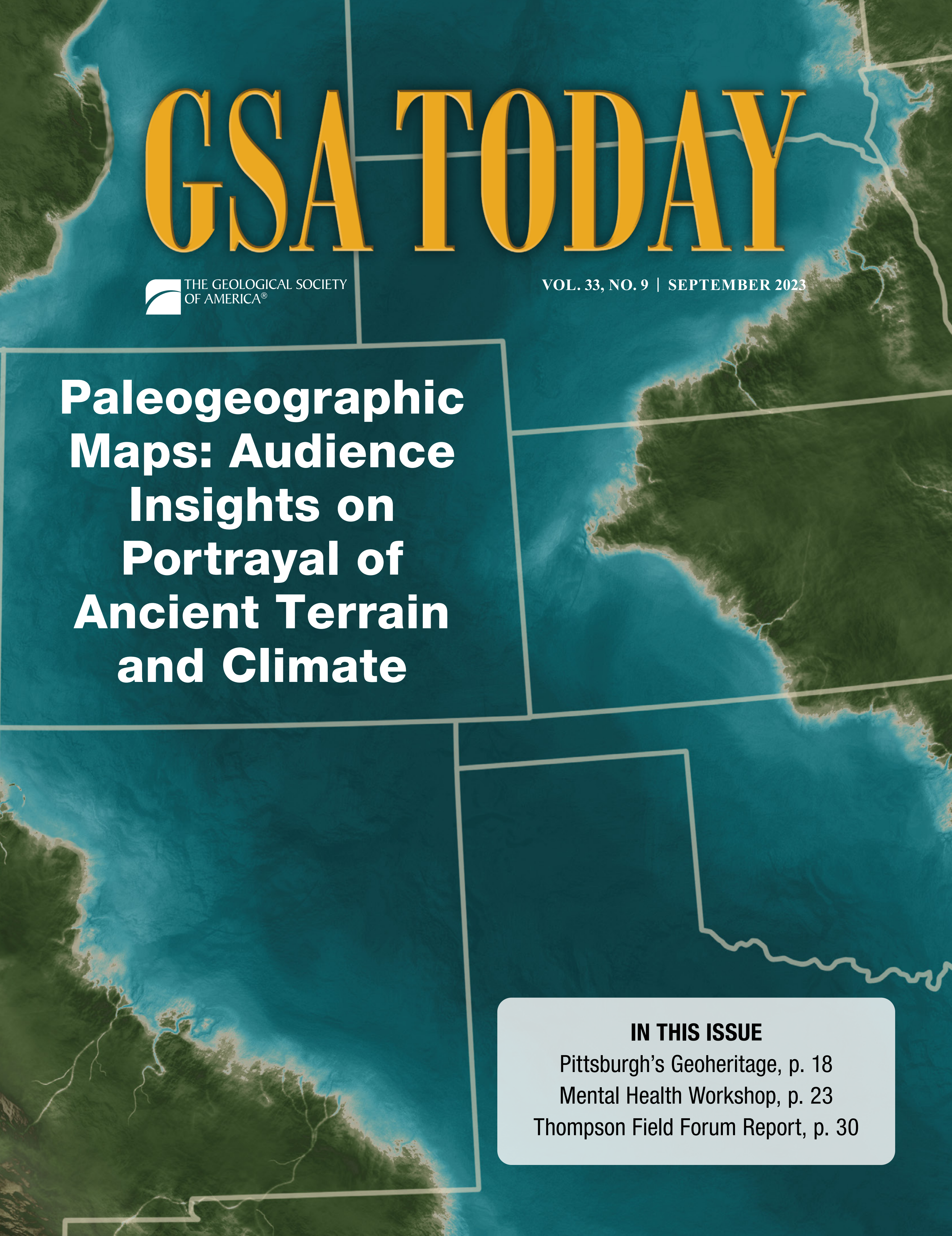

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Paleogeographic Maps: Audience Insights on Portrayal of Ancient Terrain and Climate

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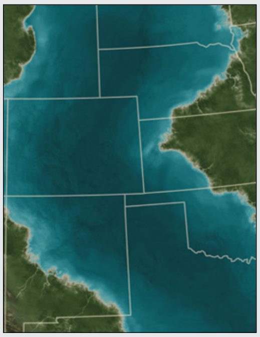

Cover: A satellite-realistic reconstruction of the Western U.S. during the Late Cretaceous (Campanian, ~80 Ma.). Paleosatellite images like this one are the most commonly used communication tool in the earth sciences — but may not always succeed at portraying the data informing them. This image was adapted to enhance communication of terrain and climate using feedback from public and professional audiences. Illustration by Hannah Bonner. For the related article, see pages 4–10.

GSA CONNECTS 2023

GSA NEWS

THE GEOLOGICAL SOCIETY OF AMERICA®

Paleogeographic Maps: Audience Insights on Portrayal of Ancient Terrain and Climate

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ABSTRACT

Paleogeographic maps are one of the most used earth science communication tools, but their efficacy with audiences remains uninvestigated. We present new data that begins to close this gap, gleaned from an intercept interview study of two communities—practicing geoscientists (i.e., "professionals") and adults who visit locations where paleogeographic maps are commonly displayed ("the public"). In this work, we sought to determine: (1) how commonly used paleogeographic maps convey the terrain and climate of ancient Earth; and (2) how community perception informs new practices for creating paleogeographic maps. When presented with paleogeographic maps, the public can identify about three large-scale landscape features (often including mountains and ocean) but not smaller or more subtle geomorphic features (e.g., rivers, volcanos, or plains). In contrast, practicing geoscientists identify about five features at a variety of spatial scales. Given an example of a warm, wet landscape, public audiences can describe one of two components of portrayed climate (i.e., warm or wet), but are less adept at identifying both climate components. Professionals are better able to identify climate components but are only able to fully describe climate 55% of the time. Paleogeographic maps catalyze curiosity in both public and professional audiences, commonly prompting questions or hypotheses about how ancient Earth reached modern-day conditions or about the time period shown. Professional geoscientists also want more information on sources of data. Recommendations to enhance the efficacy of paleographic maps include adding data sources and employing an aesthetic with detailed bathymetric shading, high contrast, and explicit climate indicators.

INTRODUCTION

Paleogeographic maps—illustrations that depict the topography and morphology of ancient Earth—are some of the most commonly used figures in the geosciences. Such maps are prized for the accessible way they portray ancient terrain and climate, in part because we assume no training or technical language is required to understand their illustrated landscapes.

Unfortunately, this assumption is not based on audience research or empirical data. Although paleoart generally increases paleoenvironmental understanding among the public (Wang et al., 2019), our community has not yet evaluated the efficacy of paleogeographic maps as science communication tools—for the public, for our students, or for our own professional geoscience community.

In contrast, geographic visualizations of modern settings enhance communication (Sheppard et al., 2008; Caquard, 2011; Xiang and Liu, 2016), aid scientific reasoning (Blank et al., 2016), improve consultation with Indigenous communities (Lewis and Sheppard, 2006), and foster responses to climate change (Bohman et al., 2015). However, the media used in these studies are usually aerial or satellite images of extant landscapes. Paleogeographic maps, while attempting to be photorealistic, blur the line between such geographic visualizations and art (aka "paleoart"). As a result, they conflict with the viewer's perception of modern Earth and may challenge unconscious assumptions or distort meanings and interpretation (Sheppard and Cizek, 2009; Witton, 2017).

We began to address this knowledge gap in a new qualitative study that explores the efficacy of three commonly used versions of this omnipresent science-communication tool. In this pilot study of professional geoscientists and the public, we sought to understand: (1) to what extent popular paleogeographic maps succeed at communicating the terrain and climate of ancient Earth, and (2) whether audience perception can inform how we create future paleogeographic maps.

STUDY APPROACH

We focused on three commonly employed types of paleogeographic maps. Our maps represent a continuum of paleogeographic artistry, from stylized paintings to realistic satellite imagery, and they capture the diversity of map styles used in public and professional settings. Likewise, our map content, a portrayal of what the western U.S. may have looked like during the early Campanian (Late Cretaceous), was chosen to include a diverse range of colors, contrast, textures, and landforms. The map ratio and region were selected to include overlays of state boundaries that would be recognizable to study participants and provide a language-independent and nonnumerical sense of scale. Maps included a "Blakey" map (Fig. 1A; see deeptimemaps.com and Blakey and Ranney, 2008, for additional examples), a "Morris" map (Fig. 1B; see Morris et al., 2016), and a Google Earth–style "satellite" map, produced by stitching together U.S. Department of Agriculture (USDA) satellite data from the Java Sea and the Andes Mountains to create a photorealistic rendition of an interior seaway bounded by mountains (Fig. 1C; https://earth.google.com/web/ [created 2017; accessed August 2021]).

Our study consisted of scripted interviews (Supplemental Material File S1[1]) with a random selection of adults, including college-age students (hereafter the "public";

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n = 110; Table S1), who visited the Denver Museum of Nature & Science (DMNS), Garden of the Gods Park (GG), and the Natural History Museum of Utah (NHMU). Interviews were also conducted with a group of geoscientists who had graduate geology degrees and used satellite imagery in their vocation (hereafter the "professionals"; n = 38). Each interviewee was handed an 8″ × 10″ color print of one of the paleogeographic maps (Fig. 1), provided with a brief description of what they were looking at, and verbally asked questions about it (see File S1 for list of questions and interview script). All three maps were shown for the final interview question.

Interview recordings were transcribed and analyzed in an emergent coding process.

Common themes were built into a coding manual (File S2 [see footnote 1]) and, to ensure reproducibility, one of us coded the entire dataset. Inter-rater reliability was assessed for each field by an additional researcher who coded 16% of the dataset. Cohen's kappa values were >0.60 for all codes and determined to have substantial to near-perfect agreement. For chi-square tests, the public audience was sorted into two groups based on their self-rated level of past experience viewing satellite imagery, including those who rated themselves 1–3 on a scale of 1–5 (our "novice" group; n = 77) and those who self-rated as 4–5 (our "experienced" group; n = 33); the geoscientist community remained in their own "professional" group for these analyses.

RESULTS

Participants were asked to list landscape or water features they saw on the map. The public distinguished areas of land and water well (95% of respondents; Table S2) and identified several specific features. Eighty-six percent of respondents noted areas of high elevation (e.g., mountains), 68% identified the portrayed water body as an ocean or sea, and 41% mentioned at least one type of shoreline feature, such as an inlet, bay, or beach. However, this group often missed subtle terrain features commonly identified by professionals. For example, 66% of professional geoscientists saw rivers, whereas only 27% of the public did.

Professionals were also more likely to identify features commonly listed by the public: 95% noted areas of high elevation, 97% identified ocean or sea, and 79% mentioned at least one shoreline feature.

This offset in performance was consistent when examining the average number of features correctly identified. The public correctly identified an average of 2.98 features, whereas the professionals identified 5.34 features (Fig. 2A); a one-way ANOVA test showed this difference to be significant

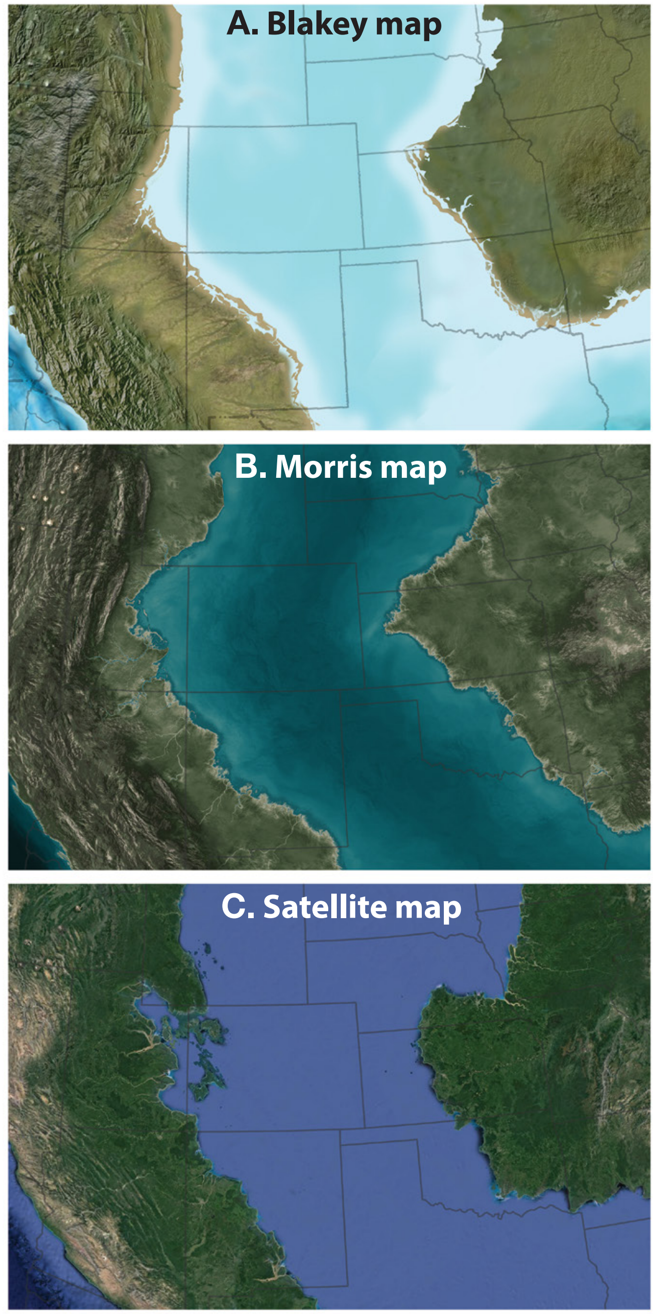

Figure 1. Paleogeographic maps used in this study, including views of the western United States ~80 m.y. ago from (A) deeptimemaps.com (see also Blakey and Ranney, 2008), (B) Morris et al. (2016), and (C) U.S. Department of Agriculture satellite imagery, stitched together from Google Earth (2017). A legend is not included because such images generally do not have one when employed in public venues, such as on reader rails, on interpretive panels, or in animations.

[1]Supplemental Material. File S1. Interview script. File S2. Coding manual. Table S1. Metadata for the public and professional populations interviewed. Table S2. Types of landscape features identified by participants. Table S3. Common questions and hypotheses expressed by participants. Please visit https://doi.org/10.1130/GSAT.S.23639358 to access the supplemental material, and contact editing@geosociety.org with any questions.

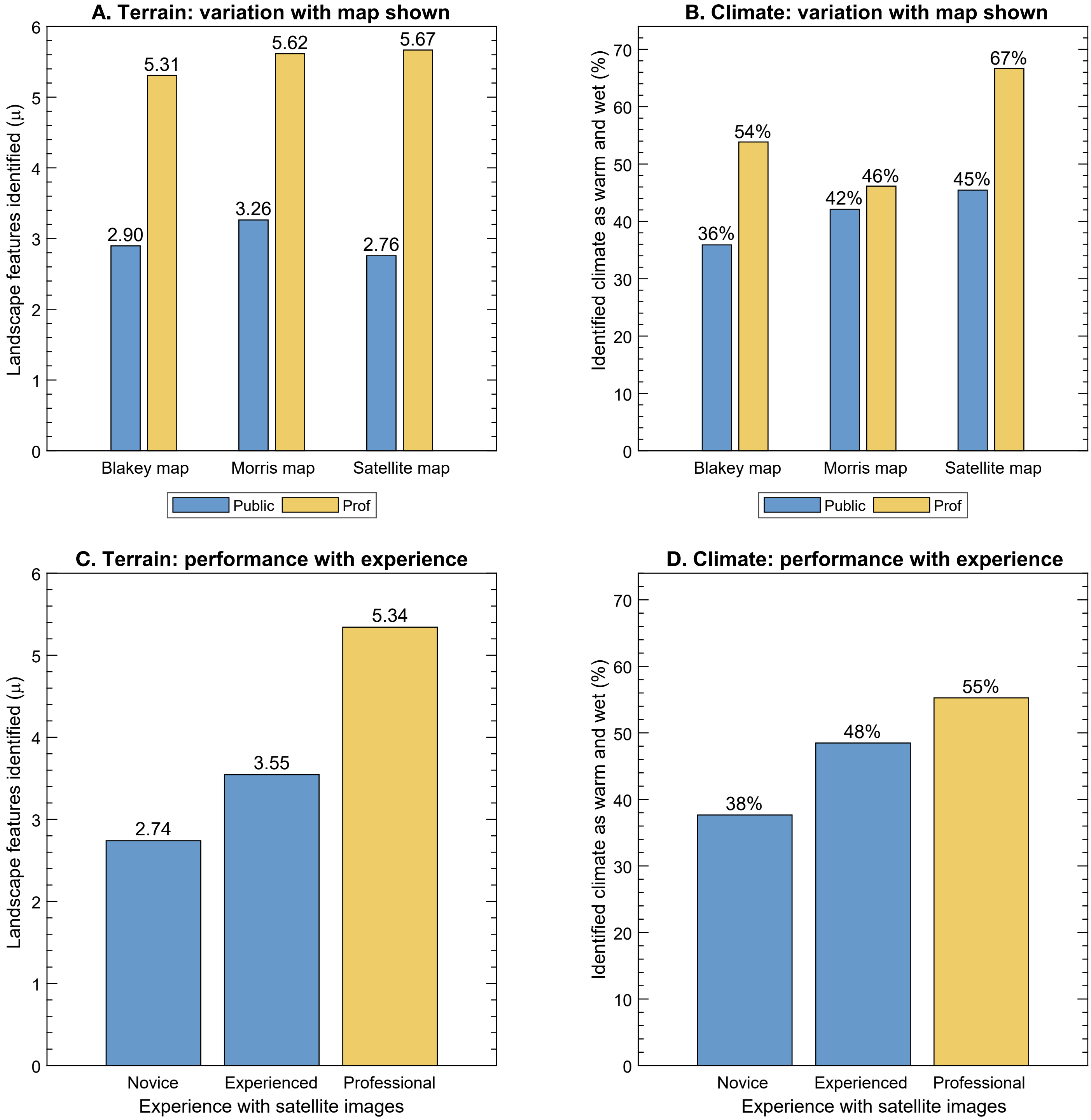

Figure 2. Performance of public and professional communities at identifying (A) multiple landscape features and (B) correct climate portrayed in three paleogeographic maps (Blakey, Morris, and satellite). (C, D) Relationship between past experience with satellite images and success at (C) identifying landscape features and (D) describing climate.

($F(1,146) = [72.12]$, $p < 0.001$). Likewise, experience viewing satellite imagery correlated with increased performance at identifying landscape features. Novices (self-rating of 1–3 experience level on a scale of 1–5) identified an average of 2.74 features, whereas more experienced members of the public (self-rating of 4–5) averaged 3.55 features. Chi-square testing confirmed correlation between number of features correctly identified and sorting into the novice public, experienced public, or professional group ($\chi^2 = 63.6$, $p < 0.001$; Fig. 2C). Interestingly, older respondents (60+ years) correctly identified an average of 3.21 features, whereas younger respondents (<60 years) averaged 2.93 features. Respondents who were shown the Morris map (Fig. 1B) identified an average of 3.29 features, whereas respondents shown the other two maps averaged 2.82 features (Fig. 2A).

Communicating the Climate of Ancient Earth

Participants were asked to describe the climate shown on the map. Although multiple subclimates were portrayed, the goal of the maps was to show the overall tropical conditions present during this time period. Only 41% of the public mentioned "tropical" (or included some synonym for "wet" and "warm") in their description. Likewise, only 55% of professionals described the climate as tropical (Fig. 2B).

Participants experienced at viewing satellite images (self-rating of 4–5) identified a tropical climate 48% of the time, whereas novices (self-rating of 1–3) identified a tropical climate only 38% of the time (Fig. 2D). However, individual variability was too high to suggest a correlation with a chi-square test (χ^2 = 3.5, p = 0.18). Both public and professional groups performed best at identifying climate when shown the satellite map (Fig. 2B).

Questions about Paleogeographic Maps

Participants were asked if they had questions about their maps. Many respondents either had a question or presented a hypothesis about how ancient Earth changed to modern Earth (39% public; 29% professionals; Table S3 [see footnote 1]). Nearly 64% of the public mentioned plate tectonics and one-third of respondents either asked about or referenced the time period shown by the map (32% public; 32% professionals). Additionally, 26% of the professionals' responses indicated that they wanted to know what sources of data were used to construct maps (vs. 6% of the public). Common secondary themes for both groups were requests to see more area than shown and confusion about what volcanoes looked like.

Preference in Map Portrayal

For the final interview question, participants were shown all three paleogeographic maps and asked to indicate which version they preferred. The public favored the Morris map (53%) versus the Blakey (25%) or satellite map (12%; Fig. 3A). Ten percent of respondents ranked two or more maps as equally preferred. This preference was statistically significant (one way ANOVA; F(2,447) = [21.63], p <0.001) and most pronounced at the DMNS and GG locations (Fig. 3A). Chi-square testing also showed correlation between age and favorite map (χ^2 = 7.7, p = 0.05), with younger public participants choosing the Morris map and older (45+ years) participants preferring the Blakey map (Fig. 3B). Professionals were split between the Blakey (39%) and Morris map (37%; Fig. 3A) and exhibited similar preferences by age (Fig. 3C).

The public primarily chose the Morris map for its detail/realism (45% of respondents) and representation of water (59%; Fig. 4). In contrast, the Blakey map was chosen for its detail/realism (33%) and high

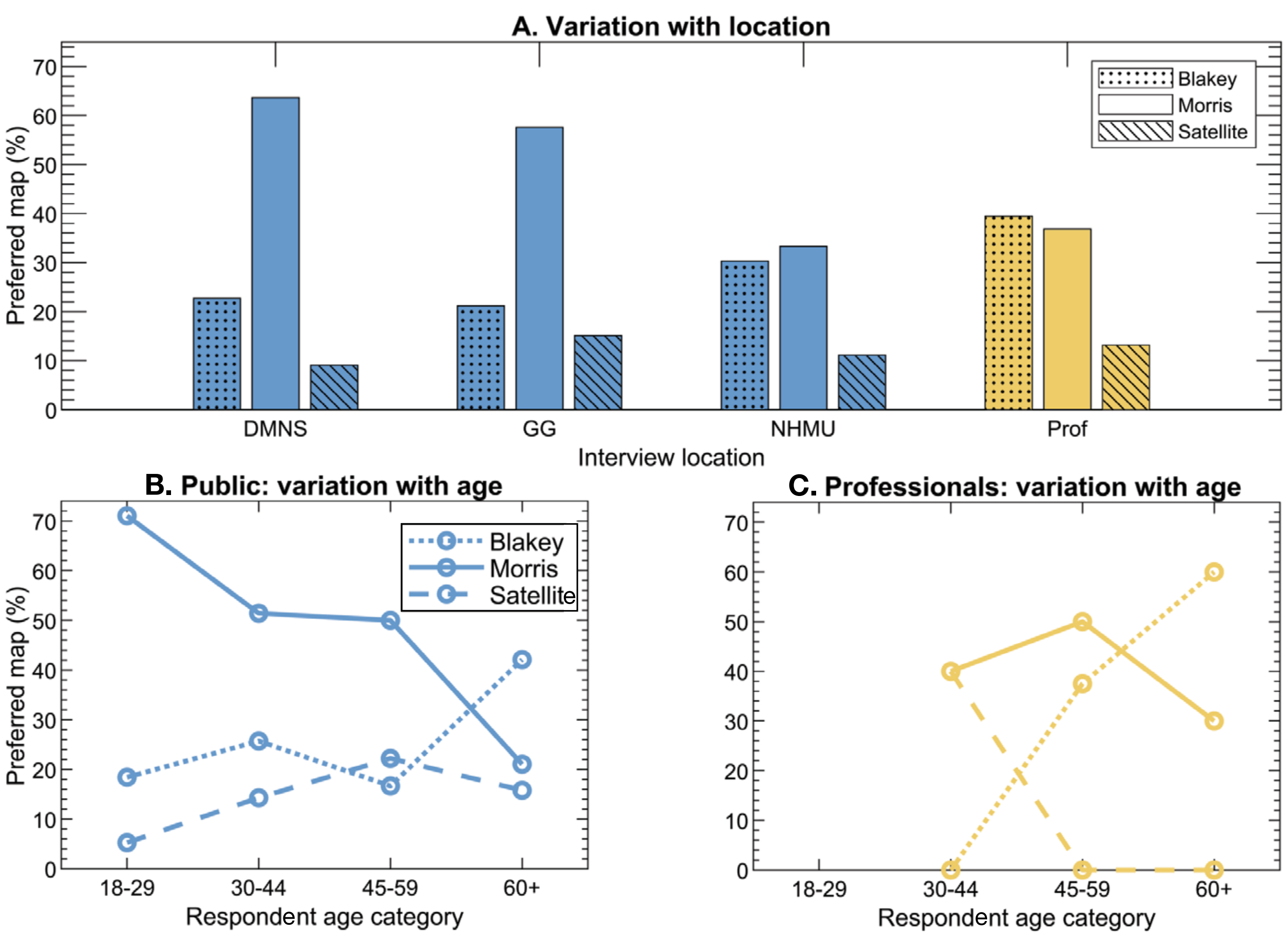

Figure 3. Variations in preferred paleogeographic map based on (A) interview location (Denver Museum of Nature & Science [DMNS], Garden of the Gods Park [GG], and Natural History Museum of Utah [NHMU]) and age of the (B) public and (C) professional (Prof) audiences.

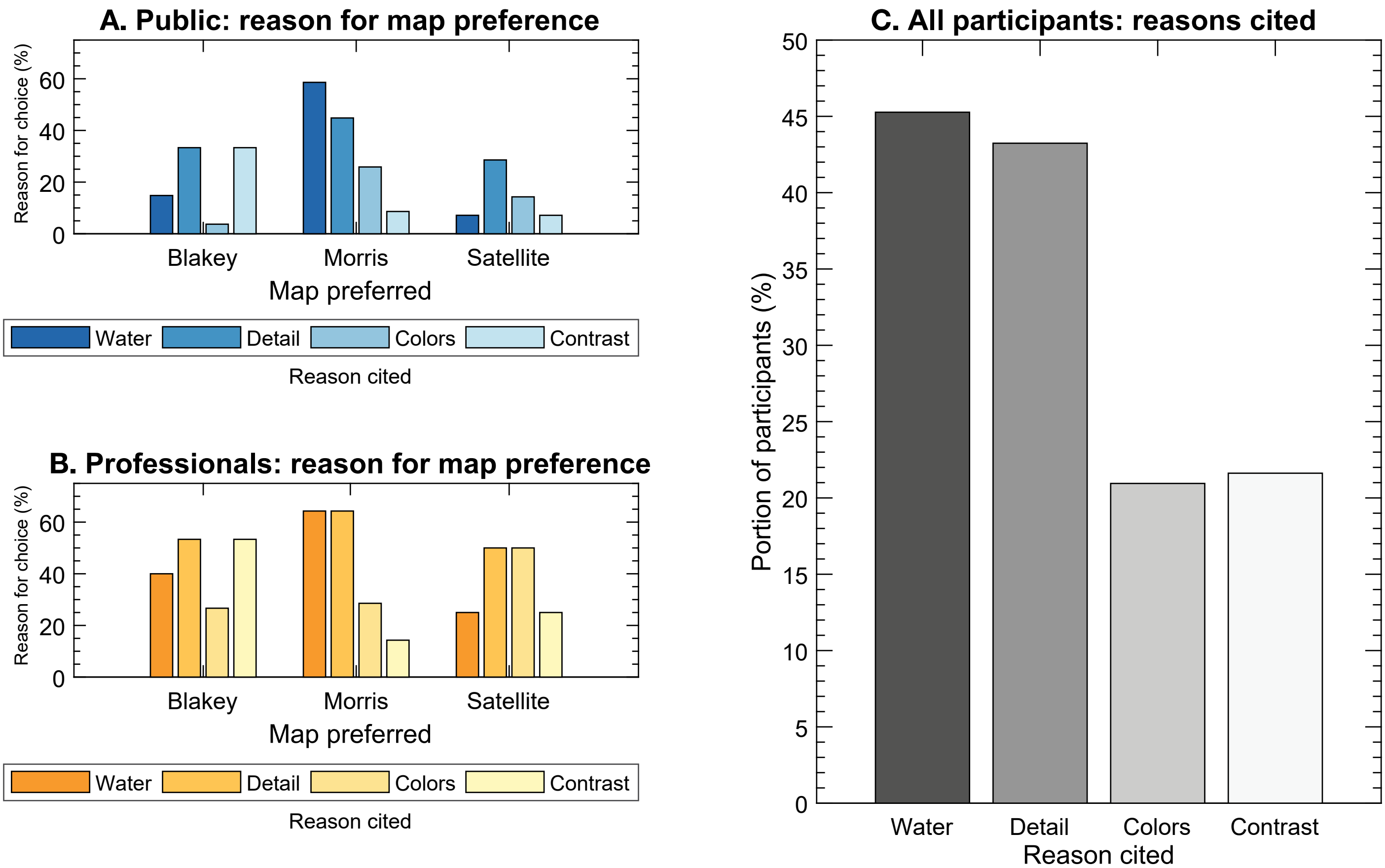

Figure 4. Reasons for preferred paleogeographic map representation among (A) public and (B) professional audiences, including the most commonly cited reasons among both communities (C).

contrast (33%). The satellite map was mostly chosen for its detail/realism (29%). These cited reasons were similar for professionals. Professionals also cited the color palette used to define landscape features as important in determining their map preference.

INTERPRETATIONS

The tested maps were successful at communicating basic terrain distinctions (e.g., areas of land vs. water) and highlighting a few large-scale features (e.g., ocean/sea, shoreline, a high-elevation feature). This interpretation is consistent with observed public audience success in interpreting satellite data (Svatoňová, 2016a). Consequently, the success of popular paleogeographic maps depends largely on the application goal. If maps are used to help viewers distinguish between land and water boundaries and highlight visually large terrain features, they are successful.

However, our results suggest that if maps are used to communicate smaller-scale terrain features (e.g., rivers, volcanoes), visualize subtle features (e.g., flatland or plains), or distinguish between similar features (e.g., delta vs. beach vs. inlet), they will not succeed for the average adult, including college-age adults. These results parallel observations of public ability to interpret modern aerial images (Lloyd et al., 2002).

More nuanced terrains are visible to the trained eye. Professionals identified more than five different terrain features (Fig. 2A), a finding supported by research on modern landscapes that shows that practice and training leads to greater proficiency at interpreting geospatial imagery (Svatoňová, 2016b; Šikl et al., 2019; Arthurs et al., 2021). Likewise, we found a correlation between self-rated experience and number of features correctly identified (Fig. 2C), suggesting that increased experience elevates performance of older public respondents versus younger respondents. This result resonates with findings that show that increased discipline-specific knowledge improves scientific observation (e.g., Barth-Cohen and Braden, 2021).

Intriguingly, the artistic style of the paleogeographic map may also influence performance. Public respondents identified ~0.5 more features using the Morris map (the map they liked best) versus the satellite map. This influence has been observed in studies on the interplay between aesthetics and viewer perception (Daniel and Meitner, 2001) and on effective and inclusive visualization (Sheppard, 2001; Sheppard and Cizek, 2009; Oliveira and Partidário, 2020). In contrast, professionals performed best on the satellite map—the map they liked least, but also the presentation they were most familiar with, given their vocation.

Surprisingly, less than half of the public population identified the tropical climate portrayed by the maps (Fig. 2B). Professionals did better, but not significantly so (55% of respondents). Although there is research on how audiences perceive aerial and satellite landscape features (Lloyd et al., 2002; van Coillie et al., 2014; Svatoňová, 2016a), no similar research has explored how audiences perceive climate. This gap may relate to the challenge of deriving climate from true-color satellite imagery. In practice, other spectral bands and remote sensing tools are used to provide data on precipitation and temperature (see reviews by Tomlinson et al., 2011; Levizzani and Cattani, 2019).

In both study groups, most participants got at least one component of climate (i.e., warm or wet) correct. However, both of these terms are subjective—a subtropical or temperate climate could also be described as warm and wet. Further, because we accepted any description of climate including synonyms for warm and wet as correct, it is possible the percentage of respondents who actually perceived a tropical climate was even lower than reported. These results suggest that paleogeographic maps may have unforeseen challenges in communicating climate. At best, such maps may exclude possible climate extremes (e.g., most participants did not perceive an overall cold or dry climate), but viewers are expected to struggle with distinguishing where in a broad spectrum of temperature and precipitation a portrayed region falls. These results are paralleled by research that demonstrates the difficulty of communicating climate change through non-satellite visualizations (Lewandowsky and Whitmarsh, 2018).

In considering our study's impact on future paleogeographic map design, practices that place emphasis on subtle landscape features of interest (e.g., a key or label pointing out volcanoes—in popular use, paleogeographic maps generally lack legends) may improve performance at identifying terrain (Lloyd and Bunch, 2010). Adding more visual context about temperature and precipitation may likewise improve performance at distinguishing climate. One important climate cue is color choice. Similar to analysis of satellite imagery, map color creates a greenness index that defines vegetation cover (Burgan and Hartford, 1993) and was frequently cited as an indicator of climate (42% of public and 66% of professionals). Accordingly, the greenest map (satellite map) was the map most likely to have its climate correctly identified as warm and wet (Fig. 2B). Landscape features may also act as climate cues (e.g., snowy mountains, glaciers, dune fields). To narrow these indicators further, we recommend adding explicit information on climate, such as a thermometer showing average annual temperature and a gauge showing annual precipitation.

The most common public feedback includes a desire to understand how the portrayed Earth changed into modern-day Earth (39% of respondents) and curiosity about the time period portrayed by the visualization (32%). These responses suggest that paleogeographic maps should be paired with an explanation or visualization of how areas change across time periods and a clear statement of the portrayed age. Furthermore, the public's common presentation of a hypothesis involving plate tectonics suggests the public was utilizing outside, but interconnected, knowledge in their interpretations. Research exploring the application of interconnected knowledge supports this linkage (e.g., Posner et al., 1982; Schlichting and Preston, 2015; van Kesteren et al., 2018).

While professional geoscientists share some interests with the public, professionals are four times more likely to question sources of data used to construct the map. This finding is supported by research that shows that scientific experience enhances critical thinking about data legitimacy (Byrnes and Dunbar, 2014; Vincent-Lancrin et al., 2019). If paleogeographic maps are being designed for a professional audience, including data sources that underpin such maps should increase viewer satisfaction.

The public preferred the Morris map, primarily because of its representation of water and detail (Figs. 3 and 4). This map had the most visible bathymetry, which was likely especially important for a map portraying so much water. In contrast, participants interviewed at NHMU and older respondents were less likely to choose the Morris map (Fig. 4). These participants instead preferred the Blakey map, commonly citing its high contrast. We hypothesize that this high contrast was more likely to be a deciding factor in settings with poor lighting (the case at NHMU) and with older participants who are likely to have declined contrast sensitivity (see experiments by Ashraf et al., 2021). These considerations may explain the relation between location, age, and map preference.

Audience preferences inform insights for increasing the impact of paleogeographic maps among public and professional audiences. For example, our findings suggest that most viewers prefer an illustrated rather than a photo-accurate paleogeographic map and that the most effective map will have detailed bathymetry, as in the Morris map, and high contrast, as in the Blakey map. The weight given to each of these components, and the aesthetic style used to achieve them, should vary based on display location and the age of the target audience (Oliveira and Partidário, 2020) and may be explored in future, specified work.

CONCLUSIONS

This study is the first to directly explore the efficacy of paleogeographic maps as communication tools. We identified both successes and limitations in the efficacy of the three paleogeographic maps we tested. For example, an average public viewer grasped the general terrain portrayed by a map, an indication that the impact of large-scale tectonics was being absorbed, but was less likely to notice subtle features visible to an experienced viewer or geoscience professional, like rivers, deltas, and plains. Surprisingly, both public and professional audiences struggled to identify all components of portrayed climate. These findings suggest that the effectiveness of popular paleogeographic maps varies largely depending on the audience (e.g., novice public vs. experienced public vs. geoscience professional) and on what the map is trying to communicate (e.g., general landscape vs. specific landscape vs. climate). Adding nontraditional content to paleogeographic maps, such as landscape feature keys or more explicit indicators of climate, is predicted to improve their efficacy as communication tools.

We also explored the impacts of paleogeographic maps. Many viewers, regardless of experience level, wanted more information about the time period portrayed in the maps and were curious about how the ancient Earth displayed in the maps reached modern-day conditions. Professionals also had questions about sources of data. We hypothesize that tailoring paleogeographic maps to include this information will increase viewer engagement and satisfaction. Likewise, participants had clear preferences for map aesthetics. All audiences tended to favor one map over another due to representation of water and how "realistic" they felt it was. The result of the high impact of oceanic depiction is striking, especially given that much of the earth-science community's efforts focus on continent reconstruction, and geoscientists tend to focus more on depictions of ancient land, rather than ancient bathymetry.

In sum, these insights on paleogeographic map efficacy and recommended future practices begin to lay a foundation for conveying ancient Earth in ways that meet the evolving needs of our audiences. We hope this pilot work is the first of many studies to explore how we as a scientific community use paleogeographic maps to communicate to the public, to students, and to each other.

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THE GEOLOGICAL SOCIETY OF AMERICA®
CONNECTS 2023
15–18 October
Pittsburgh, Pennsylvania, USA

Registration and Other Need-to-Know Information

Registration Deadline: 11:59 p.m. MDT on 13 Sept.
Cancelation deadline: 11:59 p.m. MDT on 20 Sept.

Register now: **community.geosociety.org/gsa2023/registration**

EVENTS REQUIRING TICKETS/ADVANCE REGISTRATION:

Several GSA Divisions and Associated Societies will hold breakfasts, lunches, receptions, and awards presentations that require a ticket and/or advance registration. Ticketed events are open to everyone, and tickets can be purchased in advance when you register. See the meeting website for a complete list: **community.geosociety.org/gsa2023/home.**

STUDENT VOLUNTEERS

GSA Student Members: help us out by volunteering to work at least ten hours at the meeting, and we'll help you out by covering the cost of your registration! See how the meeting works from the inside, and fill vital roles that help to make the meeting a success for everyone.

The Student Volunteer Program is now open for GSA student members in good standing to sign up. Detailed information and sign-up links can be found at **community.geosociety.org/gsa2023/registration/volunteers.**

SERVICES & ACCOMMODATIONS

The Geological Society of America strives to create a pleasant and rewarding experience for every attendee and is committed to providing universal access to our meeting.

Below you will find specific information on a variety of topics to ensure your needs are met. If you have other requests that are not addressed below, please feel free to contact us at meetings@geosociety.org.

Services & Accommodation Requests

If you would like to talk with someone to request accommodations (e.g., sign language interpreters, alternative formats), please check the box during the registration process and a GSA staff member will follow up with you. Advanced notice is necessary to arrange for some accessibility needs.

Dietary

If you have dietary considerations and have registered for a ticketed event, field trip, or short course that includes a meal, please check the dietary box during the registration process. Gluten free (GF), vegan (V), and vegetarian options will be available. For all other requests, GSA Meetings staff will follow up with you after you have registered for the meeting. After 26 Sept., we cannot guarantee the availability of a special meal.

Self-Care Room

This multipurpose room can be used to carve out space for you to nap, meditate, or take your mind from a state of anxiety into a state of relaxation. The room will be available Sat.–Wed., 15–18 Oct., 8 a.m.–5 p.m., at the David L. Lawrence Convention Center (DLCC). To access the room, please stop by the GSA registration area.

Animals

The DLCC does not allow animals into the building except for service animals.

Nursing Suites

On the second level of the DLCC, we offer a dedicated private space for nursing mothers and parents of newborns/infants. When at the DLCC, please ask a staff member for the location and how to gain access.

Assisted Hearing Devices

GSA has assisted hearing devices, Williams Sound PockeTalker, available for use during the meeting. Please visit the Information Desk on the 2nd level by registration at the DLCC to check one out. All you'll need is an ID.

Communications Access Realtime Translation (CART)

GSA is partnering with Visible Voices to provide their Communication Access Realtime Translation (CART) services for all Pardee Keynote Symposia, Presidential Address & Awards, Noontime Lectures, Special Lectures, and the Halbouty Distinguished Lecture. CART is an instant translation of the spoken word into English text. The text then appears on a laptop, monitor, or other display depending on the environment.

Childcare

Are you seeking childcare services during your visit to GSA Connects? Jovie is a nationwide reliable and vetted service provider. Their services can be offered at your hotel or home, and they offer a flexible service plan.

Please contact the Pittsburgh office and schedule an appointment:

- +1-412-837-2353
- pittsburghpa@jovie.com
- www.jovie.com/locations/pa/pittsburgh/jovie-of-pittsburgh.html

Celebrate the Excellence of our Geoscience Community!

GSA Presidential Address & Awards Ceremony

Hear from president **Chuck Bailey** about the joy of discovery in geoscience research and its relevance for understanding our home planet and the future in his presentation:

"Geoscience at the Confluence"

Sun., 15 Oct., noon–1:30 p.m.
Ballroom B/C, David L. Lawrence Convention Center

Honor your colleagues during the awards ceremony! Emcee President-Elect Carmala Garzione will announce the 2023 GSA Medal Awardees, Division Awardees, new GSA Fellows, and more.

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Let's Make This a Respectful, Inclusive Scientific Event (RISE)

GSA takes pride in offering safe, professional, inclusive events in which participants with diverse backgrounds and points of view feel welcome and can count on being treated with dignity and respect. By attending this meeting, you agree to comply with GSA's Events Code of Conduct and make GSA Connects 2023 a Respectful, Inclusive Scientific Event (RISE). Here are some simple ways you can make this a positive, engaging, and welcoming experience for everyone:

SHOW RESPECT

- Keep questions concise and on topic.
- Be considerate and listen with an open mind.
- Be constructive—critique ideas, not people.
- Avoid saying or doing anything that is or is likely to be perceived as harassment or bullying.

SPEAK UP AND ACT RESPONSIBLY

- Read and comply with GSA's Events Code of Conduct.
- Ask questions or report concerns—openly or anonymously—to our third-party hotline provider.
  - Internet: geosociety.ethicspoint.com
  - Phone: +1-844-237-8688
  - Mobile: geosociety.navexone.com
- Or direct any questions or concerns to ethics@geosociety.org or any GSA staff member or RISE Liaison.

BE INCLUSIVE

- Demonstrate that you welcome a diversity of individuals and their identities.
- Show that you value different perspectives.
- Be mindful of potential biases and avoid comments and behaviors that are likely to make others feel unwelcome or uncomfortable based on any identity-based factors. Harassment and bullying are never acceptable regardless of intent.

THINK TWICE ABOUT RECORDING AND SHARING PRESENTERS' CONTENT

- Presenters and conveners may choose not to allow photographs or audio/video recordings of their work and may not authorize others to distribute such information via social media or other channels.
- Find out what is deemed acceptable before taking pictures, making recordings, or sharing content for any purpose outside of this event.

GSA takes all concerns seriously and will take action against individuals found to have violated the Events Code of Conduct. Such action may include but is not limited to requiring offenders to leave the event without refund.

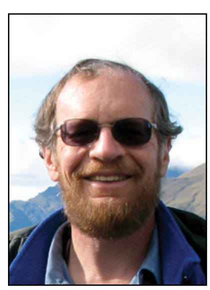
Presidential Address

Sun., 15 Oct., noon–1:30 p.m.

Christopher (Chuck) Bailey, "Geoscience at the Confluence"

The 2023 GSA Connects meeting in Pittsburgh, Pennsylvania, occurs at the confluence of the Allegheny and Monongahela rivers which come together to become the mighty Ohio River. Using confluence as a metaphor, the Presidential Address will place the geosciences at the confluence of time and place. This wide-ranging talk will highlight the joy of discovery in geoscience research and its relevance for understanding our home planet and the future.

Noontime Lecture



Mon., 16 Oct. 12:15–1:15 p.m.

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

The ocean is rising into coastal communities because of human-caused warming. Ice loss from Antarctica and Greenland is contributing, and could accelerate in the future. History and physics show that warming melts ice, and that too much warming can trigger rapid iceberg calving. Modern visitors to Glacier Bay in Alaska can now sail more than 60 miles into a fjord that held ice up to a mile thick when George Vancouver visited in 1794, and many other fjords have similarly "unzipped" into their mountains or ice sheet. If retreat of this type is triggered in any of the major Antarctic basins holding far more ice, more than 10 feet of additional sea-level rise could occur in the following century or less. Despite rapid scientific advances, large uncertainties remain. This presentation will explore the solid and speculative issues on sea-level rise.

Student and Early Career Professionals

Let's Connect!

GSA Connects offers an abundance of opportunities for students and early career professionals to learn and grow. Join us in Pittsburgh to network, find out about geoscience career paths, and discover exciting new science.

Did you know that there are multiple ways for students to receive discounts or funds to attend GSA Connects? We offer student travel grants, free registration for student volunteers, short course discounts, and much more!

For more information and to get involved please visit:
community.geosociety.org/gsa2023/connect/student-ecp

Pittsburgh Local Transportation

TAXI AND RIDESHARE SERVICE

Average taxi fare from the airport to downtown Pittsburgh is $40+. Uber and Lyft are available at the airport, as well as zTrip, a non-surge charge taxi service with mobile app and phone booking options. Download the app or call +1-412-777-7777 for more information about zTrip. Upon arrival at the airport, follow signs for ground transportation. Rideshare pickup is at Baggage Claim Door #4 at the Commercial Arrivals Curb.

Once you're in Pittsburgh, all major hotels in the downtown area have taxis waiting outside their front doors. You can also easily book an Uber, Lyft, or zTrip, or call the following taxi companies to book a ride:

Pittsburgh Transportation Group: +1-412-444-4444
VETaxi: +1-412-481-8387

PITTSBURGH REGIONAL TRANSIT (PRT)

From the Airport: 28X Airport Flyer

One-way fare to/from the airport is $2.75; exact change is required and fares are paid upon boarding. A ticketing vending machine is located at the airport, and mobile ticketing options are available. Go to https://www.rideprt.org/pdfs/28X.pdf to find the current schedule. From the airport, board the 28X Airport Flyer at Lower Level Baggage Claim, Door #2. Get off at Seventh Ave. at William Penn Pl. for the David L. Lawrence Convention Center and the Westin Pittsburgh. For additional information, please visit https://www.rideprt.org/.

Around Town

Pittsburgh Regional Transit (PRT) has three dedicated busways, a light rail system, and two funicular railways (the Monongahela and Duquesne Inclines) to make getting around Pittsburgh quick and easy. PRT's fleet of 700 buses operate 365 days a year, servicing more than 7,000 stops throughout Allegheny County, and the "T," a 26.2-mile light rail system, runs from the North Shore and downtown Pittsburgh through Pittsburgh's southern neighborhoods and many South Hills suburbs. PRT also sponsors the ACCESS program, the nation's largest paratransit program of its kind for senior citizens and persons with disabilities. Contact Pittsburgh Regional Transit at https://www.rideprt.org/ for schedules and other valuable information on how to navigate Pittsburgh. Travel within downtown Pittsburgh (the Triangle) is FREE.

Pittsburgh Regional Transit: +1-412-442-2000.

PARKING

ParkPGH is the smartphone app that provides real-time parking availability for garages in Pittsburgh's Cultural District. You can find parking near you by downloading the ParkPGH app, visiting the website, https://parkpgh.org/, texting "PARKING" to 412-423-8980, or calling +1-412-423-8982.

There are over 20,000 parking spaces in Downtown Pittsburgh operated by ALCO Parking and the Pittsburgh Parking Authority. On-street metered parking is also available in downtown Pittsburgh. Look for the nearest kiosk after parking to pay using your license plate number.

STUDENT & EARLY CAREER

NIGHT AT THE MUSEUM

15 OCTOBER 2023
TICKETS: $25

SENATOR JOHN HEINZ HISTORY CENTER
IN ASSOCIATION WITH THE SMITHSONIAN INSTITUTION

INVITED GUESTS:

GSA FELLOWS
TICKETS: $65

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TICKETS AVAILABLE FOR PURCHASE DURING 2023 CONNECTS REGISTRATION

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THE GEOLOGICAL SOCIETY OF AMERICA® CONNECTS 2023 15–18 October Pittsburgh, Pennsylvania, USA

GEOLOGY CLUB MEET UP

Network with students from other universities by sharing ideas and resources at GSA Connects on Tuesday, 17 Oct. from 9–10 a.m.

GSA is creating events specifically for geology clubs, attend for more information!

THE GEOLOGICAL SOCIETY OF AMERICA® CONNECTS 2023 15–18 October Pittsburgh, Pennsylvania, USA

Pittsburgh's Geoheritage: A Legacy of Late Paleozoic and Pleistocene Glacial Events

Lon Abbott** and **Terri Cook

When thousands of geologists gather in Pittsburgh this October for GSA Connects 2023, their scientific discussions will unfold at the nexus between Carboniferous land and sea and between Pleistocene water and ice. These nexuses, separated by 300 million years of geologic time and both resulting ultimately from global glacial episodes, sculpted western Pennsylvania's landscape and shaped Pittsburgh's human history. A delightful day trip 65 km northwest of Pittsburgh to McConnells Mill State Park puts this geological heritage on scenic display.

Western Pennsylvania's bedrock consists exclusively of upper Carboniferous sedimentary rock so noteworthy that the upper Carboniferous in North America is named the Pennsylvanian Period. The cyclic repetitions of interbedded sandstone, shale, coal, marine and lacustrine limestone, and chert horizons, associated with layers and nodules of siderite, an iron carbonate mineral, are textbook examples of the famous cyclothems (Riegel, 1991; Hannibal et al., 2011) exposed across vast portions of the American Midwest.

During Pennsylvanian time, what is now western Pennsylvania consisted of a huge delta that straddled the equator and was fed by rivers draining the actively rising Appalachian Mountains (Fleeger et al., 2003). Because of Pittsburgh's equatorial position, the Late Paleozoic Ice Age affected Pittsburgh indirectly, albeit profoundly. Repetitive growth and shrinkage of ice caps at Gondwana's high latitudes, driven by 100 ky and 400 ky Milankovitch Cycles, triggered repeated transgressions and regressions across the delta (Brezinski and Kollar, 2011). Those sea-level fluctuations produced the repetitive cyclothems, which included valuable coal, oil-producing black shales, chert, and iron ore—raw materials that Pittsburgh's human inhabitants would harness 300 million years later and that would eventually fuel Pittsburgh's rise as a great industrial city in the 19th and 20th centuries.

McConnells Mill and the nearby covered bridge. Photo by DodgeDart via Wikimedia Commons. https://creativecommons.org/licenses/by-sa/4.0/deed.en.

During the last 2.7 million years—the Pleistocene Ice Age—the globe once again cooled to the threshold temperature necessary for Milankovitch orbital forcing to trigger glacial-interglacial cycles. During each glacial advance, the Laurentide ice sheet crept south out of Canada into northwestern Pennsylvania, stopping each time just short of Pittsburgh. The region's preglacial river network flowed generally northwestward, so as the penultimate Pleistocene ice sheet retreated northward ~135 ka, its glacial ice dammed those preexisting valleys, which filled with meltwater to create a series of glacial lakes. As lake levels rose, they overtopped local drainage divides and carved canyons through them, thereby stitching together today's Ohio River network that drains southward to the Gulf of Mexico.

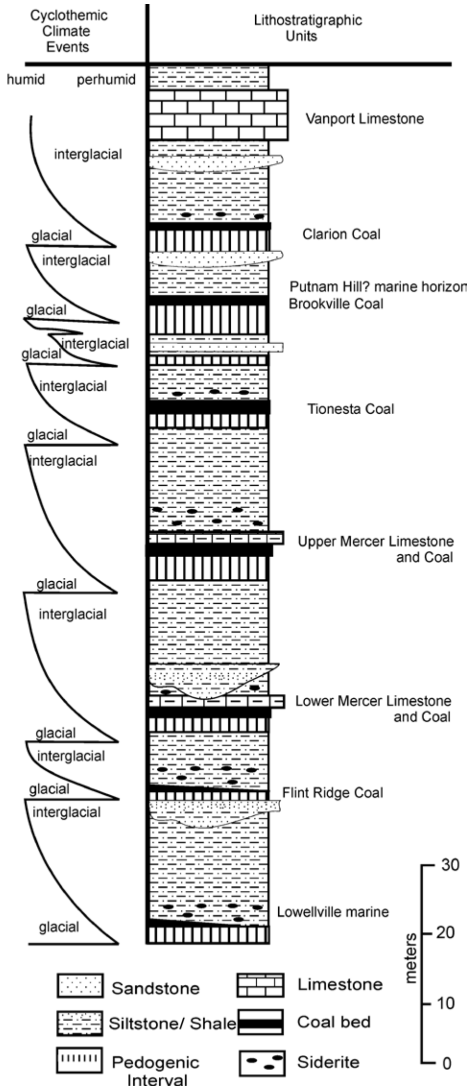
HOW HUMANS HARNESSED CARBONIFEROUS CYCLIC SEDIMENTATION

Western Pennsylvania's first human inhabitants used the cyclothems for shelter 14,000 years ago. The Meadowcroft Rockshelter, 48 km southwest of Pittsburgh, contains the oldest record of human habitation in North America (Swaminathan, 2014). A shallow cave, excavated from Birmingham shale, one cyclothem component, is sheltered by an overhang made of resistant Morgantown sandstone, another component deposited on a river point bar (Benyon and Donahue, 1982). The abundant stone tools recovered from the ^{14}C-dated cave sediments were fashioned from chert and jasper components of regional cyclothems (Goodyear, 2005).

Descendants of the Meadowcroft people have occupied the Pittsburgh area ever since. When the first Europeans arrived in the 1600s, the area's two dominant Native American cultures belonged to two distinct language groups—the Algonkian and the Iroquoian (Pennsylvania Historical and Museum Commission, 2015). Both groups relied on the geologic raw materials they derived from the Pennsylvanian cyclothems. For example, for hundreds of years members of the Seneca Nation, part of the Iroquois Confederacy, collected oil from seeps for use as a salve, insect repellent, and tonic (Ginsburg, 2009). When the Europeans arrived, they weren't interested in the oil—yet. They focused instead on the chert, to make millstones (Hannibal et al., 2011), and on the siderite iron ore; Pennsylvania's first iron smelter was erected in 1692 (Gray et al., 2015).

Over time, tensions rose over resource access, between both the Euroamericans and Native Americans and the English-speaking and French-speaking colonists. Pittsburgh got its start in 1754 when, at the recommendation of a young military commander named George Washington, the English constructed Fort Prince George at the strategic confluence of two mighty rivers, the Allegheny and Monongahela, which together form the Ohio River downstream.

https://doi.org/10.1130/GSATG112GH.1



Stratigraphic section of upper Pottsville Formation and lower Allegheny Formation rocks exposed along U.S. 422 at Moravia Street Interchange, New Castle, Pennsylvania (modified from Skema, 2005). This interval is interpreted to have been deposited during the early Pennsylvanian humid period. Climatic cycles (left column) are interpreted to be the Appalachian equivalent to Midcontinent cyclothems produced during repeated advances and retreats of high-latitude continental glaciers. (From Brezinski and Kollar, 2011.)

The French captured the fort just one month later at the beginning of the French and Indian War (Gray et al., 2015).

The war ended in 1763 with the British firmly in control of Pennsylvania. English-speaking American colonists began moving to western Pennsylvania in large numbers. The area's first industries were sawmills and gristmills. McConnells Mill, the centerpiece of the eponymous state park, is a picturesque example of an early gristmill. Mills were constructed wherever a sufficient drop occurred on a river to turn the wheel; McConnells Mill was built in 1870, sited where Slippery Rock Creek tumbles over a ledge of resistant Homewood sandstone. The mill is equipped with a buhrstone grinding wheel. Burhstone is a light-colored chert abundant in the local cyclothems; it was the premier material used for making millstones (Hannibal et al., 2011).

THE RISE OF PITTSBURGH AS AMERICA'S IRON AND STEEL CAPITAL

Iron smelters quickly followed the mills as economic engines thanks to the abundance of 30–40%-pure siderite iron ore and limestone—another legacy of the cyclothems—and expansive hardwood forests from which the colonists made charcoal to fuel the furnaces. More than 60 iron furnaces were operating by the onset of the Revolutionary War (Gray et al., 2015).

The growing economy's voracious appetite for trees used in smelting and building meant that the once-extensive forest nearly vanished by the 1850s. But the region's abundant coal easily replaced charcoal as fuel for the blast furnaces (Hannibal et al., 2011). By the 1870s, Superior Province iron ore supplanted the local siderite, sounding the death knell for many rural smelters (Fleeger et al., 2003). But Pittsburgh's iron industry was already firmly established, and the city's abundant coal reserves ensured that it continued to flourish. By 1911, Pittsburgh-produced steel accounted for nearly half of total U.S. production (Gray et al., 2015).

Hells Hollow in McConnells Mill State Park is a scenic place to see remnants of western Pennsylvania's early iron industry. A gentle creekside trail traverses Vanport limestone, an especially thick marine limestone deposited during a particularly high sea-level stand. The Vanport is called a "ferriferous limestone" because of the high iron content at the top of the formation (Fleeger et al., 2003). The Lawrence iron smelter was built here in 1846 because of this convenient juxtaposition of iron ore and limestone, the latter used as flux to remove impurities. The smelter lies on private land, but the trail passes a shallow quarry and adjacent lime kiln. The Vanport limestone has developed karst drainage, with disappearing streams that gave the Hollow a fearsome reputation (Hannibal et al., 2011). A narrow, flume-like section of creek flows along a collapsed karst cave (Fleeger et al., 2003). The trail ends at Hells Hollow Falls, which cascades over a ledge of resistant Clarion sandstone.

PLEISTOCENE CREATION OF THE OHIO RIVER SYSTEM

Pittsburgh owes its location to its strategic geography at the head of the Ohio River, but prior to establishment of the modern drainage network 135 kyr, its location wouldn't have been especially strategic. The scenic gorge of Slippery Rock Creek in McConnells Mill State Park puts this reorganization on scenic display.

The gorge's deepest (at 120 m) and narrowest point is seen from the Cleland Rock scenic vista. The vista is particularly spectacular during peak fall foliage, which should occur during GSA Connects 2023. Gorge depth decreases to both north and south of Cleland Rock, as does the stream gradient—28 ft/mile in the gorge, diminishing to 8 ft/mile outside it (Fleeger et al., 2003). Both characteristics result from the gorge's position on the Pleistocene drainage divide. Back then, the section of modern Slippery Rock Creek south of Cleland Rock was a small, south-flowing drainage that geologists call Wurtenburg Run. The section to the north was an equally small, north-flowing drainage named McConnells Run. The Laurentide ice sheet blocked northward-draining McConnells Run, filling it with glacial meltwater to form Lake Prouty. When the lake reached the height of Cleland Rock, it spilled southward into Wurtenburg Run, linking the upper and lower portions of today's Slippery Rock Creek and cutting the modern gorge.

Today, Muddy Creek, a west-flowing Slippery Rock tributary 10 km northeast of McConnells Mill State Park, is impounded by a

Hells Hollow Falls at McConnells Mill State Park. Photo by J7u via Wikimedia Commons. https://creativecommons.org/licenses/by-sa/4.0/deed.en.

dam to form Lake Arthur, which is the centerpiece of Moraine State Park. Lake Arthur is a smaller modern version of Pleistocene Lake Watts, which was dammed by the Laurentide ice sheet. Progressive ice-sheet retreat caused Lake Watts to spill southward through a succession of low points on the intervening drainage divide. Geologists call these spill points Alpha, Beta, and Gamma passes (Fleeger et al., 2003). Alpha Falls tumbles over a resistant ledge of Homewood sandstone at the first Lake Watts spill point. Even larger glacial lakes—Lake Edmund to the north and Lake Monongahela, which covered Pittsburgh itself, to the south—formed similarly in response to glacial damming of the preexisting drainage (Fleeger et al., 2003; Kollar and Noe, 2022). The cumulative effect of multiple glacial lake spillover events stitched several previously separate river segments together to form today's Allegheny River, which joins the Monongahela at Pittsburgh to form the Ohio.

BIRTH OF THE U.S. OIL INDUSTRY

Moraine State Park is a great place to learn about the history of Pennsylvania's oil industry, yet another legacy of the Carboniferous cyclothems thanks to their oil-producing black shale components. The most famous chapter of the story unfolded 110 km to the north in Titusville, where in 1859 Edwin Drake drilled the first commercial oil well. Drake was inspired by the existence of abundant oil seeps across western Pennsylvania in the 19th century. Slippery Rock Creek's name comes from an oil-covered rock at a Native American ford 10 km downstream of McConnells Mill (Fleeger et al., 2003). Similar seeps fouled Samuel Kier's salt brine wells at Tarentum, 30 km north of Pittsburgh. One day Kier noticed that the oil closely resembled a potion his wife used regularly, so in 1852 he began marketing it as "Rock Oil" for medicinal purposes. He later distilled it for use in oil lamps (Gray et al., 2015), generating a market.

A drilling boom quickly followed Drake's success, and by 1862 Pennsylvania produced 3 million barrels of oil per year, surpassing Russia as the world's largest oil producer (Gray et al., 2015). The Muddy Creek Field was discovered at modern Moraine State Park in 1891. Well #19 has been transformed into the Muddy Creek Oil Well Living History exhibit, which includes a Bessemer gas engine, the type that powered late 19th century wells. Volunteers periodically rev it up so visitors can witness how America's early oil industry operated (Carter and Sager, 2010).

Taking a day trip to McConnells Mill State Park from GSA Connects 2023 is an opportunity to admire fall foliage at the rim of a scenic gorge carved by spillage of Pleistocene glacial lakes. It's also a great way to acquaint yourself with Carboniferous cyclothems, their abundant raw materials, and the industries that relied on them. We can think of no more graphic illustration of geoheritage—the recognition that geologic processes sculpt all landscapes and that every human activity is fueled by resources that are a legacy of local geologic history.

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ATTENTION

In an effort to inspire the next generation of geoscientists, GSA and Association for Women Geoscientists are looking for photos of women working geoscience roles for a Pardee Keynote Symposium, *Spotlight on Positive and Diverse Female Role Models.*

Here's how to submit your photos:

1. Find two photos (.jpg) and crop them to square. Name the files firstname_lastname.jpg
2. Start an email to diverse.geos2023@gmail.com
3. Attach your photos and send us your name, occupation, employer, and location.
4. Press SEND!

WHERE DO YOU DO YOUR SCIENCE?

Please attend this Pardee Session:

SPOTLIGHT ON POSITIVE AND DIVERSE FEMALE ROLE MODELS

Monday, 16 Oct. from 1:30–5:30 p.m.
Pittsburgh, Pennsylvania

This session will be followed by the popular Women in Geology Mentor Reception from 5:30–7:00 p.m. enabling you to meet with positive, diverse role models.

Association for Women Geoscientists

THE GEOLOGICAL SOCIETY OF AMERICA®

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MENTAL HEALTH WORKSHOP

"An opportunity to break the barriers between mental health and geology."

INVITEES

- Students
- Professionals
- Academics

WHEN

Thursday, 19 October
8 a.m. - 5 p.m.
After GSA Connects

WHERE

Omni William Penn Hotel
530 William Penn Place
Pittsburgh, PA 15219

About

GSA recognizes the challenges and stressors geoscientists face and the impact these obstacles have on the personal and professional lives of members of our community.Our leadership is working toward creating a dedicated resource center that will provide comprehensive support and materials that promote mental health and well-being.

If you have a passion or interest in improving the mental health climate in our community, please apply to attend this one-day workshop, *Encouraging Positive Mental Health in the Geosciences.* This opportunity is supported and funded by the National Science Foundation, proposal # 2329987.

Those selected to participate will receive either a $450 honorarium or a $250 honorarium, plus a one-night hotel stay for Wednesday, 18 October.

Subscribe for application information:
https://bit.ly/GeosocietyWorkshop

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PRELIMINARY ANNOUNCEMENT AND CALL FOR PAPERS

Northeastern Section

59th Annual Meeting of the Northeastern Section, GSA

Manchester, New Hampshire, USA
17–19 Mar. 2024

www.geosociety.org/ne-mtg

Credit: iStock.com/William Reagan

LOCATION

The meeting will be held in Manchester, New Hampshire, USA, the largest city in northern New England. Manchester is situated on the Merrimack River about 50 miles northwest of Boston and 60 miles south of the White Mountains. The meeting location is the DoubleTree by Hilton, in the heart of downtown, less than 10 miles from the Manchester-Boston Regional Airport (MHT) and proximal to a wide variety of shops and restaurants. The location, situated between the Atlantic coast and White Mountains, offers many opportunities to experience picturesque New England. We invite you to join us at Manchester 2024, where we have developed a strong technical program that covers a broad scope of geologic topics and discussions on the recruitment of the next generation of geoscientists.

CALL FOR PAPERS

Abstracts deadline: 12 Dec. 2023, 11:59 p.m. PST
Submit online at **www.geosociety.org/ne-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, hclark@geosociety.org.

TECHNICAL PROGRAM

Symposia

S1. **Applied Investigations by Northeastern State Geological Surveys: Honoring the Tradition of Robert Marvinney.** Amber Whittaker, Maine Geological Survey, amber.h.whittaker@maine.gov; Shane Csiki, New Hampshire Geological Survey, shane.csiki@des.nh.gov; Benjamin DeJong, Vermont Geological Survey, benjamin.dejong@vermont.gov.

This session will provide staff members of State Geological Surveys and their coauthors the opportunity to provide updates on their technical investigations and how such work directly supports and integrates with societal needs.

S2. **Neoproterozoic and Paleozoic Geological Connections Among Northwest Africa, Europe, and Eastern North America—A Session Honoring the Career of Sandra M. Barr.** *Endorsed by GSA Structural Geology and Tectonics Division; GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division.* Yvette Kuiper, Colorado School of Mines, USA, ykuiper@mines.edu; Margaret Thompson, Wellesley College, USA, mthompso@wellesley.edu; Chris White, Acadia University, Canada, chrisewhite@gmail.com; Saïd Belkacim, Ibn Zohr University, Morocco, s.belkacim@uiz.ac.ma; Faouziya Haissen Hassan II, University of Casablanca, Morocco, faouziya.haissen@gmail.com; Pilar G. Montero, University of Granada, Spain, pmontero@ugr.es.

We invite contributions focused on geological comparisons and potential correlations among Neoproterozoic (or older) and Paleozoic rocks in northwest Africa, Europe, and eastern North America, or on the Alleghanian/Variscan/Hercynian orogen, as part of IGCP 683. This session is a celebration of the career of Sandra M. Barr.

Theme Sessions

T1. **Unveiling Pathways into the Geological, Atmospheric, Marine, and Environmental Sciences.** Julie Bryce, University of New Hampshire, julie.bryce@unh.edu; Jennifer Bourgeault, University of New Hampshire, jen.bourgeault@unh.edu; Florencia Fahnestock, University of New Hampshire, florencia.fahnestock@unh.edu; Lara Gengarelly, University of New Hampshire, lara.gengarelly@unh.edu; Gulnihal (Rose) Ozbay, Delaware State University, gozbay@desu.edu; Ruth Varner, University of New Hampshire, ruth.varner@unh.edu.

The geological, atmospheric, marine, and environmental sciences (GAMES) play crucial roles in addressing 21st century global challenges. Here we invite presentations from those working to enhance participation in GAMES with innovative programs engaging the K–12 community, convergent research, citizen science, private-public partnerships, and collaboration with communities insufficiently represented in GAMES.

T2. **What is the Future of Field Camp?** Sara Mana, Salem State University, smana@salemstate.edu; Lauren Neitzke Adamo, Rutgers University, lneitzke@eps.rutgers.edu; Morgan Schaller, Rensselaer Polytechnic Institute, schall@rpi.edu.

This session aims to advance the conversation about creating effective field-based learning experiences, emphasizing the skills, workforce needs, sustainable and inclusive best practices, and technological advances that will shape the next generation of geoscientists. Diverse perspectives and presentations on pilot studies, curriculum design, and measured results are encouraged.

T3. **Northern Appalachian Magmatism: From the Precambrian to the Cretaceous.** Michael J. Dorais, Brigham Young University, dorais@byu.edu; Sean Kinney, Columbia University, kinney@ldeo.columbia.edu; Jennifer Cooper Boemmels, Southern Connecticut State University, cooperj1@southernct.edu.

The northern Appalachians contain igneous rocks with a variety of compositions and ages from Precambrian through Cretaceous. Tectonic settings include subduction zones, continent to continent collisions, supercontinental rifting, passive margin, and anorogenic settings. We invite submissions that portray the diversity of igneous rocks throughout the region.

T4. **Recent Advances in the Crystalline Basement of the Adirondack and Appalachian Orogens.** Erkan Toraman, Salem State University, etoraman@salemstate.edu; Gregory J. Walsh, U.S. Geological Survey, gwalsh@usgs.gov.

Basement massifs form the foundation of the Appalachian and Adirondack Mountains. This session will focus on a broad range of approaches from field and analytical studies that will provide insight into the origins of the crystalline basement and improve our understanding of the terrane affinities in both orogenic belts.

T5. **The Missing, Near-Missing, and Cryptic Geologic Record of the Northern Appalachian Orogen.** Dwight Bradley, Dartmouth College Visiting Scholar, bradleyorchard2@gmail.com; Justin Strauss, Dartmouth College, justin.v.strauss@dartmouth.edu; Doug Reusch, University of Maine Farmington, reusch@maine.edu.

This session focuses on gaps and near-gaps in the geologic record of the Northern Appalachians, and on the tools that help to elucidate them. We invite submissions on detrital geo-thermo-chronology and provenance, xenoliths and roof pendants, crystallization depths of plutonic rocks, reconstructed crustal thicknesses, cryptic metamorphic events, and more.

T6. **New Insights into Convergent Margin Processes from Collaborative Field and Laboratory Studies Programs in Northern New England and Quebec.** David Converse, New Hampshire Statemap Program, drconverse7@gmail.com; Joshua Keeley, New Hampshire Geological Survey, joshua.a.keeley@des.nh.gov; Morgann Perrot, McGill University, perrot.morgann@uqam.ca; Wallace Bothner, University of New Hampshire, wally.bothner@unh.edu; Lori Summa, Rice University, llsumma@att.net.

The Appalachians of northern New England and Quebec preserve a unique record of overlapping orogenic events. Recent multidisciplinary field and laboratory studies have provided an exceptional opportunity to gain insights into regional orogenic processes through collaboration among multiple government agencies and universities. This session showcases highlights of recent efforts.

T7. **Unraveling Appalachian Orogenic Events Using Geological and Geophysical Methods.** *Endorsed by GSA Geophysics and Geodynamics Division; GSA Structural Geology and Tectonics Division.* Maureen Long, Yale University, maureen.long@yale.edu; Yvette Kuiper, Colorado School of Mines, ykuiper@mines.edu; Paul Karabinos, Williams College, pkarabin@williams.edu; Laura Webb, University of Vermont, lewebb@uvm.edu.

We invite any contributions that focus on unraveling the tectonic history of the Appalachians using geological and geophysical methods. Work based on geological OR geophysical methods, where the other method is desired, is welcome too. The purpose is to enhance discussion between geologists and geophysicists.

T8. **Micro to Macro: Linking Structural Geology, Petrology, Geochronology, and Tectonics across Scales.** *Endorsed by GSA Geochronology Division; GSA Structural Geology and Tectonics Division; GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division.* Emily Peterman, Bowdoin College, epeterma@bowdoin.edu; Nicholas Roberts, Hamilton College, nmrobert@hamilton.edu.

This session will highlight research in structural geology, petrology, and geochronology that connects microscale observations and data to their macroscopic structural and/or tectonic settings. We welcome contributions from experimental, laboratory, and/or field research and encourage contributions from early career researchers and students.

T9. **Clocks in Rocks: Radiogenic Isotope Tracers for Tectonic, Climatic, and Biotic Processes.** *Endorsed by GSA Geochronology Division; GSA Structural Geology and Tectonics Division; GSA Geobiology Division.* Athena Eyster, Tufts University, athena.eyster@tufts.edu; Emily Peterman, Bowdoin College, epeterma@bowdoin.edu; Cullen Kortyna, University of Connecticut, cullen.kortyna@uconn.edu; Kyra Croft, Boston College, croftky@bc.edu; Dylan Seal, Boston College, seald@bc.edu.

Geochronologic and radiogenic isotope datasets are critical for understanding the interdependent processes involved in the evolution of Earth. We invite contributions that quantify timing, calibrate tempos, and/or test models for the evolution of tectonic, climatic, and biotic processes in the Appalachians and globally, across all spatial and temporal scales.

T10. **Glacial Geology and Geomorphology of Northeastern North America: Current Gaps and Future Directions.** *Endorsed by GSA Quaternary Geology and Geomorphology Division.* Simon Pendleton, Plymouth State University, simon.pendleton@plymouth.edu; Alia Lesnek, CUNY Queens College, alia.lesnek@qc.cuny.edu; Aaron Barth, Rowan University, bartha@rowan.edu.

While glaciation and its impacts on northeastern North America have been widely studied for more than a century, gaps still remain in our understanding of regional glacial histories and processes. We propose a session that highlights the current state of glacial geology and geomorphology research in northeastern North America.

T11. **Phosphorus Contributions to Cyanobacteria Blooms by Groundwater, Surface Water, and Internal Sediment Loading in Northeastern Lakes.** Edwin Romanowicz, SUNY Plattsburgh, romanoea@plattsburgh.edu; Peter Ryan, Middlebury College, pryan@middlebury.edu; Jonathan Kim, Vermont Geological Survey, jon.kim@vermont.gov.

Many lakes are impacted by high phosphorus concentrations. Quantifying the phosphorus budget of lakes requires an understanding of external loading and the recycling of phosphorus from lake sediments due to water temperature and anoxia. We seek presentations on lake phosphorus budgets and the effects of phosphorus loading on water quality.

T12. **Current Research in Lacustrine Sedimentary Records and Processes for Understanding Climate and Environmental Change.** *Endorsed by GSA Limnogeology Division; GSA Quaternary Geology and Geomorphology Division; GSA Sedimentary Geology Division.* Mike Retelle, Bates College, mretelle@bates.edu; Tim Cook, University of Massachusetts, tlcoo0@umass.edu; Catherine Beck, Hamilton College, ccbeck@hamilton.edu; Brad Hubeny, Salem State University, bhubeny@salemstate.edu.

Lacustrine sediments provide reconstructions of climate and environmental change across a range of spatial and temporal scales, allowing for assessment of recent changes in a long-term context. We encourage presentations on lake sediment records and process studies that aid in calibration of the sediment archive and record current changes in the lacustrine system.

T13. **Reassessing New England's Postglacial Paleoclimate Record.** Lisa Doner, Plymouth State University, ladoner@plymouth.edu.

New England lakes were some of the first to focus on postglacial climate change. Many of these publications are more than 40 years old and focused primarily on stadials. This session invites reports that use new and traditional methods to understand transitions into warm intervals in northeastern North America.

T14. **Phanerozoic Paleoceanographic and Climatic Changes (Posters).** Adriane R. Lam, Binghamton University, alam@binghamton.edu; Stephen Pekar, CUNY Queens College, stephen.pekar@qc.cuny.edu.

This poster session brings together modeling and proxy studies to improve our understanding of past ocean and climate events and of changes between long-term climate/ocean conditions throughout the Phanerozoic.

T15. **Development and Application of Organic Geochemical Proxies for Paleoclimate Reconstruction.** Boyang Zhao, Brown University, boyang_zhao@brown.edu; Emily Tibbett, University of Massachusetts Amherst, etibbett@umass.edu.

Organic biomarkers preserved in natural archives offer important insights into the Earth's paleoclimate. We seek studies investigating lipids and their stable isotopic composition to infer environmental and climatic conditions in the present or past. The contributions can be from any timescale and depositional environment, including proxy development studies.

T16. **Global Change During the Late Triassic Hothouse.** Michael Naylor Hudgins, Rensselaer Polytechnic Institute, hudgim@rpi.edu; Morgan F. Schaller, Rensselaer Polytechnic Institute, schall@rpi.edu; Sara Mana, Salem State University, smana@salemstate.edu.

The Late Triassic hothouse is Earth's most recent example of a truly ice-free world, one that witnessed major evolutionary and climatic changes and terminated by a mass extinction and emplacement of the Central Atlantic Magmatic Province. This session invites research in geochemistry, paleogeography, paleontology, paleoclimate, and earth system dynamics during the Late Triassic.

T17. **Trace Elements in the Environment.** Melissa Lombard, U.S. Geological Survey, mlombard@usgs.gov; Benjamin Bostick, Columbia University, bb2461@columbia.edu; Florencia Fahnestock, University of New Hampshire, florencia.fahnestock@unh.edu.

This session will highlight current research that focuses on the sources, occurrence, fate, and transport of trace elements such as arsenic, lead, mercury, and uranium. Presentations and posters are welcome that include trace element occurrence in biota, soil, sediment, groundwater, and surface water, as well as their interfaces and/or interactions.

T18. **Naturally Occurring Radon in the Northeastern U.S. and Globally: Geologic, Hydrologic, and Geochemical Controls on Occurrence and Distribution.** Philip T. Harte, U.S. Geological Survey, pharte@usgs.gov; William C. Brandon, U.S. Environmental Protection Agency, brandon.bill@epa.gov.

This session examines geologic and structural controls on occurrence and distribution of radon-222 (and associated uranium-238) in rocks and soil, including geochemical and hydrogeologic influences on formation and migration of radon-222 in vapor and aqueous phases, and methods for mapping, assessing, and mitigating radon occurrence and exposure, including innovative methods.

T19. **Recent Advances in PFAS and Emerging Contaminant Science: From Human Health Risk Assessment to Fate and Transport.** Andrea Tokranov, U.S. Geological Survey, atokranov@usgs.gov; Zachary Hopkins, U.S. Geological Survey, zrhopkins@usgs.gov; Andrew Shapero, Roux, ashapero@rouxinc.com; Sara Barrientos, Roux, sbarrientos@rouxinc.com.

Human health risk assessment for PFAS and emerging contaminants relies on the best available science to support decision making. This session welcomes abstracts on PFAS and emerging contaminant risk assessment, fate and transport, food web transfer, site investigation and remediation, occurrence, regulatory compliance, product testing, air pollution, and litigation.

T20. **Groundwater–Surface Water Interactions: Hydrological and Chemical Processes across Interfaces.** James W. Heiss, University of Massachusetts Lowell, james_heiss@uml.edu; Andrew S. Reeve, University of Maine, asreeve@maine.edu.

Groundwater interaction with surficial systems influences biogeochemical processes, water availability, and ecosystem health. This session includes presentations using monitoring and modeling tools to understand groundwater's importance in near-surface coastal and freshwater environments.

T21. **Advances in Hydrologic Modeling of Groundwater and Surface Water.** Janet Barclay, U.S. Geological Survey, jbarclay@usgs.gov; Kalle Jahn, U.S. Geological Survey, kjahn@usgs.gov.

This session is focused on hydrologic modeling of groundwater and surface water. We welcome submissions across the range of (1) model purposes (flow, transport, water quality, water levels, etc.), (2) modeling approaches (mechanistic, statistical, machine learning, hybrid, etc.), and (3) model development (data compilation, model setup, calibration, uncertainty analysis, prediction).

T22. **The Functions of Floodplains and Wetlands.** Rebecca Diehl, University of Vermont, rebecca.diehl@uvm.edu; Kristen Underwood, University of Vermont, kristen.underwood@uvm.edu.

This session encourages contributions addressing research focused on the measurement or modeling of the multiple functions of floodplains and wetlands, including sequestration of sediment and nutrients, storage of flood waters, and support of diverse riparian plant and animal communities.

T23. **Watershed Processes and the Fluvial Forms and Dynamics They Produce.** Sean Smith, University of Maine, sean.m.smith@maine.edu; Anne Lightbody, University of New Hampshire, anne.lightbody@unh.edu.

Water and sediment supplies govern the shapes and dynamics of streams and rivers and the ecosystem services they provide. This session focuses on fluvial geomorphology, responses of fluvial systems to changes to water and sediment flux from human interventions and climate change, and related watershed management decision making and sustainability solutions.

T24. **Current Research along the Land-Ocean Continuum.** Robert Letscher, University of New Hampshire, robert.letscher@unh.edu; Kai Ziervogel, University of New Hampshire, kai.ziervogel@unh.edu; Cristina Schultz, Northeastern University, c.schultz@northeastern.edu.

Lacustrine, riverine, and coastal marine systems are dynamic incubators of biomass, organic matter, nutrient, and lithogenic particle transformations and transport. These processes are rapidly changing under anthropogenic influence. This session welcomes all research on processes along the land-ocean continuum using field, laboratory, engineering, remote sensing, and modeling approaches.

T25. **Estuary and Tidal Marsh Dynamics, Resiliency, and Restoration.** Tim Cook, University of Massachusetts Amherst, tlcoo0@umass.edu; Brian Yellen, University of Massachusetts Amherst, byellen@umass.edu; Zoe Hughes, Boston University, zoeh@bu.edu.

This session is focused on understanding changes in estuaries and tidal marshes due to human activity, sea-level rise, and changing sediment dynamics. We welcome studies utilizing diverse approaches and are particularly interested in work that diagnoses vulnerabilities to climate change and/or assesses restoration and climate adaptation strategies.

T26. **Current Research in Coastal and Nearshore Processes.** *Endorsed by GSA Marine and Coastal Geoscience Division.* Bryan Oakley, Eastern Connecticut State University, oakleyb@easternct.edu; Mark Borrelli, University of Massachusetts Boston, mark.borrelli@umb.edu.

Marine and lacustrine coastal systems are dynamic. Studies of past and ongoing coastal processes allow for a better understanding of the future impacts of sea-level rise, storms, and the resulting coastal change. This session welcomes all research on coastal/nearshore processes using field, laboratory, engineering, remote sensing, and modeling studies.

T27. **Artificial Intelligence in the Geosciences.** William Odom, U.S. Geological Survey, wodom@usgs.gov; Mary DiGiacomo-Cohen, U.S. Geological Survey, mdicohen@usgs.gov; Phillip Goodling; U.S. Geological Survey, pgoodling@usgs.gov; Aaron Maxwell, West Virginia University, aaron.maxwell@mail.wvu.edu.

Machine learning and deep learning techniques are increasingly used in the geosciences to identify trends in large datasets, classify geologic materials, and model complex systems. This session welcomes all research using AI-based techniques to address geoscientific questions over a range of spatial and temporal scales.

T28. **Mapping in the Geosciences: Processes and Products (Posters).** Gregory Walsh, U.S. Geological Survey, gwalsh@usgs.gov; Jonathan Kim, Vermont Geological Survey, jon.kim@vermont.gov; David Soller, U.S. Geological Survey, drsoller@usgs.gov.

This session creates an opportunity for researchers to share geoscience maps and mapping techniques that are best presented as posters. We welcome all submissions, but especially encourage examples of new bedrock and surficial geologic maps, geophysical maps, and derivative maps, plus topics addressing mapping techniques, data management, and web accessibility.

T29. **Geohazards in the Northeastern U.S.: Investigation and Mitigation.** Lindsay Theis, Maine Geological Survey, lindsay.theis@maine.gov; Peter Slovinsky, Maine Geological Survey, peter.a.slovinsky@maine.gov.

Geohazards have the potential to impact millions of people in the northeastern U.S., especially in the face of changing climate. This session seeks submissions of new research related to characterization of mass wasting, erosion, flooding, and drought events in the northeastern U.S. (coastal or inland), as well as mitigation/remediation strategies.

T30. **Opportunities and Challenges for Geothermal Energy in the Northeast.** J. Matthew Davis, University of New Hampshire, matt.davis@unh.edu.

This session will focus on the growing use of geothermal energy to electrify heating in the Northeast and seeks contributions from researchers, practitioners, policymakers, and other stakeholders. Both low-temperature heat pump applications and higher-temperature direct use applications are of interest.

T31. **Economic Geology and Critical Mineral Resources.** Myles Felch, Maine Mineral and Gem Museum, mfelch@mainemineralmuseum.org; John F. Slack, U.S. Geological Survey (Emeritus), jfslack@gmail.com.

In 2022, the USGS published a list of 50 "critical minerals" and commodities. These resources play a significant role in national security and renewable energy technologies. This session will provide an overview of recent work on newly discovered and revisited critical mineral deposits in northeastern North America.

T32. **Expanding your Professional Capacity: Navigating Leadership, Communication, Mentoring, Work-Life Balance, and Mental Health.** Jennifer Nocerino, The Geological Society of America, jnocerino@geosociety.org, Brandy Myers, The Geological Society of America, bmyers@geosociety.org.

Over the last five years, the workforce and our workplaces have seen many changes, including retirements, resignations, hybrid work, and culture shifts. Some of these changes have positive impacts, such as reducing burnout and increasing our capacity for connecting with our colleagues. This session aims to grow your leadership capacity by providing tools for navigating change, communication and mentoring strategies, boundaries in the workplace, and compassionate mental health practices. Who we are, as a geoscientists, is just as important as the work we do.

We encourage abstract submissions that do not necessarily fit into the above symposia and theme session topics. Additional discipline sessions, organized by topic, will be created to accommodate abstracts that are not submitted to the specific sessions listed above.

TOWN HALL PANEL DISCUSSION

Recruiting the Next Generation of Geoscientists

This panel discussion will feature individuals from colleges and universities, the K–12 community, federal and state geological agencies, and the private consulting industry to discuss the future needs across all sectors of the geoscience community, and the importance of recruiting younger individuals into the geosciences to fulfill these needs.

FIELD TRIP

Field trip registration opens in December. For additional information, or to propose an additional field trip (before 15 Sept. 2023), please contact meeting chair Dave West, dwest@middlebury.edu.

Bedrock Quarries of Southeastern New Hampshire. Michael Wright, RESPEC, michael.wright@respec.com; Kirsten Egan, RESPEC, kirsten.egan@respec.com; Keith Gray, RESPEC, keith.gray@respec.com.

This field trip explores the general geology and production history of active quarry sites located within a 25-mile straight-line radius of Manchester, New Hampshire. Early Paleozoic rocks observed will include the Rangeley, Berwick, and/or Perry Mountain formations, plus the Concord Granite and/or Ayer Granodiorite. Major structures at each site will be discussed.

SHORT COURSES

Short course registration opens in December. For additional information, or to propose an additional short course (before 15 Sept. 2023), please contact meeting chair Dave West, dwest@middlebury.edu.

Teaching Environmental Justice with Geoscience. Gary Gomby, Central Connecticut State University, garygomby@ccsu.edu.

This highly relevant and timely short course describes the rationale for and process involved in teaching environmental justice with a geoscience focus. Case studies contextualize geoscience within a framework of justice and equity, thereby increasing the relevance of basic geoscience to address societal issues.

Using GMDE and LiDAR Texture Shading in the Field and Lab. Richard W. Allmendinger, Cornell University, rwa1@cornell.edu.

This short course covers how to use the GMDE family of desktop and iOS programs for field work and in your teaching, with an emphasis on workflows. The course will use texture-shaded LiDAR digital terrain models (DTMs), which are reminiscent of X-rays through tree cover.

REGISTRATION

Early registration deadline: 13 Feb. 2024
Cancellation deadline: 19 Feb. 2024

Registration opens in December. For further information or if you need special accommodations, please contact meeting chair David West, dwest@middlebury.edu.

ACCOMMODATIONS

Hotel registration deadline: 23 Feb. 2024

A block of rooms has been reserved at the DoubleTree by Hilton Manchester Downtown, 700 Elm Street, Manchester, New Hampshire 03031. The meeting rate is US$159 per night plus tax. The hotel offers many amenities (restaurants, bar, pool, Wi-Fi) and a complimentary shuttle to and from the Manchester-Boston Regional Airport (MHT). Reservations can be made by calling +1-603-625-1000. Please be sure to identify yourself with the group code GEO and say that you are attending the GSA Northeastern Section Meeting. Parking is available at the hotel.

OPPORTUNITIES FOR STUDENTS AND EARLY CAREER PROFESSIONALS

Career Mentoring Luncheons

Ask your career-related questions and learn about nonacademic 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. Nontechnical 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.

Learn more at **www.geosociety.org/mentors/.** Questions? Contact Jennifer Nocerino at jnocerino@geosociety.org.

Student Volunteers

Take advantage of work opportunities to earn free meeting registration. Students interested in helping with the various aspects of the meeting should contact Sara Mana, Salem State University, smana@salemstate.edu.

PROFESSIONALS

If you like to share your interest, enthusiasm, and experience in applied geology, consider being a GSA mentor. Being a mentor is a rewarding experience. To learn more, contact Jennifer Nocerino at jnocerino@geosociety.org.

The Northeastern Section meeting also offers an excellent opportunity to earn CEUs toward your continuing education requirements for your employer, K–12 school, or professional registration. The CEU certificate may be downloaded from the meeting website after the meeting.

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THE GEOLOGICAL SOCIETY OF AMERICA®
Thompson FIELD FORUM

Old or Young?: The Topographic Evolution of the Sierra Nevada, USA

Conveners: Craig Jones, Christopher Henry, Elizabeth Cassel, John Wakabayashi

Participants: Mary Grace Albright, Snir Attia, Mark Brandon, Isabelle Bristol, Cathy Busby, Owen Callahan, Russell Callahan, Joella Campbell, Robinson Cecil, Odin Christensen, Helen Dow (née Beeson), Becky Flowers, Jackie Giblin, Allen Glazner, Emma Heitmann, Mike Hren, Chelsea Hutchens, Jeff Lee, Erin Marsh, Scott McCoy, Matt O'Neal, Chris Pluhar, Sophie Rothman, Joel Scheingross, Greg Stock, Holli Swarner, Haley Thoresen, Dean Tonenna, Alex Tye, Elijah Werlyklein. Jaclyn Hager, Michael Ort, and Fred Phillips participated remotely due to medical issues. In addition, Manny Gabet, Jim Wood, and Jeff Schaffer provided stop suggestions and text for the field guide.

After more than 150 years of geological investigation, the topographic history of the Sierra Nevada remains contentious. Is the range a continuation of a high-elevation Cretaceous Sierran arc? Or is the range a young phoenix, rising from the lower, eroded remnants of the earlier range? A pre-late Cenozoic range indicates Cenozoic erosion has little altered bedrock relief. Likewise, an absence of uplift as a thin crust over a hot upper mantle replaced thicker lithosphere in the eastern Sierra would indicate that foundering of the lower lithosphere is not a significant driver of elevation change here. If the range is young, repeated measurements of paleoelevation proxies are in error or, at minimum, biased high, bringing their broader application into question. A young range rising in a transtensional regime would be an unusual orogenic event. A lower mid-Tertiary elevation to the Sierra impacts interpretations of the Nevadaplano of Nevada-Utah, expanding implications into the interior of the Cordilleran orogen.

This Field Forum (FF) focused on disputed geologic features across much of the northern and central Sierra Nevada that create the observational basis for the large extent of surface uplift and elevation estimates. Sites visited included those with key geologic relations and significant implications for the analytical results of thermochronologic, isotopic-climatologic, paleobotanical, and detrital zircon (DZ) analyses. A variety of specialties has been employed to address this problem, reflecting broad scientific interest in the Sierra Nevada.

Westward-flowing paleorivers that crossed the Sierra Nevada, their channels, and their sedimentary deposits (the "auriferous gravels" and overlying volcanic rocks) were a major focus because (1) the deposits are the only Cenozoic rock record in the Sierra Nevada, even though sedimentary ages are incompletely constrained, (2) the channels record the erosional history, although their initiation and evolution are not well known, (3) when rivers connected the Sierra and the Nevadaplano to the east is a related and debated key question, (4) steeper gradients of transverse versus parallel channel segments in the Sierra have long been used to interpret late uplift (Lindgren, 1911; Hudson, 1955), (5) apparent tilting of late Miocene lava flows in three channels is some of the strongest evidence for late uplift, and (6) the dramatic change from the older, regional, wide, aggrading drainages headed on the Nevadaplano to the modern deep, narrow canyons restricted to the Sierra Nevada must be explained.

Figure 1. Sierra Nevada Field Forum 2022 group photo. Back row, left to right: Cathy Busby, Becky Flowers, Matt O'Neal, Odin Christensen, Joella Campbell, Russell Callahan, Greg Stock, Allen Glazner, Scott McCoy, Craig Jones, Owen Callahan, Jeff Lee (in mask), Emma Heitmann. Middle row, left to right: Liz Cassel, Joel Scheingross, Mike Hren, Jackie Giblin, Mary Grace Albright, Mark Brandon, Chris Henry, Snir Attia, Alex Tye, Sophie Rothman. Front row, left to right: John Wakabayashi, Robinson Cecil, Chelsea Hutchens, Elijah Werlyklein, Isabelle Bristol, Helen Dow, Erin Marsh, Haley Thoresen, Holli Swarner, Chris Pluhar, Dean Tonenna. Photograph by Jennifer Kent, University of Nevada, Reno.

Timing is a critical aspect, considered at many locations throughout the Forum, but only well established for development and initial erosion of the Cretaceous batholith and for Oligocene and younger volcanic and sedimentary deposits. The batholith intruded between ca. 120 and 90 Ma, younging eastward into western Nevada. Low-T thermochronology and Great Valley Group sedimentation demonstrate that the batholith underwent coeval major erosion. Attendee Robinson Cecil reviewed her previous publication documenting the cooling of batholithic rocks to ~180 °C between 90 and 70 Ma and to ~65–70 °C between 70 and 60 Ma (Cecil et al., 2006). The paleorivers probably developed at least as early as Late Cretaceous and certainly existed by 70–60 Ma.

Events between late Cretaceous batholith cooling and the deposition of well-dated, ≤32 Ma volcanic and sedimentary rocks remain poorly dated. During this interval, erosion shifted to deposition in the paleochannels. The largest of the giant, paleoplacer Sierran gold deposits accumulated in the bottoms of paleovalleys. Forum participants paid special attention to these rocks because inferences based on these deposits have led to support for both young and old Sierran uplift models. Auriferous gravels were long considered middle Eocene (ca. 50 Ma; MacGinitie, 1941) based on floral assemblages only present in upper parts of the gravels and incomplete stratigraphic correlation.

Examination of the gravels at several locations, DZ dates (Cassel; Cecil), their clay mineralogy (Wood), and dates of overlying ignimbrites (Henry), as well as reevaluation of the leaves (Hren), revealed that some upper gravels are no older than 41 Ma and as young as 32 Ma (Schorn, 2012). The lowest gravels may be ca. 50 Ma based on clay mineralogy, timing of the Early Eocene climatic optimum, and probable correlation with Ione Formation (Hren, Henry, Cassel, O'Neal, Wood [FF]; Creely and Force, 2007).

Continuity of Sierran rivers eastward into Nevada through time is variably interpreted and was examined on several days. The evolution of overall drainages is significant for interpreting the Sierran deposits as well as providing a broader context for the rivers. What sediment sources were available, the size of drainage basins, and if and how divides were breached all affect interpretations of Sierran erosional and depositional history. Additionally, the connection of Sierran rivers to highlands to the east requires some continuity of topography and structure that expands the constraints on interpretation of Sierran topography as well.

Expanding on published data by Cecil et al. (2006), van Buer et al. (2009), and Sharman et al. (2015) on batholithic and pre-Mesozoic DZ U-Pb ages in auriferous gravels, Cecil (FF) and Tye and Niemi (FF) place an Eocene drainage divide in the modern high Sierra. In contrast, Cassel et al. (2009) and Henry et al. (2012) place a divide in central Nevada at least by the Eocene–early Oligocene partly based on an interpreted 3–4-km-high Nevadaplano (DeCelles, 2004). Detrital zircons as old as 41 Ma might indicate early river continuity from east of the Sierra (Cassel et al., 2012), but the possibility of airborne transport (Tye and Niemi) leaves open a possible late Eocene divide. Henry showed ignimbrite sections that correlate along paleovalleys from central Nevada to the western foothills of the Sierra Nevada, demonstrating river continuity by 31.5 Ma and ending the era of uncertain dates and unresolved drainage areas.

Gold deposits in the aptly named auriferous gravels also play into questions about river continuity. Marsh presented evidence for purely local reworking from Mother Lode veins, which would not require

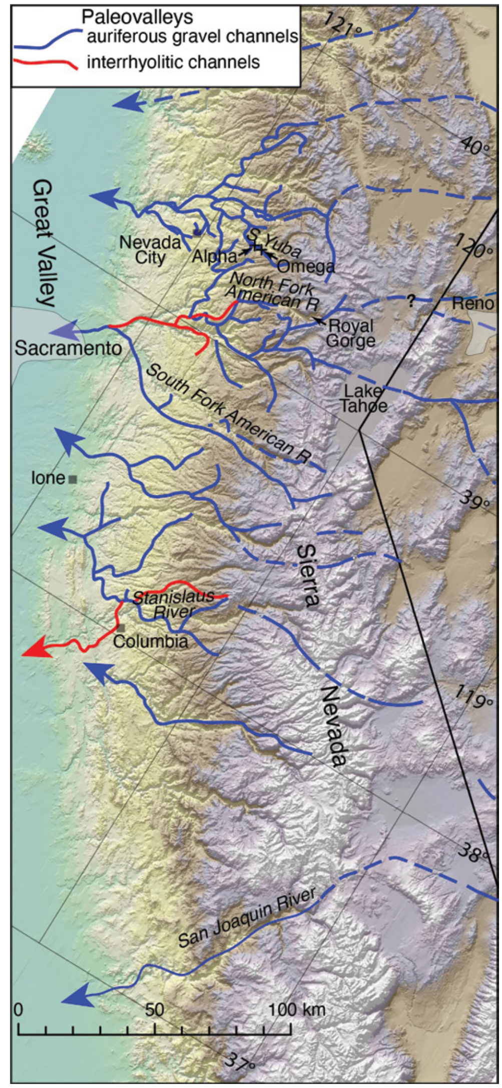

Figure 2. Map of paleochannels in the Sierra and placenames from the text.

rivers continuing beyond the modern Sierra. Christensen previously suggested a significant contribution from Nevada, implying early continuity, but now interprets erosion of epithermal systems above the batholith to be more likely, which does not imply early continuity.

The Forum visited materials preserved in the paleochannels in several localities. Some deposits potentially preceding erosion of the deepest channels might be at the Alpha and Omega mines, where Cassel showed extremely large boulders (rarely up to 8 m diameter) left on strath terraces that appear to demand fast-flowing rivers, not ones consistent with lower grades that a young tilt would seem to require. Observation of the gravels, including deposition of higher gravels on older stream-polished strath terraces at Omega, suggests that the older gravels could have a cut-and-fill history, which would mean that gravels deposited on bedrock do not correlate and instead represent different rivers at different times.

Why did these gravels accumulate? Two possibilities are (1) that the river system was overwhelmed with sediment (Tipp and Gabet, 2020) or (2) that the river gradients (or at least some channel reaches) or flow levels had relaxed enough to permit sedimentation (Cassel and Graham, 2011). The Ione Formation near its type locality alternates between shallow marine and subaerial deposits. As Field Forum participants examined the rocks near the edge of an inferred delta from the paleo–Calaveras River, the failure of the fan to prograde rapidly into the marine environment suggested to one convener that, at least at the time of deposition of the Ione, Sierran river channels were not too overfull of sediment. But, as Lindgren (1911) recognized and the Forum examined around Nevada City and Columbia, the paleorivers were overwhelmed and locally realigned by the great influx of sediment at the ca. 37–32 Ma onset of major volcanism in Nevada.

The Forum also visited younger markers of possible uplift. Twice they examined Miocene lava flows that have been controversial measures of range uplift, one capping a series of table mountains along the San Joaquin River (Hildreth et al., 2022) and the other topping the Stanislaus Table Mountain (Pluhar and Mitchell [FF]). Work at both flows suggests about 1° of tilt since ca. 10 Ma. Noteworthy was a visit to an unexhumed part of the Stanislaus Table Mountain Latite, where preserved channel walls strongly indicate that meanders were primary and not accidents of erosion.

Many studies explicitly or apparently posit that modern rivers partly to mostly re-excavated the paleorivers (Wakabayashi, 2013; Beeson and McCoy, 2022; and Gabet, 2014, 2020, all of whom contributed to the Forum); the depth of incision below the paleorivers would be greater the less the paleorivers and modern rivers coincide. Based on several locations, Henry and O'Neal independently found that modern rivers generally do not coincide with and were not re-excavated from paleorivers. Incision of modern rivers is also contentious. If tilting and uplift are substantial, why are many modern rivers only incised a short distance below the base of the Eocene(?) channels? Dow and McCoy answer that most northern Sierra rivers are not in steady-state equilibrium, and only the very lowest parts of these rivers now reflect the current tilt of their drainages. In many places the migration of knickpoints up drainages appears to be slowed by the underlying geology, leading to the mild incision of the South Fork of the American River where the Forum visited, compared to the far deeper incision of the North Fork we visited near Royal Gorge. A key difference for those skeptical of this analysis is whether the inferred migrating knickpoints are actually lithologic knickpoints (i.e., Gabet, 2023; Beeson and McCoy, 2023). In the southern Sierra, knickpoints associated with the stepped topography of Wahrhaftig seem stuck (Callahan and Riebe [FF]; update of Jessup et al., 2011), while other knickpoints might develop within otherwise uniform bedrock (Rothman and Scheingross [FF]), both potentially complicating river network analysis.

Summary. The Miocene table mountains provided some of the most compelling evidence in favor of a westward tilt of the range in the last 10 Ma. This seemed in good agreement with the Dow and McCoy analysis of the evolution of the drainages, which might be strengthened by specific examination of knickpoints unrelated to bedrock strength variations. Challenges in determining the geometry of the Eocene river system leave ambiguity in the magnitude of tilt of these features, if indeed they have tilted at all. The strong evidence for post–10 Ma uplift of the Sierra conflicts with the strong evidence from paleoaltimetry studies, using stable isotope ratios, paleoflora, and sedimentologic measures, for an Eocene Sierra as high as modern and an even higher Nevadaplano. Accepting both suggests an unrealistic steep topographic gradient between the two near the California-Nevada border. This dichotomy further suggests some apparently reasonable data sets are wrong or misinterpreted.

Looking forward, the Forum spent the morning of the last day digesting their observations and discussions with a goal of identifying work to resolve the evident differences. Additional geo- and thermochronology are particularly needed to help resolve timing of the troublesome Eocene gravels and the complex incision of Eocene and modern channels. Are the channels much older than the gravels, and did lower and upper parts of the Eocene drainages exhume at different times, which would confirm that the channels evolved through upstream migrating knickpoints that separated aggrading downstream segments from incising upstream segments? Geochemical characterization of detrital zircons and analysis of exotic chert clasts, detrital gold, and other heavy minerals would help determine the geometry and evolution of the drainage network. Expansion of paleohydrological analysis to more of the NNW-SSE–trending channel segments might clarify whether these channels have been tilted.

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Earth Science Week 2023: Geoscience Innovating for Earth and People

Lindsay Mossa, Lauren Brase, Ed Robeck, *and* ***Sequoyah McGee***

For more than 25 years, the American Geosciences Institute (AGI) has organized Earth Science Week (ESW) to engage teachers, students, professionals, and the general public with topics that raise awareness of the geosciences and their varied applications in everyone's daily lives. This year, ESW will be held 8–14 Oct. and will celebrate the theme, "Geoscience Innovating for Earth and People." ESW 2023 will highlight how emerging technologies and new techniques are helping to address the world's greatest challenges, as defined by the United Nations' Sustainable Development Goals (SDGs, https://sdgs.un.org/).

Each year, an ESW Toolkit is developed by AGI and its partners to provide geoscience lessons, activities, and other materials for use in formal and informal educational settings. This year's Toolkit will allow students to engage with information on a variety of innovations. ESW partners, including the Geological Society of America (GSA), provide funding that enables the development of high-quality educational materials. For example, for the past several years, GSA has contributed to the development of each year's Geologic Map Day poster, which this year illustrates how lidar is used to enhance geologic maps and collect other geoscience-related data.

As part of this year's ESW activity calendar, GSA's Center for Professional Excellence designed a classroom experiment that measures how a material's color can impact its temperature. The activity also explores how a building's roof color can cause the roofing material to heat up and can affect the temperature of a building's interior. The analysis of data collected during this activity challenges students to consider energy usage when heating and cooling buildings, which relates to SDG 7 (Affordable and Clean Energy) and the need for energy-efficient systems. Students also consider the potential impacts of choices made in the construction of homes and businesses, which relates to SDG 9 (Industry, Innovation, and Infrastructure) and the need for innovative construction to produce more sustainable buildings that have less of an effect on the environment.

The success of ESW is dependent on the involvement of AGI's partners, especially those who are willing to host and attend ESW events. Every year, museums, universities, and other organizations throughout the U.S. and other countries host interactive and educational programs geared toward students and the general public.

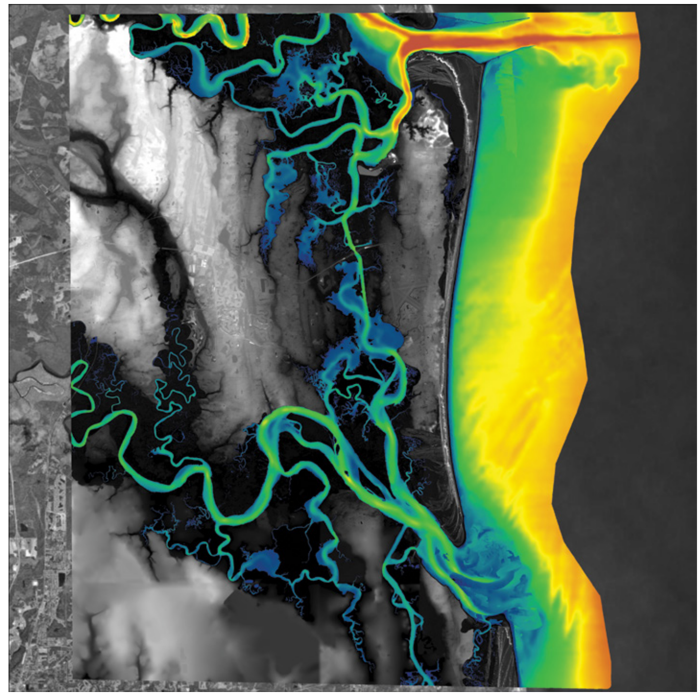

Figure 1. This year's Geologic Map Day poster has many images that illustrate applications of lidar, like this one, which demonstrates the use of lidar to map bathymetry in shallow coastal areas. Bathymetric data can assist with ship navigation, coastal change monitoring, tide modeling, and studying marine habitats such as coral reefs and estuaries. This example shows the coastal transition of a river estuary near Amelia Island, Florida, and was created for the U.S. Geological Survey Coastal National Elevation Database (CoNED). Credit: Florida Geographic Information Office.

These events offer participants the opportunity to learn about the geosciences, and this year, many of these events will likely focus on innovations that enable a deeper understanding of our Earth and processes that occur on it. We at AGI encourage you to participate in ESW events by giving presentations on your work, volunteering as a judge at your local science fair, or hosting interactive events where students can participate in geoscience-related activities.

For more information about Earth Science Week, related educational materials, and to learn how to volunteer, please visit www.earthsciweek.org or e-mail info@earthsciweek.org.

Don’t Miss the Foundation at GSA Connects 2023!

The GSA Foundation Trustees and staff are excited to see you in Pittsburgh! Student donors—come get a special thank you at our booth. Donors—stop by to hear about current GSAF efforts to support Society programs. Student and professional attendees—come learn about support available to you and programs you might be passionate about supporting to help those following in your footsteps.

AT THE BOOTH

All GSA Connects Attendees

Come by our booth to visit with Foundation staff, Trustees, and students throughout GSA Connects**.**

Students and Tektonikos: Building the Future

Students and Tektonikos members, make your way to the GSA Foundation booth to collect or learn how to get your very own rock hammer bandana!

You can also learn how to join **Tektonikos: Building the Future**, one of the Foundation’s most dynamic and enthusiastic groups of contributors to GSA. Every year, more than 1,100 students make gifts to support student-related funds. Together, they form our student giving society. The Foundation is proud to recognize the generous, forward-thinking financial support of this group.

PENROSE CIRCLE AND STUDENT AWARDS RECEPTION

Penrose Circle members have received their invitations to join us at the Penrose Circle and Student Awards Reception, where we will celebrate aspiring geologists as well as the generous support of the Penrose Circle that is helping them develop their futures in the geosciences.

PENROSE CIRCLE LOUNGE

If you are a Penrose Circle member, we hope you enjoy the return of our Penrose Circle Lounge at GSA Connects 2023. Available throughout GSA Connects 2023, the Penrose Lounge offers an opportunity to relax, refresh, and prepare. Keep an eye out for your notice about the Lounge to enjoy this unique benefit for Penrose Circle members. To learn more about Penrose Circle membership, contact Debbie Marcinkowski at dmarcinkowski@geosociety.org or +1-303-357-1047.

The GSA Foundation booth at GSA Connects 2022 in Denver, Colorado, USA.

Assistant Professor, Solid Earth Geosciences, Baylor University

Baylor University's Department of Geosciences invites applications for a tenure-track faculty position at the assistant professor level in the field of solid earth geosciences, effective Fall 2024. We seek applicants who demonstrate a commitment and potential to develop an outstanding, externally funded research program.

The most competitive candidates will establish a clear connection between their research program and current big-picture questions in the field of solid earth geosciences. The specific area of expertise is open and includes field- and lab-based methods in topics including, but not limited to, geodynamics, active tectonics, geophysics, volcanology, basin analysis, geochronology, structure, petrology, mechanics, faulting, hazards, seismology, geodesy, and high-temperature geochemistry.

Top applicants will also enthusiastically commit to teaching and mentoring undergraduate and graduate students and postdoctoral researchers. Teaching opportunities may include a broad scope of undergraduate and graduate classes such as structural geology, mineralogy, petrology, volcanology, geochemistry, geophysics, and field camp. It is expected that teaching responsibilities will include existing undergraduate and graduate courses in the Department of Geosciences and new course offerings in the candidate's area of expertise.

To apply, please submit a cover letter, curriculum vitae, statements describing your research agenda and funding goals and your teaching philosophy, experience, and interests, a copy of a transcript from the highest degree grant institution, and contact information for three references via Interfolio using this link: https://apply.interfolio.com/127680.

Complete applications must be submitted by 20 Oct., 2023. For further information or questions contact the Search Committee Chair, Dan Peppe, at daniel_peppe@baylor.edu.

Assistant Professor of Environmental Science, The Pitzer and Scripps Colleges

The shared Science Department of Pitzer and Scripps Colleges invites applications for a tenure-track appointment as assistant professor of environmental science, to begin July 2024.

We seek to hire a broadly trained earth scientist who studies climate change. Potential areas of specialization include, but are not limited to, atmospheric science, biogeochemistry, climatology and paleoclimate, climate modeling, hydrology, glaciology, quaternary geology, and oceanography. A Ph.D. in a relevant discipline and a record of scholarly publication are required. Postdoctoral experience is strongly preferred.

We seek a teacher-scholar with a clear capacity for and dedication to excellence in teaching, who will develop a vibrant research program that fully and inclusively engages undergraduate students, and who possesses a demonstrated commitment to our colleges' (Pitzer and Scripps) goal of improving higher education for underrepresented students.

The Department, which houses the biology, chemistry, environmental science, neuroscience, and physics faculty for Scripps and Pitzer Colleges, offers innovative and interdisciplinary programs in the natural sciences. The successful candidate will join a vibrant Intercollegiate Environmental Analysis Program and a community of other new faculty in climate-related fields. We particularly seek candidates who will build interdisciplinary connections with colleagues across the liberal arts curriculum. We are also especially interested in applicants whose research tools can contribute to Department strengths and growing activity in the areas of computational/data science, geochemistry, GIS, and/or remote sensing. Teaching responsibilities include participation in the introductory environmental science course sequence, one upper-division course in global climate change, and one upper division course in the candidate's area of specialty.

The Department supports faculty success through mentorship, opportunities for professional development, and regular sabbaticals. Faculty of the Pitzer-Scripps Science Department are part of the rich intellectual environment of the Claremont Colleges consortium and benefit from close proximity to major research universities in the Southern California region, enabling collaboration both within and outside the Department. The Department will open its new state-of-the-art science facility, the Nucleus, in Fall 2024.

Applications should be uploaded to http://apply.interfolio.com/128042 and must include a cover letter describing your interest in and summarizing your capacity for the position, a curriculum vitae, a description of your proposed undergraduate-centered research program, a statement describing your approach to teaching and how you pursue excellence in teaching, a description of how you have fostered and will foster the promotion of diversity, equity, and inclusion, and the names and e-mail addresses of three references. Please notify your three references that we will require letters of recommendation promptly should you advance to the semifinalist stage. Inquiries regarding the position may be emailed to associate professor Colin Robins at crobins@scrippscollege.edu. Review of applications will begin 15 Oct., 2023, and the position will remain open until filled.

The salary range for this position is $90,000–$98,500 and will be set based on a variety of factors including, but not limited to, internal equity, experience, education, specialty, and training.

The shared Science Department of Pitzer and Scripps Colleges is an equal-opportunity employer. In a continuing effort to enrich its academic environment and provide equal educational and employment opportunities, the Department actively encourages applications from women and members of historically underrepresented groups in higher education.

Tenure-Track Faculty Position, Land Surface Processes, California Institute of Technology

The Division of Geological and Planetary Sciences at the California Institute of Technology is seeking outstanding applicants for a tenure-track faculty position. We seek individuals who will lead an innovative research program and are committed to teaching and mentorship of students and postdoctoral fellows and enhancing the diversity of the Institute. We invite applicants who study physical, chemical, and/or biological processes at Earth's surface and shallow subsurface and their impact on life-sustaining resources, habitats, and climate. Research areas of interest include the carbon cycle and terrestrial ecology, hydrological and biogeochemical cycles, dynamics of the cryosphere, soil formation and dynamics, and interactions of the land surface with the climate system. We are interested in basic and applied science, including the impact of global change on land surface processes.

The term of the initial appointment at the assistant professor level is four years and is contingent upon completion of a Ph.D. degree. Reappointment beyond the initial term is contingent upon successful review conducted prior to the commencement of the fourth year. Exceptionally well-qualified candidates may also be considered at the tenured professor level. Initial review of applications will begin on 5 Sept., 2023, and applications will be accepted until the position is filled.

Interested applicants should submit an electronic application that includes a brief cover letter, a curriculum vita (including publications), a short research statement (no more than 2 pages), a teaching statement (1 page), and three letters of recommendation. We also ask that applicants submit a diversity and inclusion statement (1 page) that discusses past and/or anticipated contributions to improving diversity, equity, and inclusion in the areas of research, teaching, and/or outreach. We will evaluate each applicant's research accomplishments and potential, as well as the teaching, mentoring, collaboration, and leadership skills necessary to run a successful academic research group (e.g. initiative, persistence, enthusiasm, communication).

Applications can be submitted at: https://applications.caltech.edu/jobs/land.

Questions about the application process should be sent to gps-faculty-search@caltech.edu.

The California Institute of Technology is an equal opportunity employer, and all qualified applicants will receive consideration for employment without regard to age, race, color, religion, sex, sexual orientation, gender identity, national origin, disability status, protected veteran status, or any other characteristic protected by law.

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Northeastern Section Meeting

Manchester, New Hampshire
17–19 March

www.geosociety.org/ne-mtg

Left: Beach near Portsmouth, New Hampshire.

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Joint Cordilleran/ Rocky Mountain Section Meeting

Spokane, Washington
15–17 May

www.geosociety.org/cd-mtg

Below: Spokane Falls. Photo credit: Chad Pritchard.

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Joint North-Central/ South-Central Section Meeting

Springfield, Missouri
21–23 April

www.geosociety.org/nc-mtg

Right: Smallin Civil War Cave. Photo credit: Springfield CVB.

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Southeastern Section Meeting

Asheville, North Carolina
15–16 April

www.geosociety.org/se-mtg

Above: Blue Ridge mountains.

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TAKING ON 21ST CENTURY CHALLENGES CREATING 21ST CENTURY LEADERS

From the Earth's core to outer space, research at The University of Texas at Austin's Jackson School of Geosciences is advancing the understanding of our world and beyond for the benefit of humankind.

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