Pan Postdoctoral Research Fellowship, Rice University

The Department of Earth, Environmental and Planetary Sciences is inviting applications for the Pan Postdoctoral Research Fellowship. We are seeking candidates with independent research interests that intersect with one or more faculty within our department and who contribute positively to the diversity of the department through outreach or other means. Both domestic and international applicants are welcome. A Ph.D. is required at the time of appointment, but candidates must have received their Ph.D. no more than three years before their start date at Rice. Fellowships will be supported for two years pending satisfactory progress with an annual stipend of $60,000, a benefits package, and an additional annual research allowance of $3,500. Applicants are requested to develop a proposal of research to be undertaken during their fellowship that should encompass independent ideas and explore new directions beyond the applicant's Ph.D.

Additional position details and requirements can be found at https://eeps.rice.edu/eeps-job-opportunities

Application deadline: November 14, 2022.

Submit single PDF application to eeps-postdoc@rice.edu along with 2 letters of reference by the same deadline.

Rice University is an Equal Opportunity Employer with commitment to diversity at all levels and considers for employment qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national or ethnic origin, genetic information, disability or protected veteran status. We encourage applicants from diverse backgrounds to apply.

### Three Tenure-Track Faculty Positions, Physical Hydrology, Geochemistry/Petrology, and Climate/Environmental Change, University of Florida

The Department of Geological Sciences (https://geology.ufl.edu/) invites applications for three tenure-track Assistant Professor positions in the areas of Climate/Environmental Change, High-Temperature Geochemistry/Petrology, and Physical Hydrology, which will begin August 16, 2023. The broadly defined positions represent distinct and independent areas of research and teaching. The successful candidate will have initiated a strong research program, demonstrate a compelling plan for future research, be expected to contribute to the department curriculum, and demonstrate the desire to mentor undergraduate, MS, and Ph.D. students. Many opportunities for collaborations and outstanding analytical and computational facilities exist within the department and across the university, a top-five public institution. Information about the positions, who to contact with questions, and how to apply can be found at https://geology.ufl.edu/tenure-track-faculty-searches/. The Department of Geological Sciences particularly welcomes applicants who can contribute to a diverse and inclusive environment through their scholarship, teaching, mentoring, and professional service. The University of Florida is an Equal Opportunity Institution.

### Assistant Professor of Geosciences, Mineralogy/Petrology, Tarleton State University

The Department of Chemistry, Geosciences, and Physics is seeking applications for a tenure-track Assistant Professor in Geosciences in the field of Mineralogy/Petrology to start Fall 2023.

The successful candidate will support the geosciences program through engaging, student-centered teaching, develop an active research program that involves undergraduates, and actively contribute to service and outreach initiatives that advance the department, college, and university. Candidates will be expected to instruct the following courses: Mineralogy, Igneous and Metamorphic Petrology, core geo- and earth sciences, and other courses as deemed fitting. Primarily responsible for the teaching/learning process and will also participate in the necessary operations of the institution. Work hours: Mon.–Fri., 8 a.m.–5 p.m. or as work and teaching requirements indicate. Requires the ability to teach and/or work remotely, at the University's discretion.

Applicants must have an earned doctorate/terminal degree approved by the University and recognized by the Southern Association of Colleges and Schools Commission on Colleges with appropriate academic credentials verified by Tarleton's faculty credentialing processes.

All submissions must be made electronically through Tarleton's employment site, https://jobs.tarleton.edu. Must attach CV, cover letter, and unofficial transcripts.

Review of applications will begin immediately and continue until the position is filled.

Tarleton State University (Stephenville, Texas), a member of The Texas A&M University System, provides a student focused, value-driven educational experience marked by academic innovation and exemplary service, and dedicated to transforming students into tomorrow's professional leaders. With campuses in Stephenville, Fort Worth, Waco, Midlothian and online, Tarleton engages with its communities to provide real-world learning experiences and to address societal needs while maintaining its core values of integrity, leadership, tradition, civility, excellence, and service.

Tarleton State University is an Equal Opportunity/Affirmative Action/Veterans/Disability Employer. As a member of The Texas A&M System, Tarleton will provide equal opportunity for employment to all persons regardless of race, color, sex, religion, national origin, age, disability, genetic information, veteran status, sexual orientation or gender identity and will strive to achieve full and equal employment opportunity through The Texas A&M System.

### Tenure Track Assistant Professor in Landscape Evolution and Land Use/Cover, University of Dayton

Are you looking for a university that will support your commitment to preparing the next generation of Environmental Geoscientists;

where you will work with highly motivated students in and out of the classroom; you can contribute to a thriving academic program; where you will be a member of a mission-driven institution and you can live affordably in a central location with easy access to both recreation and urban amenities? The University of Dayton, Department of Geology and Environmental Geosciences is seeking a dynamic faculty member with a specialization in landscape evolution and land use/cover at the rank of tenure track assistant professor to begin August 16, 2023.

The successful candidate will work with a diverse faculty in the department engaging in a wide range of high-impact environmental geoscience teaching and research. They will also have opportunities to contribute to the University of Dayton's emphasis on sustainability education and research initiatives as well as engaging with the University of Dayton River's Institute which provides leadership training and engages with a suite of local partners around issues pertaining to regional freshwater resources. The University has been consistently ranked by the Sierra Club in the top 10% of all evaluated schools in terms of its environmentally conscious curriculum, practice, and activism.

Expectations of the position include developing a nationally competitive, extramurally funded research program that involves undergraduate students, contributing to transformative teaching and mentoring at the undergraduate level, and intersecting creatively to strengthen and/or complement the department of Geology and Environmental Geosciences. Main teaching expectations include introductory courses in geosciences and upper-level courses in environmental geosciences. Mentoring undergraduate research is also expected.

The University's 382-acre campus is located at the southern edge of Dayton, Ohio, which has a metropolitan area population of approximately one million. With a burgeoning downtown area, 20 expansive metroparks, hundreds of miles of paved walking/biking trails (top in the nation!), a bike- (and now scooter!) share program, several historic neighborhoods, and of course, the Dayton Aviation Heritage and National Historical Park, this is a great place for those who want a bit of everything with a low cost of living, great schools, and manageable traffic. Go to daytoncvb.com for more information about the area.

At the University of Dayton, we value inclusive excellence because we recognize that diversity, equity and inclusion are fundamental to academic and institutional excellence. Inclusive excellence requires a comprehensive, cohesive and collaborative alignment of infrastructure, resources and actions. We strive to be active, intentional, and sustain engagement with and celebration of diversity in every dimension of institutional life. Because we seek a workforce with a wide range of perspectives

Duke
UNIVERSITY

## Assistant Professor, Geochemistry of Earth-Water-Air Systems

*Division of Earth and Climate Sciences, Nicholas School of the Environment, Duke University*

**Job # 22646**
Assistant Professor, Geochemistry of Earth-Water-Air Systems
Division of Earth and Climate Sciences, Nicholas School of the Environment, Duke University
**Job Location:** Nicholas School of the Environment, Duke University, Durham NC

**Apply Now: https://apptrkr.com/3426684**
Anticipated start: July 1, 2023

The Division of Earth and Climate Sciences in the Nicholas School of the Environment at Duke University invites applications for a tenure-track position at the Assistant Professor level in area of Geochemistry of Earth-Water-Air Systems. We seek applicants with a strong background in earth sciences and expertise in chemical reactions among rocks, water, the atmosphere, soils, and/or biota. We are particularly interested in scientists whose research pertains to fundamental questions related to climate change, mitigation of climate change, and energy transformation.

Duke University is an Affirmative Action/Equal Opportunity Employer committed to providing employment opportunity without regard to an individual's age, color, disability, genetic information, gender, gender identity, national origin, race, religion, sexual orientation, or veteran status. Candidates with backgrounds underrepresented in science and women are especially encouraged to apply.

Candidates should have Ph.D. degree received no later than May, 2023.

Complete applications should consist of a single PDF file containing:

1) One-page cover letter;
2) Curriculum Vitae;
3) up to three publications or manuscripts;
4) A statement of research interests, accomplishments, and future plans (up to 2 pages);
5) A statement of teaching and mentoring activities or plans (up to 2 pages);
6) A statement describing contributions to advancing diversity, equity, and inclusion, including activities to date (up to 2 pages); and
7) Names and contact information for three references.

Questions regarding this position can be addressed to the Chair of the Search Committee: Professor Avner Vengosh, (vengosh@duke.edu).

and experiences, we encourage all candidates to apply.

**Minimum Qualifications**

- Ph.D. in Geosciences or a related discipline specializing in landscape evolution and land use/cover change
- Promise of excellence in:
  - conducting research in the field of landscape evolution and land use/cover change
  - teaching and course development in geosciences at the undergraduate level
- Articulated commitment to the principles of diversity, equity, and inclusion in teaching at the undergraduate level
- Effective written communication skills.
  - **Application Process:** A complete application consists of the following:
- a one-page cover letter addressing all minimum qualifications and all pertinent preferred qualifications met
- curriculum vitae
- a statement of research interests that is no more than three pages
- a statement of teaching interest and philosophy of no more than two page
- a one-page statement of commitment to the principles of diversity, equity, and inclusion and how these principles inform your teaching and other aspects of your work
- Contact information for at least three references. Letters of recommendation will be required at a later part of the interview process.

For a full list of qualifications and to apply, please go to https://employment.udayton.edu/cw/en-us/job/500314/assistant-professor-specializing-in-landscape-evolution-and-land-usecover-change

Applications must be received by 11:55 PM EST on December 1, 2022.

The University of Dayton is a top tier, Catholic Research University with offerings from the undergraduate to the doctoral levels. Founded in 1850 by the Society of Mary, the University is a diverse community committed to advancing the common good through intellectual curiosity, academic rigor, community engagement and local, national, and global partnerships. Guided by the Marianist educational philosophy, we educate the whole person and link learning and scholarship with leadership and service.

Informed by its Catholic and Marianist mission, the University is committed to the principles of diversity, equity, and inclusion. Informed by this commitment, we seek to increase diversity, achieve equitable outcomes, and model inclusion across our campus community. As an Affirmative Action and Equal Opportunity Employer, we will not discriminate against minorities, women, protected veterans, individuals with disabilities, or on the basis of race, color, national origin, religion, sex, sexual orientation, or gender identity.

The University is also pleased to provide support for spouses of prospective and newly hired faculty through its dual career program. While we cannot guarantee placement, we serve as an effective resource and support system for your spouse. Information can be found at http://www.udayton.edu/hr/employee_resources/dual_career_resources.php.

## Assistant/Associate Professor Positions, Indiana University Bloomington

The Department of Earth & Atmospheric Sciences invites applications for one or more tenure-track Assistant or Associate Professor positions to begin in fall of 2023. We welcome applications that complement our research strengths in climate change, critical zone science, or evolving crust, especially in the areas of Earth materials, hydrology, paleoclimate, or biogeochemistry. Specific subdisciplines could include but are not limited to mineralogy/petrology, clay mineralogy, hydrogeology, crustal fluids, isotopic proxies of climate change, soils, or nutrient cycling. Candidates who bridge these and other areas of Earth Sciences are strongly encouraged to apply. Ph.D. is required at time of appointment.

Diversity, equity, and inclusion are core values, and we are interested in candidates who are committed to nurturing a climate of mutual respect wherein everyone is empowered to succeed.

Before a conditional offer of employment with tenure is finalized, candidates will be asked to disclose any pending investigations or previous findings of sexual or professional misconduct. They will also be required to authorize an inquiry by Indiana University Bloomington with all current and former employers along these lines. The relevance of information disclosed or ascertained in the context of this process to a candidate's eligibility for hire will be evaluated by Indiana University Bloomington on a case-by-case basis. Applicants should be aware, however, that Indiana University Bloomington takes the matters of sexual and professional misconduct very seriously.

Indiana University is an equal employment and affirmative action employer and a provider of ADA services. All qualified applicants will receive consideration for employment based on individual qualifications. Indiana University prohibits discrimination based on age, ethnicity, color, race, religion, sex, sexual orientation, gender identity or expression, genetic information, marital status, national origin, disability status or protected veteran status.

Apply online at https://indiana.peopleadmin.com/postings/13870 with a cover letter, a CV, statements on research, teaching, and diversity equity and inclusion, and contact information for referees. Review of applications will begin November 15, 2022, and continue until the positions are filled. Queries can be sent to department chair David Polly (easchair@indiana.edu).

## Structural Geologist, Western Washington University

The Geology Department invites applications for a tenure-track Assistant Professor position specializing in Structural Geology to begin Fall 2023. We seek individuals who will establish a vigorous research program, are enthusiastic about teaching, will involve undergraduate and Masters-level students in their research, and will work to improve diversity, equity, and inclusivity through their teaching, research, and service efforts.

The ideal candidate will complement our existing teaching and research strengths in tectonics, petrology, geomorphology, and geophysics by developing new courses and research avenues in structural geology. We broadly seek individuals who will apply field-based observations and analytical techniques to understand the structural and tectonic evolution of the Earth's continental crust and lithosphere. Areas of interest include but are not limited to the structural analysis and evolution of mountain belts, the kinematics and rheology of faults or shear zones, and the timescales and rates of continental deformation. Primary teaching responsibilities include structural geology, field mapping and methods (field camp), and advanced courses in structural geology and tectonics, as well as introductory / physical geology courses.

For details about the position, application information and instructions, go to the WWU Employment website: Careers - Faculty | Human Resources | Western Washington University (wwu.edu) 9-month salary range will be $75,000-82,000 depending on experience.

Review of applications begins December 16, 2022, and continues until position is filled. Please contact the search committee chair, Sean Mulcahy (mulcahs@wwu.edu) or the Geology Dept chair, Bernie Housen (bernieh@wwu.edu) for questions about this position.

## Tenure-Track Faculty, Assistant or Associate Professor, College of Charleston

The College of Charleston Department of Geology and Environmental Geosciences invites applicants with a Ph.D. in Geosciences or closely related field for a tenure-track faculty position to begin in August 2023. We seek a faculty colleague able to teach courses in marine geology, seafloor mapping, introductory geology, and one or more courses in their field of specialty, and mentor student experiential learning activities. Candidates who can develop their own research program and secure external funds in areas such as marine geology, hydrography, and geoinformatics are strongly desired.

Read the complete position description and apply at https://jobs.cofc.edu/postings/12735.

Any questions should be directed to Timothy Callahan at callahant@cofc.edu. Applications will be reviewed beginning on November 11, 2022; the position will remain open until filled.

### Assistant Professor of the Practice in Environmental Geology, University of Kansas

The Department of Geology seeks an Assistant Professor of the Practice in the field of Environmental Geology in support our growing environmental geology master's programs, to begin January 1, 2023. The position is a non-tenure track, full-time, academic-year appointment with a 3-year, renewable contract. Given the primarily online/hybrid nature of our programs, a commitment to excellence in online/on-campus hybrid teaching is essential. We seek an instructor with the ability to teach six courses per year from the following courses or subjects: Introductory, physical, and chemical hydrogeology, environmental site assessment, soil and water remediation, hydrogeophysics, environmental microbial geochemistry, or other relevant topics. For complete information and to apply go to https://employment.ku.edu/academic/23308BR.

## OPPORTUNITIES FOR STUDENTS

**Ph.D. and MS Students, Baylor University.** The Department of Geosciences invites applications for Ph.D. and MS students starting in August 2023. Admission to the program includes five years of financial support for Ph.D. students and two years of financial support for MS students through graduate assistantships. Admitted students also receive a tuition waiver, 80% health insurance subsidy, annual conference travel funding, and research funding for graduate students on a competitive basis. Candidates should have at least an undergraduate degree in geology, geophysics, or in a related area and excellent analytical and writing skills. Students holding a BS degree may apply directly to the Ph.D. program.

Faculty research covers a broad spectrum of geosciences, with strengths in biogeosciences, energy geoscience, hydrological and surface processes, lithospheric processes, paleoclimate, and solid Earth and planetary sciences. For more information about the Department of Geosciences, our research areas, and the graduate program please visit www.baylor.edu/geosciences.

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# Chemistry Education for the Geosciences: Perceptions of Importance and Relevant Knowledge

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The role of chemistry in preparing geologists is not well defined or quantified. Chemistry content and coursework can present challenges and misconceptions that act as barriers for many students (Anderson and Libarkin, 2016; Barbera, 2013). The American Geosciences Institute (AGI) *Geoscience Handbook* (Carpenter and Keane, 2016) identifies key chemistry concepts and skills for the geosciences. With the diversity of career paths in the geosciences, universal chemistry training guidelines for all is impractical. Our goal is to elucidate geologists' perceptions of the foundational chemistry knowledge students need for a geoscience degree. We use the term "geosciences" throughout, reflecting the range of degree programs that would align with content outlined in the AGI handbook. Results from this pilot survey can inform curricular choices, course content, and program requirements for geology students.

## MATERIALS AND METHODS

The pilot survey was developed to investigate the perceived importance of chemistry, the amount of chemistry preparation, and the chemistry skills needed for a geoscience degree (see Supplemental Material[1] item 1). The first section contained 18 items assessing perceptions of the importance of chemistry and chemistry preparation. Participants responded to statements such as, "Chemistry is an integral component of a geoscience student's undergraduate degree," using a five-point Likert-style scale ranging from "strongly disagree" (1) to "strongly agree" (5). The second section asked participants to report how many semesters of chemistry they perceive are necessary for a geoscience student to be successful in a bachelor's degree, master's degree, Ph.D., industry career, and academic career. A third section asked participants to rate how often (e.g., "never," "seldom," "often," or "every day") they think each concept or skill is "necessary for an undergraduate degree in the geosciences." The list of chemistry skills was selected from topics in the AGI *Geoscience Handbook*, which was developed from input from 240 geoscience experts (Carpenter and Keane, 2016). We added skills to include aqueous, gas, and solid materials chemistry. For example, in the AGI handbook, it states, "Apply properties of elements to solid earth materials," and we added two parallel items about aqueous chemistry and gases. Demographic information was collected on the final page of the survey to determine participants' level of expertise (e.g., undergraduate, graduate student, or professional). For content validity, two geochemistry faculty reviewed the content and language of the items.

We distributed the survey in the exhibit hall at the 2018 Geological Society of America (GSA) Annual Meeting in Indianapolis, Indiana (5,625 attendees), USA, through the Geocognition Research Lab (GRL) Booth hosted by Michigan State University (MSU). Incentives for completion of the survey were snacks (e.g., candy bar, bag of chips). A total of 146 surveys were completed, from which we omitted incomplete surveys and participants whose expertise fell beyond the categories described below (e.g., K–12 teachers). Surveys from 108 participants were grouped based on self-reported current position as: (1) undergraduate students ($n$ = 41); (2) graduate students (e.g., M.S. or Ph.D.) ($n$ = 36); and (3) experts (i.e., industry or academia professionals) ($n$ = 31).

Reliability analyses performed using SPSS Version 26 confirmed the latent structure of the survey dimensions for importance and preparation, and good reliability ($\alpha$ = 0.759). Parametric statistics assumptions were checked (Sullivan and Artino, 2013). The "preparation" sub-scores were normally distributed, and the "importance" sub-scores skewed positive and leptokurtic. Total sub-scores were computed for "importance" and "preparation" statements by summing the Likert-style values (1 for "strongly disagree" to 5 for "strongly agree"). A one-way ANOVA compared the means between the three expertise groups (e.g., undergraduates, graduate students, and faculty or professionals). A Pearson's Chi Square analysis compared the group means for the number of semesters needed for the various geoscience degrees or career paths (e.g., B.S., M.S., Ph.D., industry, academia). To analyze participants' ratings of the skills necessary for undergraduate geoscientists, we totaled the number of participants from each expertise group responding at each level of frequency (Fig. 1). Complete data files are available in Supplemental Material item 2 (see footnote 1).

## RESULTS

There was no significant difference in ratings for importance statements between the three expertise groups ($F$[2,97] = 0.283, $p$ = 0.754), nor for the preparation statements ($F$[2,97] = 0.409, $p$ = 0.665). Participants from all groups agreed that two semesters of chemistry are necessary for a B.S. in the geosciences ($X^2$ [8, $N$ = 108] = 7.844, $p$ = 0.449) and four are necessary for a geoscience career in industry ($X^2$ [8, $N$ = 98] = 5.943, $p$ = 0.654) or academia ($X^2$ [8, $N$ = 102] = 14.038, $p$ = 0.081). Undergraduates and experts differed on how many semesters of chemistry are necessary for an M.S. ($X^2$ [8, $N$ = 99] = 23.171, $p$ = 0.003) or a Ph.D. ($X^2$ [8, $N$ = 99] = 23.020, $p$ = 0.003). Experts reported that three semesters are

*GSA Today*, v. 32, https://doi.org/10.1130/GSATG527GW.1. 

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[1]Supplemental Material. Item 1: original survey administered in this study. Item 2: original data from this study. Go to https://doi.org/10.1130/GSAT.S.20449821 to access the supplemental material; contact editing@geosociety.org with any questions.

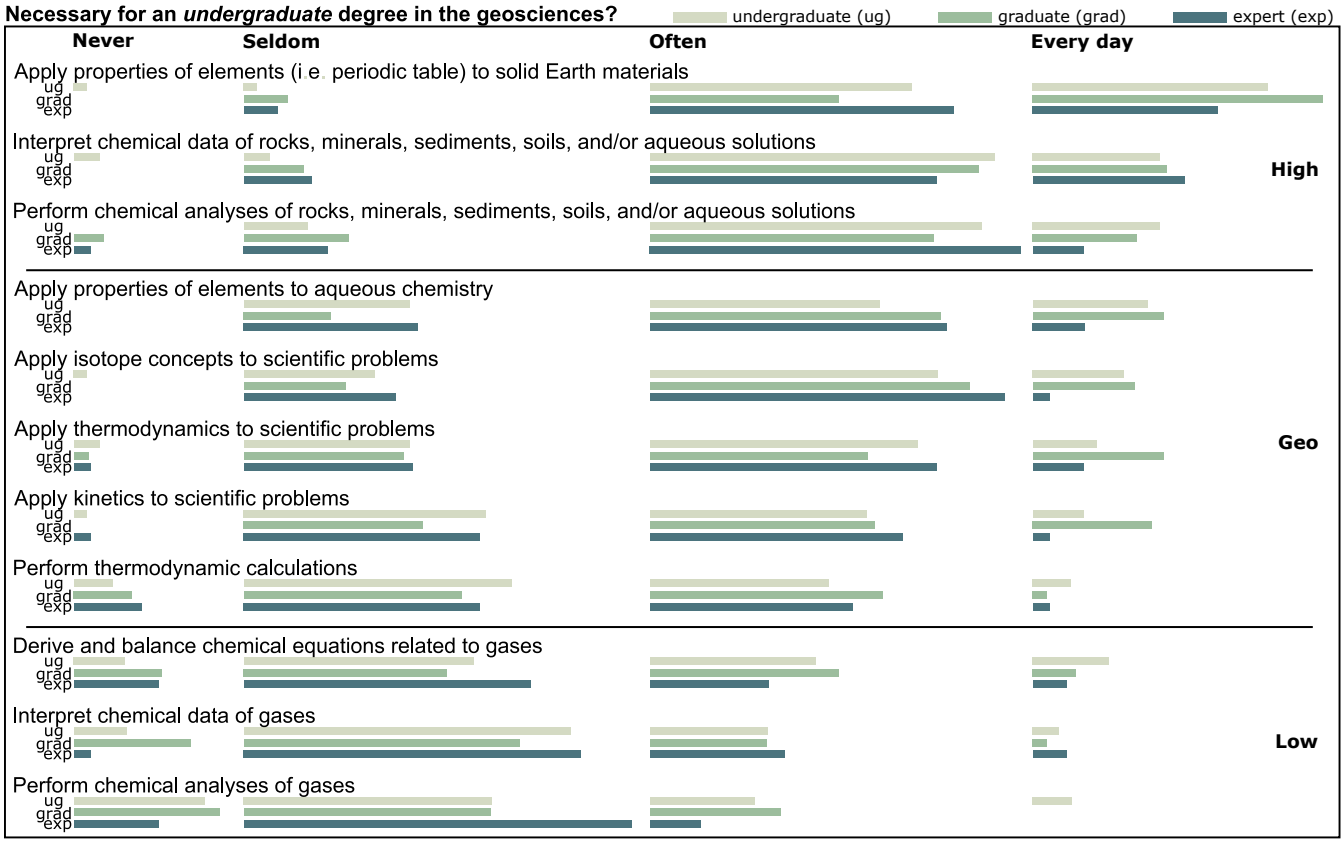


**Figure 1. Participant ratings of 11 of the 20 chemistry-related skills surveyed, including three highest and lowest, and five most geoscience relevant topics.**

needed for an M.S. or Ph.D. geoscience degree, while undergraduates reported an average of four courses for these degrees. Note: We did not ask which chemistry courses should be required.

Figure 1 shows 11 of the 20 skills participants rated. For visual clarity, we only included the three highest- and three lowest-rated skills and five skills particularly relevant to the geosciences (e.g., isotopes). Participants agreed that the most important skills (labeled "high") related to applying properties, interpreting chemical data, and performing analyses of solid Earth materials. The lowest-rated skills were those involving gases. Graduate students and experts indicated they "often" engage in "applying isotope concepts to scientific problems" ($n_{ug}$ = 7 of 41; $n_{grad}$ = 22 of 36; $n_{exp}$ = 21 of 31 (ug—undergraduate; grad—graduate student; exp—professional).

## DISCUSSION AND NEXT STEPS

Overall, the three expertise groups shared general consensus regarding the importance and amount of chemistry necessary for the geosciences. Participants ranked chemistry content and skills associated with aqueous and solid chemistry higher than those associated with gas chemistry (Fig. 1). Applying isotopes to scientific problems ranked highly but is not a focus of most general chemistry courses. Second semester general chemistry does focus on thermodynamics, which participants noted they use often.

The results of this pilot study provide preliminary perceptions of the type and quantity of chemistry content geologists value for a geoscience degree. However, the survey instructions did not define the parameters of a "geoscience degree." GSA attendees draw from 22 scientific Divisions, and the survey participants represented this perspective. We did not analyze participants' discipline of expertise. The findings suggest tutorials focused on improving geoscience students' basic chemistry skills, similar to "The Math You Need" tutorials (Wenner and Baer, 2015), may be useful for topics of high importance but absent from the general chemistry curriculum. Targeted training can alleviate barriers associated with learning chemistry as a geoscience major.


## ACKNOWLEDGMENTS

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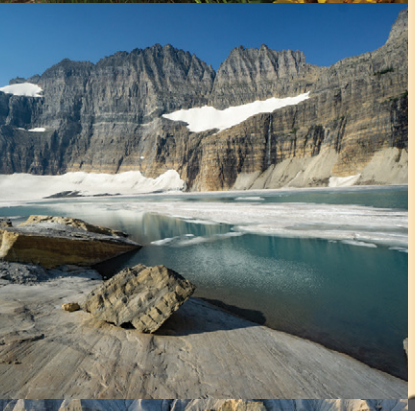

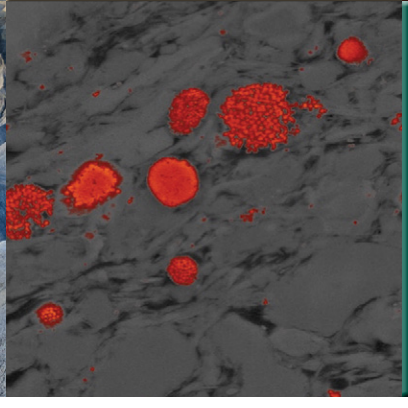

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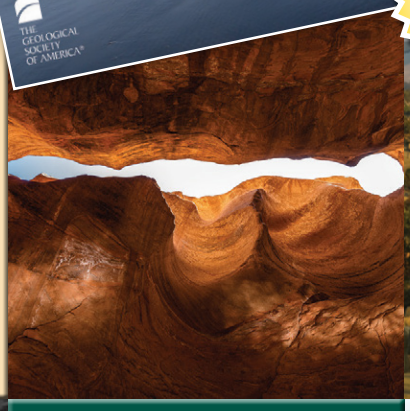

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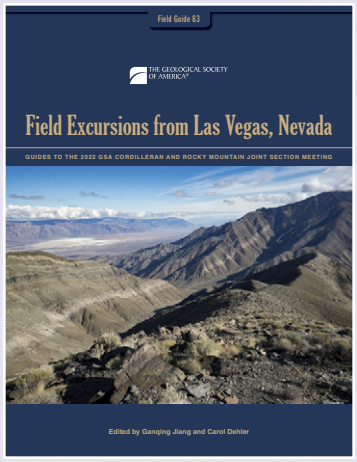


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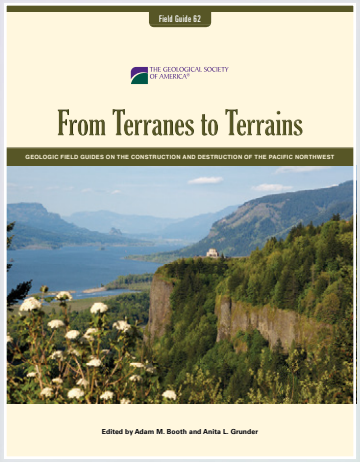


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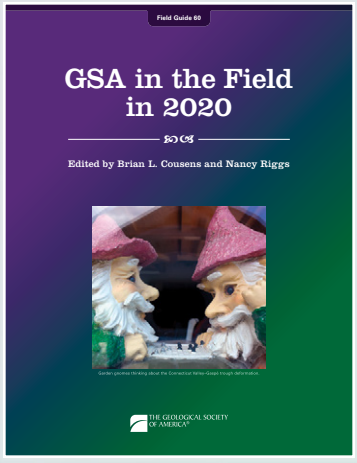


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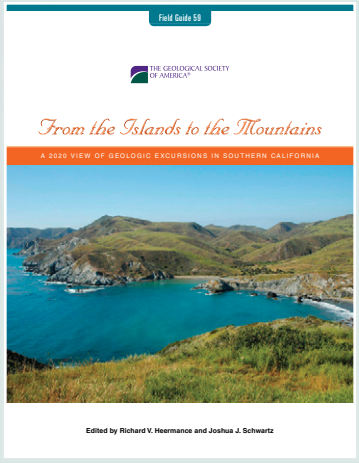


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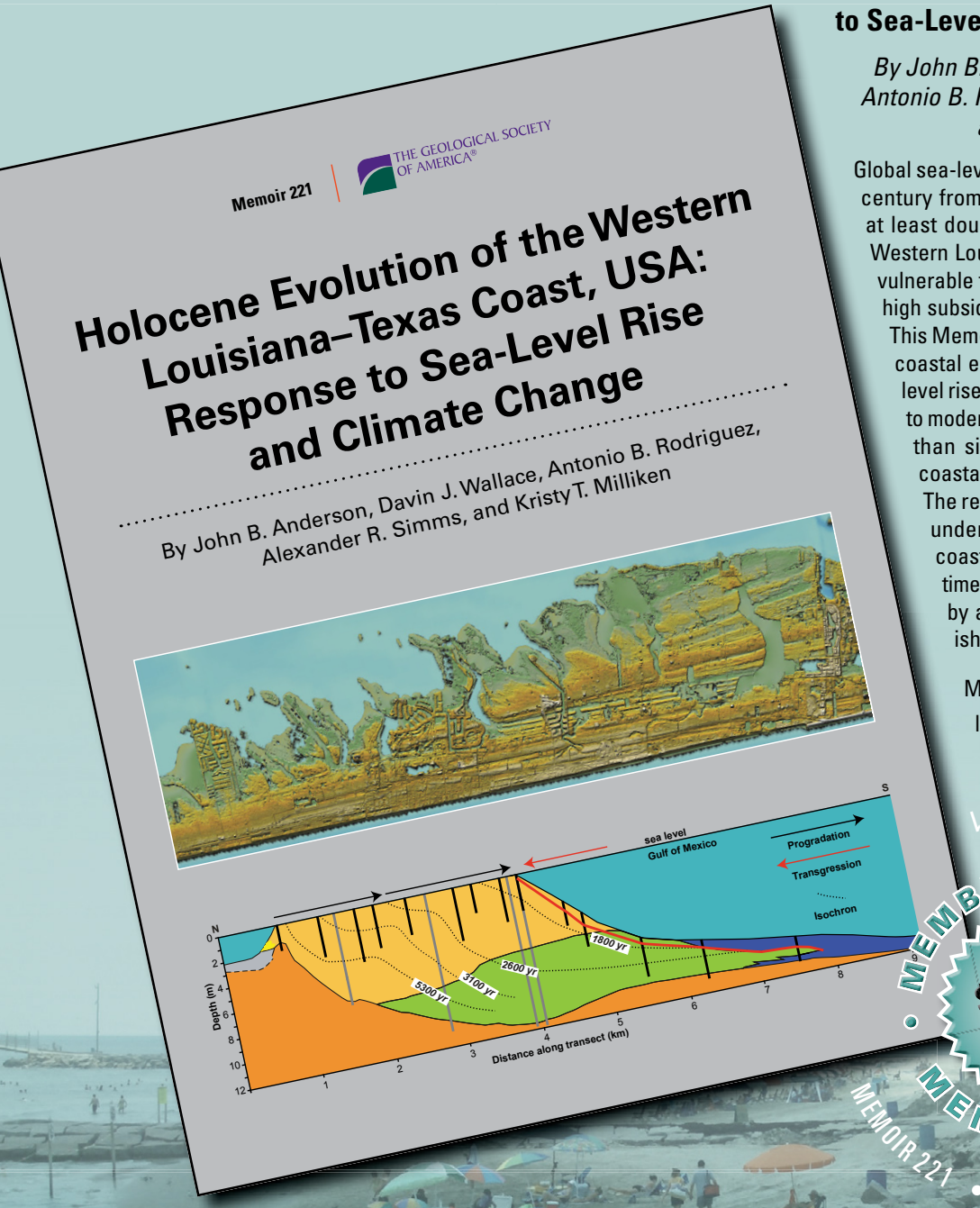


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