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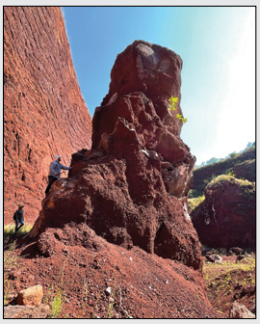

Cover: Quarry outcrop showing a cylindrical feeder dike in the Cerrito Colorado scoria cone, Michoacán-Guanajuato Volcanic Field, México. Photo by Martha Gabriela Gómez Vasconcelos. See related article, p. 4–10.

GSA NEWS

THE GEOLOGICAL SOCIETY OF AMERICA®

New Insights into Feeder Dike Swarms in Scoria Cones and Their Structural Control: A Case Study in the Michoacán-Guanajuato Volcanic Field

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ABSTRACT

Understanding the feeder systems in scoria cones is essential because they serve as the conduits that feed the most common eruptions worldwide. Feeder dikes and their emplacement are presumably controlled by the tectonic stress field. However, the mechanism of dike propagation and structural control in monogenetic scoria cones remains poorly understood, as well as the conditions that allow dike swarms in scoria cones and in low magma-flux monogenetic volcanic fields.

This is the first direct study of a magma feeder system in the Michoacán-Guanajuato Volcanic Field in central México. Quarrying in the Cerrito Colorado scoria cone displays six orthogonal feeder dikes—four of them are N-S oriented, parallel to the least compressive stress, intruding preexisting faults, and two are E-W oriented, perpendicular to the least compressive stress, forming their own fracture at the time of the eruption.

Single feeder dikes are common in monogenetic volcanoes, but dike networks (swarms) can develop locally in the vicinity of scoria cones and other vent structures. We suggest that bifurcation of feeder dikes can result from temporary blockages of the conduit and during changes in the magma ascent rate and magma pressure. Feeder dikes at the surface can appear as tabular dikes, cylindrical conduits, or as a combination of both geometries. We suggest that tabular dikes splay-off tangentially, and cylindrical conduits bifurcate radially and axially to the main vent. Our study attests to the complexity and structural control that even small scoria cones can present.

INTRODUCTION

Scoria cones are the most common volcanic form globally, placing countless neighboring populations at risk (Valentine and Gregg, 2008). They form from explosive Strombolian eruptions fed through planar magma-filled conduits, which constitute a feeder dike when magma cools and solidifies (Valentine and Keating, 2007; Tibaldi, 2015). Feeder-dike systems play an essential role in eruptive dynamics (Carracedo-Sánchez et al., 2017); therefore, understanding the role they play is crucial for identifying factors controlling their emplacement and for further forecasting volcanic hazards. However, feeder dikes are poorly understood because they are rarely exposed (Re et al., 2016), and their direct study represents a big challenge for volcanologists. They are usually inferred from seismicity and other geophysical methods (Belachew et al., 2011).

The magma plumbing system in monogenetic scoria cones often consists of a single feeder dike (Németh and Kereszturi, 2015). Nevertheless, some studies suggest it can be composed of an interconnected dike-sill network (Muirhead et al., 2016; Foucher et al., 2018). In addition, the regional and local stress fields frequently control the dike propagation through a newly formed fracture in the upper crust (Connor et al., 2000; Acocella and Neri, 2009), and often, a dike intrusion can use a preexisting fault as a pathway to the surface (Le Corvec et al., 2013). However, the conditions that allow it to intrude a preexisting fault are still discussed (e.g., Valentine and Krogh, 2006), and little is known about the factors that govern a feeder dike bifurcation.

In central México, the Michoacán-Guanajuato Volcanic Field (MGVF) is ideal for studying feeder dikes in monogenetic scoria cones. There are ~900 scoria cones (Hasenaka and Carmichael, 1985), and many of them are exploited as quarries where the feeder-dike system is at times left exposed. However, no feeder dike has been studied in detail. This study presents a direct survey of the Cerrito Colorado scoria cone's feeder-dike system in the MGVF, explored through geological, structural, and drone spatial data. Cerrito Colorado offers unprecedented three-dimensional exposure of its plumbing system, allowing a detailed survey of its geometry and the factors that control the magma emplacement.

VOLCANO-TECTONIC SETTING

The Cerrito Colorado scoria cone sits in the Bajío basin, at the northernmost part of the MGVF within the Trans-Mexican Volcanic Belt's (TMVB) central portion (Fig. 1). The TMVB is a Neogene E-W–oriented 1000-km-long continental volcanic arc related to the Cocos and Rivera plates' subduction along the Middle America trench (Demant, 1978; Pardo and Suárez, 1995). The MGVF is a late Pliocene–Quaternary volcanic field (Hasenaka and Carmichael, 1985) that occurs in an N-S to

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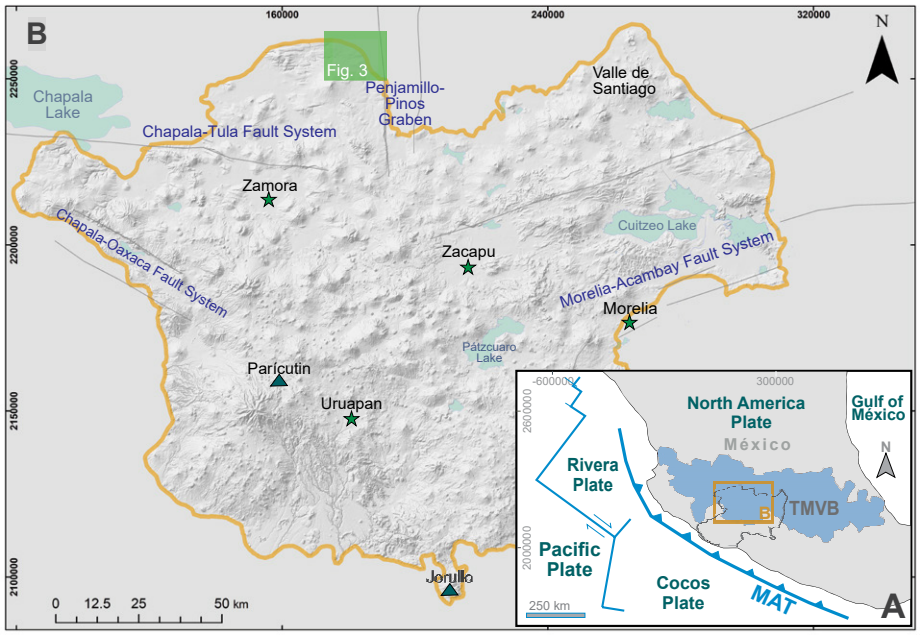

Figure 1. (A) Tectonic setting of the Trans-Mexican Volcanic Belt (TMVB) in central México. (B) Location of the study area (green box; Fig. 3) in the northern Michoacán-Guanajuato Volcanic Field; represented as an orange box in A and an orange polygon in B. MAT—Middle-American Trench.

NNW-oriented extensional tectonic regime (Suter et al., 2001), where volcanoes spatially coincide with three regional active fault systems: N-S, E-W, and NE-SW. N-S–oriented faults belonging to the southern Basin and Range province originated 30 m.y. ago as normal faults and are still active today as dextral strike-slip faults (Aguirre-Díaz and McDowell, 1993). This fault system controlled the formation of the N-S normal faults in the study area and the Penjamillo-Pinos Graben east of the Cerrito Colorado scoria cone (Fig. 1). The E-W–trending faults, known as the Chapala-Tula fault system, originated 19 m.y. ago as sinistral strike-slip faults, and today they are active as normal faults with a sinistral component (Johnson and Harrison, 1989; Garduño-Monroy et al., 2009). E-W–oriented faults control the formation and evolution of lacustrine basins and grabens in central México. The NE-SW faults correspond to a transfer fault system acting as normal to oblique-slip faults. These faults exhibit a significant structural control for the volcanic spatial distribution and geothermal manifestations (Gómez-Vasconcelos et al., 2020; Olvera-García et al., 2020).

METHODS

A microdrone MD-200 aerial vehicle was used to model the volcano and exposed feeder dikes. A photogrammetric flight was performed at the height of 120 m above the volcano (~1890 m above sea level), allowing us to obtain 471 multispectral stereoscopic photographs with a spatial resolution of 30 cm (scale 1:30) in seven photogrammetric flights. Photogrammetric images were processed and georeferenced (coordinate system: WGS 1984 UTM 13N) using the GeoSuite software to construct 3D models and orthoimages. A digital elevation model (DEM) and an orthomosaic were generated in Agisoft Metashape Pro to perform a geomorphological analysis identifying volcanic geoforms, dikes, and faults. The geomorphic characterization of Cerrito Colorado was done with the orthomosaic, 3D model and a Google Earth timelapse for 1985, because, at this moment, the volcano is partially destroyed by quarrying activities.

The volume was calculated with the following equation:

$$V = H\left(BD^2 + BD * CD + CD^2\right)/12, \quad (1)$$

where V is the volume, H is the height, BD is the basal diameter, and CD is the crater diameter.

A rock sample from the main feeder dike was analyzed at the Oregon State University (OSU) Argon Geochronology Lab to determine the age of the Cerrito Colorado volcano. A groundmass separate was irradiated for 30 min in the TRIGA Reactor along with the neutron fluence monitor mineral Fish Canyon Tuff flux monitor with a calibrated age of 28.201 ± 0.023 Ma (1σ) after Kuiper et al. (2008). The $^{40}Ar/^{39}Ar$ age was obtained by incrementally heating the material using a defocused 25-watt CO_2 laser. The resulting gasses were analyzed using an ARGUS-VI multi-collector mass spectrometer. A more detailed analytical method is available from the OSU Argon Lab.

Structural data were obtained in the field by directly measuring tectonic structures (strike, dip, kinematics) and dikes (strike, dip, thickness). Structural lineaments were traced in ArcMap, and the CoGo tool was used to obtain their direction, which was plotted in a rose diagram with Rozeta software. Dihedral angle diagrams were computed using Win_Tensor 5.8.8 with kinematic fault-slip data based on the Angelier stress ratio in the study area.

CERRITO COLORADO SCORIA CONE

The Cerrito Colorado is an NNW-elongated scoria cone with a low topographic profile. It had a basal diameter of 0.6 km, a crater diameter of 0.08 km, a height of 0.04 km, an area of 0.35 km^2, and a volume of 0.0003 km^3. However, nearly 50% has been destroyed by quarrying activities. Pyroclastic deposits associated with this scoria cone consist of non-welded reddish diffuse stratified to massive successions of well to poorly sorted scoria fall deposits. Fall deposits consist of coarse lapilli fragments interstratified with fine lapilli fragments and a low percentage of bread-crust scoria bombs, though ballistic content increases in the western part of the cone (Fig. 2A). Scoria lapilli and bombs show porphyritic textures with plagioclase, olivine, and pyroxene phenocrysts. Scoria is altered to reddish, and fissures are often filled with silica minerals. We dated groundmass from a juvenile fragment using $^{40}Ar/^{39}Ar$ geochronology that yielded a plateau age of 1.68 ± 0.02 Ma. Cerrito Colorado overlies an undifferentiated thick, aphanitic basaltic lava plateau of unknown age.

Feeder Dikes Characterization

The magma plumbing system of Cerrito Colorado is exposed due to quarrying activities. It comprises a network of orthogonal and interconnected conduits presenting two main directions: N-S and E-W. This dike complex fed the Cerrito Colorado eruption, consisting of six sub-vertical to steeply dipping feeder dikes; four are N-S oriented, and two are E-W oriented.

N-S–oriented dikes—Dike 1 is a tabular dike located in the central part of the scoria

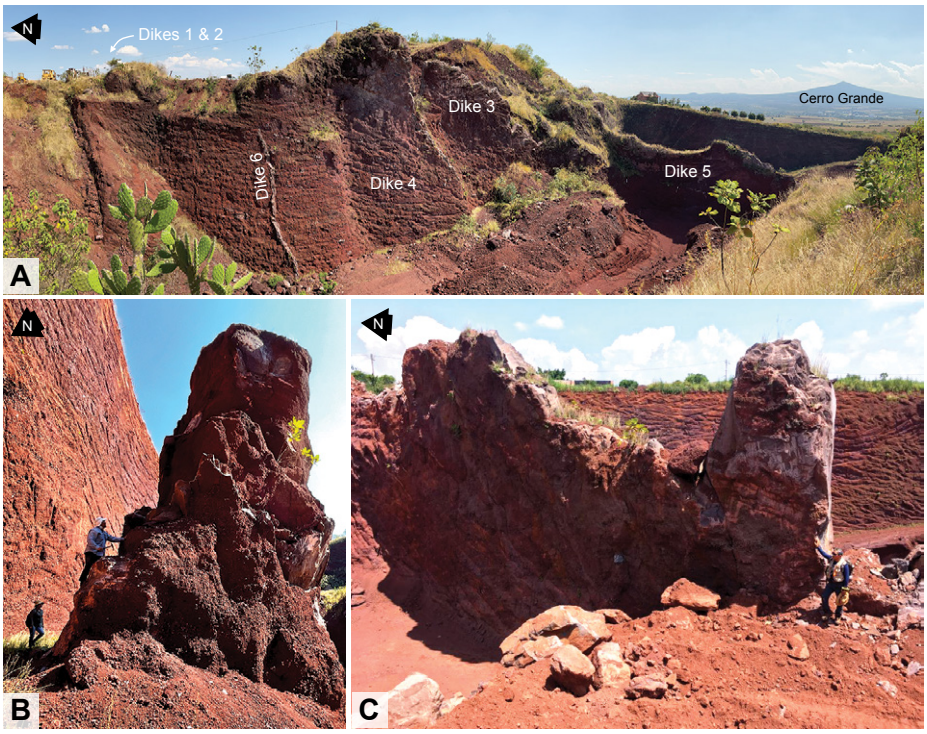

Figure 2. (A) Quarry outcrops showing the orthogonal dike complex in Cerrito Colorado scoria cone and ballistic-rich deposits in the western portion of the volcano. (B) Aspect of dike 2 showing a cylindrical structure. (C) Dike 1: Main N-striking tabular feeding conduit.

cone. It is 180 m long at the surface and 1.1–1.9 m thick. It strikes 006° on average, but in the northern part changes to 023° and dips 82° mainly to the E. This dike shows vertical striae. Dike 2 is 60 m E of dike 1. It is a tabular dike that presents a cylindrical geometry at a shallower depth (>8 m depth) in its northern part. The tabular portion is 130 m long and 0.4–1.1 m thick. The cylindrical portion measures 6 m in diameter at 8-m -depth with 0.3-m -thick annular walls, diminishing to 2.5 m in diameter at the surface (Fig. 2B). It strikes 186° and dips 85° to the W on average, but in its southern part, it dips to the E (supplemental material Fig. S1B[1]). Dike 3 is 50 m W of dike 1. It is a tabular 70-m-long and 1–1.1-m-thick structure. On average, it strikes 001° and dips 83° to the E. Dike 4 is 10 m west of dike 3, showing a left-stepped en échelon geometry. It is a tabular 80-m-long and 0.5–1-m-thick conduit. It strikes 351° and dips 80°E on average (Figs. 2 and 3).

E-W–oriented dikes—Dike 5 is a tabular conduit in the central part of the scoria cone. It crosscuts and is perpendicular to dike 3. It is 120 m long and 1.5 m thick. It strikes 98° and dips 80° to the S on average. Dike 6 lies 70 m north of dike 5. It shows a tabular geometry, and it crosscuts and is perpendicular to dike 4. It is at least 20 m long and 0.4–0.5 m thick. It strikes 069° and dips 83°S on average (Figs. 2 and 4).

All dikes display a single brecciated chilled and dense margin and a vesicular core. Vesicles are spherical toward the periphery, larger and vertically elongated toward the core. All dikes seem to have arrived all the way to the surface, feeding the eruption (see the free-surface effect on dike 2; Fig. S1B [see footnote 1]); except for dike 6, which may have not reached the surface (at least not the exposed segment that is 4 m below the surface) (Figs. 2, S1, and S2 [see footnote 1]). Dike 1 arrives all the way up to the original cone summit, dikes 1 and 4 preserve on their top the original vegetation, and dikes 3–5 apex contour the original slopes of the volcano.

Characterization of Faults

Regional fault traces and lineaments show three main directions: N-S, E-W, and NE-SW. The E-W direction is the most common, followed by the N-S (Fig. 3B), represented by normal to oblique-slip and dextral to oblique-slip, respectively, en échelon faults. Fault kinematics are revealed by geomorphology, structural data, and regional fieldwork (striae, Riedel structures) and endorsed by previous work. The Cerrito Colorado scoria cone lies on top of a 5-km-long N-S–striking dextral-normal steeply dipping fault (355°/84°E) (Fig. 3).

Faults cut Dikes 1 and 5. Dike 1 is cut by E-W- and NE-SW–striking and steeply dipping (76°N and 85°SE, respectively) faults. Dike 5 is cut by N-S–striking and steeply dipping (82°W) faults that displace the scoria cone's deposits by at least 0.2 m (Fig. S1 and Table S1 [see footnote 1]).

DISCUSSION

Structural Control on Magma Emplacement

The regional tectonic stress field usually controls a dike intrusion's orientation. The geometric aspect of the dike is perpendicular to the least compressive stress (σ3) (Martí et al., 2016), but its emplacement can be influenced by local preexisting faults or fractures (e.g., Connor et al., 2000), which may or may not be perpendicular to σ3 at the time of the eruption. Local rotation of principal stresses by 90° may be favored when pressurized magma exceeding σ3 intercepts a discontinuity like a steeply dipping preexisting fault, easing magma ascent at shallow depths because shear strength here is lower than that of the surrounding rock (Valentine and Krogh, 2006; Gudmundsson, 2020).

The MGVF is a low magma-flux field where dikes and normal faults take up active extension. Here, dikes are prone to intercept a preexisting fault, even if it is not oriented with the principal stresses at the time of the eruption. This results in many N-S and E-W–oriented volcanic alignments along this monogenetic field, which parallel the dominant preexisting fault trends (Cebriá et al., 2011; Gómez-Vasconcelos et al., 2020).

In the Cerrito Colorado scoria cone, N-S dikes 1–4 do not strike normal to the least principal stress (σ3), and E-W dikes 5–6 strike normal to the least principal stress at the time of the eruption. The usage of preexisting structures by ascending magma is favored in this region because the main fault plane is an active steeply dipping transfer fault parallel to σ3 and perpendicular to σ2, the magma pressure exceeds σ3,

[1]Supplemental Material. Figures S1 and S2: Field pictures. Figure S3: Ar/Ar plateau age plots. Table S1: Characterization of the dike swarm. Go to https://doi.org/10.1130/GSAT.S.20379540 to access the supplemental material; contact editing@geosociety.org with any questions.

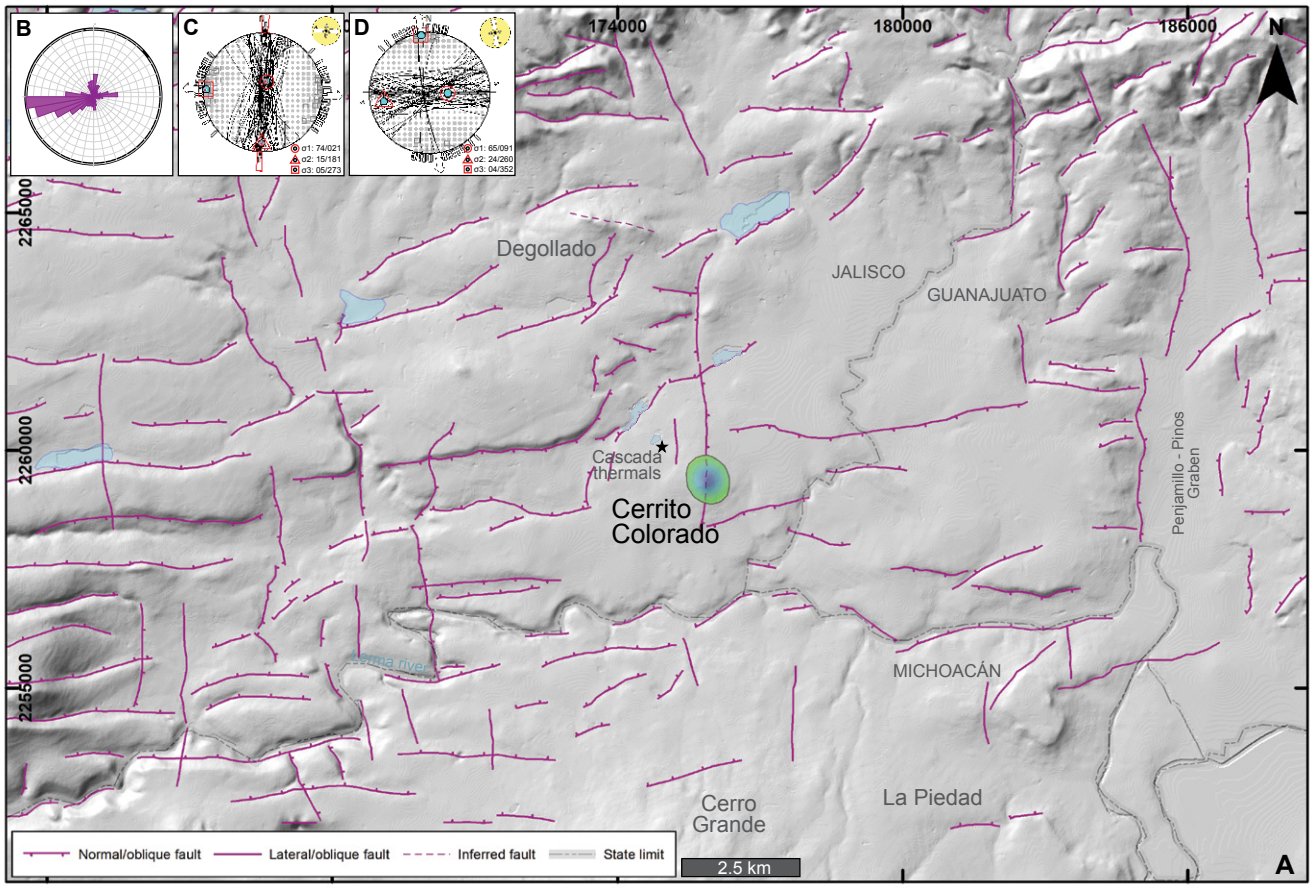

Figure 3. (A) Location of the Cerrito Colorado scoria cone and surrounding fault traces. (B) Rose diagram for the regional and local faults (lower hemisphere projection). (C) Dihedral angle diagram of the Oligocene-Miocene stress field agrees with N-S normal faults and tension fractures. (D) Dihedral angle diagram for the Miocene-present stress field agrees with E-W normal faults and tension fractures. Data computed using Win_Tensor 5.8.8 with kinematic fault slip data in the study area (see structural data in Table S1 [see text footnote 1]).

and the horizontal stress differential between σ3 and σ2 must have been very low at the time of the intrusion (e.g., Yale, 2003; Heidbach et al., 2007). We infer a low horizontal stress ratio because magma overpressure will increase σ3 and thus make it similar to σ2. We also infer this low-stress ratio because both E-W and N-S faults are active under the same regional stress regime; N-S faults act as anti-Riedel structures in a transtensional setting. N-S faults are dextral faults with a normal component and used to act as normal faults in the late Miocene-Oligocene, so are more prone to dilate, allowing a magma pathway to the surface. The fact that dikes are intruding through preexisting N-S faults also evidences that σ3 and σ2 are interchanged. Therefore, the regional tectonic stress field and preexisting tectonic structures conditioned the orientation (spatial distribution) of the Cerrito Colorado feeder-dike system. Further, the ascent of geothermal fluids was also fault-controlled, evidenced by abundant quartz minerals and proximity to the Cascada thermal pools (Fig. 3).

Eruption Evolution and Eruptive Dynamics

The Strombolian-style eruption of Cerrito Colorado had the following dike order: 1, 2/3, 4, 5, 6. We suggest this dike order because of their heights, widths, and cross-cutting relations; dikes 5 and 6 cut dikes 3 and 4, respectively (Figs. 3–5). Magma overpressure diminishes toward the end of the eruption; therefore, we infer larger and wider dikes will come first. The eruption begun with feeder dike 1 (largest and widest dike) arriving at the surface using a preexisting N-S steeply dipping (84°) dextral fault, not coinciding with the stress field at the time of the eruption. We suggest the magma intrusion intercepted the preexisting fault in the shallow crust as it encountered this subvertical E-dipping shear zone. Vertical striae in some parts of feeder dike 1 could denote shearing from vertical magma flow. The emplacement of magma could have also relaxed the friction across the host fault plane, triggering a co-intrusive fault slip if the preexisting fault was near failure (e.g., Gaffney et al., 2007). Eventually, the vent from dike 1 became closed (local implosion) or buried by scoria fragments, revealed by a further propagation of dike 1 to the north and a slight orientation change from N-S to NE-SW, possibly related to its emplacement through weakly consolidated scoria deposits. This orientation change in dike 1 could indicate limited degassing and gas accumulation beneath the surface, causing an overpressure rise (e.g., Valentine and Krogh, 2006). Therefore, new vents had to be formed, allowing the release of pressure through N-S preexisting fractures parallel to the main fault plane (dikes 2, 3, and 4) and through a tangential self-propagating tabular dike coinciding with the stress field at the time of the eruption (parallel to the greatest principal stress; dikes 5 and 6). Synchronously with the first

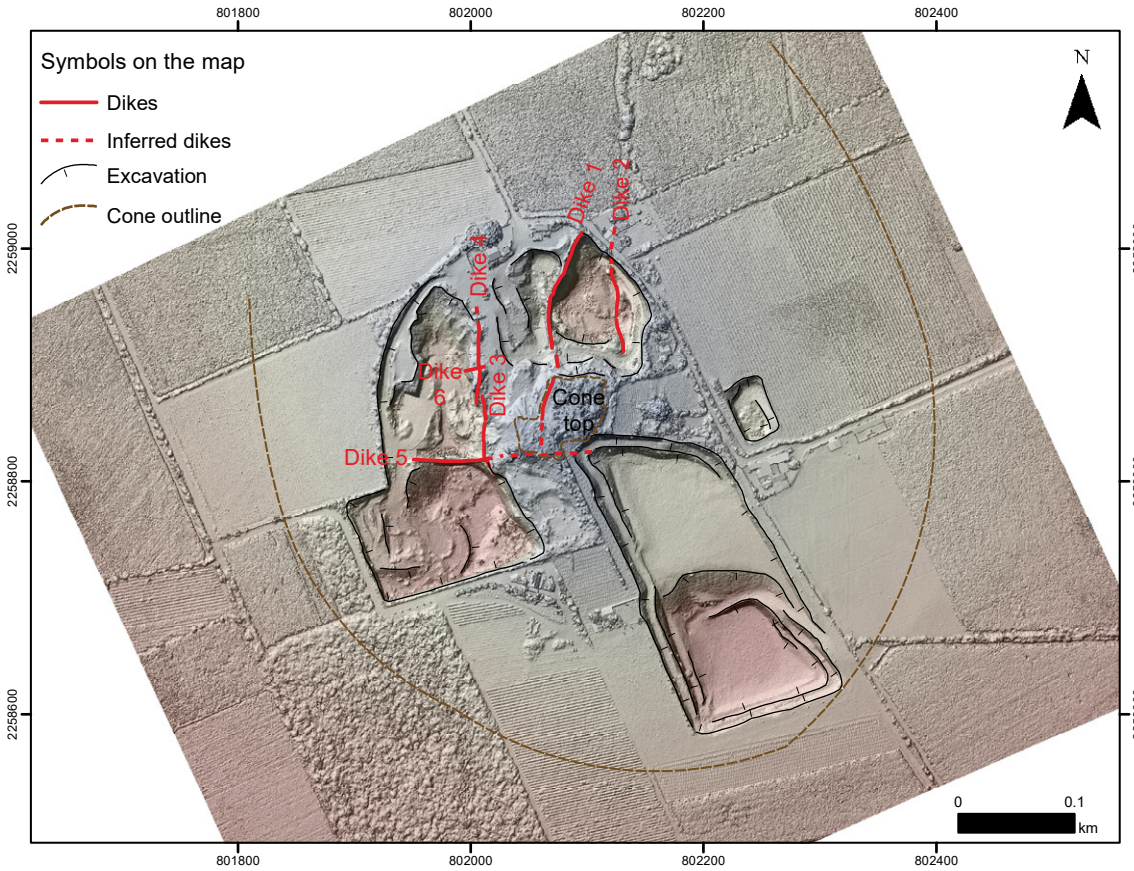

Figure 4. Shaded-relief model of the Cerrito Colorado scoria cone generated with the aerial vehicle. The model allows identifying the quarrying excavation, the exposed dike-feeding system and its cross-cutting relations.

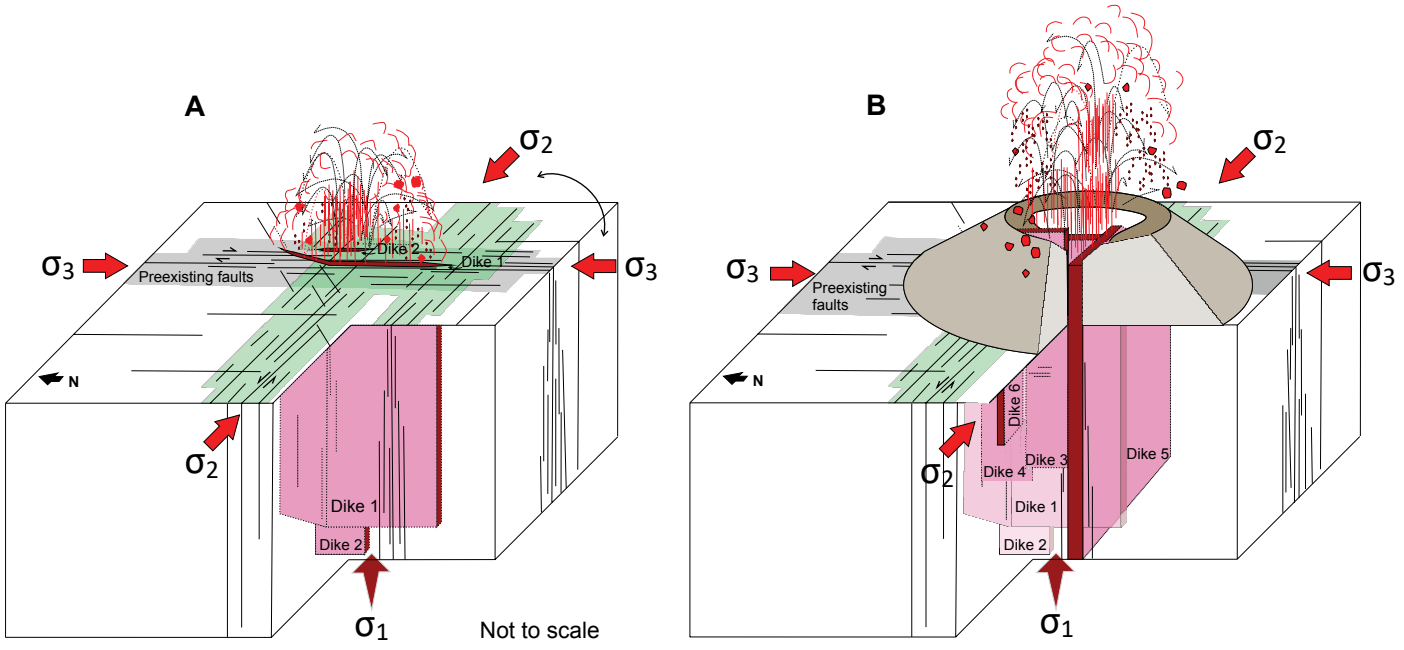

Figure 5. Magma emplacement model for a complex feeder-dike system in monogenetic scoria cones. (A) Magma encounters a stress barrier and intrudes a steeply dipping dextral-normal N-S preexisting fault parallel to the least principal stress (σ3). (B) Magma bifurcates into 5–6 E-W feeder dikes (orthogonal to 1–4 feeder dikes) through self-propagating fractures coinciding with the stress field at the time of the eruption (normal to the least principal stress).

dike intrusion, magma diverged into a secondary vent: either dikes 2 or 3, assuming dike widths tend to diminish during the eruption (Fig. 5). Dike 2 could have broken out of the main fault plane to propagate vertically at shallow depth (e.g., Connor et al., 2000) all the way to the surface, evidenced by dike 2 chilled margins (Fig. S1 [see footnote 1]). Magma plumbing bifurcation is encouraged with a magma ascent rate increase that creates magma overpressure (e.g., Geshi, 2005). The rise in magma's ascent velocity is supported by its transition into a cylindrical mix-flow conduit in its northern part at a shallower depth (<8 m depth; slug flow: continuous gas phase flowing radially and axially; e.g., Suckale et al., 2010; Cashman and Sparks, 2013) denoting a gas-dominated flow that allowed a larger and more stable magma flux (e.g., Costa et al., 2009). The slug flow in the cylindrical conduit could have conditioned a change in the eruptive style (e.g., violent Strombolian activity) where pyroclastic fall deposits become finer-grained and stratified. However, this would need a more detailed granulometric analysis to verify the change in eruptive style. Dikes 3 and 4's new vent opening allowed repressurization of the system with a relatively cool (non-spatter) ballistic-rich eruption and ash-lapilli scoria fragments, typical of a vent-opening stage (e.g., Thivet et al., 2020). Since dikes 1, 2, 3, and 4 dip E, bomb-rich deposits mainly lie on the western part of the scoria cone (Fig. 2A). Subsequently, an E-W dike formed (dike 5) through a new tangential self-propagating vent perpendicular to σ3. Dikes 4 and 6 show thinner and irregular widths because they intruded through unconsolidated scoria fragments. The last dike (thinner dike: dike 6) did not reach the surface to feed the eruption, probably because at this stage of the eruption, the magma overpressure was reduced and did not exceed σ3. It is possible that dike 1 continued actively throughout the eruption because it lies higher than the other dikes and arrives all the way up to the original cone summit.

CONCLUSIONS

Studying the interior of a scoria cone and its magma plumbing system is a great challenge for volcanologists. Nonetheless, quarrying activities in the MGVF help with the direct study of these structures.

This is the first direct and detailed study of a magma feeding system in a monogenetic scoria cone in México. Our study supports many analog models and theoretical studies, providing new and direct evidence for magma emplacement in low-magma–flux regions. We propose that at least two ingredients are needed for an orthogonal dike swarm growth in monogenetic scoria cones: (1) relatively similar (isotropic) horizontal principal stresses (σ3 and σ2) in order to be interchanged; and (2) changes in local magmatic pressure (magma overpressure, poor degassing, or high flow rates at the surface). Moreover, we suggest that tabular dikes bifurcate tangentially (at times en échelon), and cylindrical vents bifurcate radially (annular geometry) and axially to the main conduit derived from local magma overpressure and centrifugal force.

In transtensional, low-magma–flux regions (e.g., MGVF), dike intrusions are tectonically controlled by regional and local stress fields and can easily develop orthogonal dike systems. Dike intrusions at shallow depths can intercept a preexisting fault that may or may not be perpendicular to σ3 at the time of the eruption, especially when magma is overpressured and when preexisting faults are steeply dipping (>75°) and parallel or perpendicular to σ3.

Our study attests that Strombolian eruptions are very unstable. Even slight local changes in magma pressure or stress field (caused by local stress barriers like preexisting structures) can alter their feeding system, inducing changes in the eruption dynamics with important implications on their volcanic hazard. The feeder system to the Cerrito Colorado eruption was controlled by N-S preexisting structures, the regional and local tectonic stress field, and magma pressure changes.

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2022 GSA J. David Lowell Field Camp Scholarship Awardee Report

Leyla Namazie

This summer, I attended a field camp course with the South Dakota School of Mines and Technology (SDSMT): "Depositional Systems of Western California." The course focused on the nature of submarine sedimentary deposits, with particular emphasis on submarine canyon formation. We spent the first week at Point Lobos State Natural Reserve, where we were tasked with mapping and examining the stratigraphic cyclicity of sedimentary units, structures, and bedforms in the Paleocene Carmelo Formation. Two competing hypotheses have been used to model the conditions of deposition within this formation. The first suggests a prolonged period of mass transport leading to repeated layers of sandstone, mudstone, and shale. The second claims a shorter time frame of deposition and proposes that thrust faulting within the formation is leading to an overestimation of total formation thickness. Using our maps and observations, we took the time to put forth our own models that either critiqued or reinforced the two hypotheses. This approach to studying sedimentary stratigraphy required that we create a small research project and proposal from start to finish—a practice rarely implemented in classroom settings.

As a geophysics major during COVID, I had minimal opportunities to explore field geology in a guided, hands-on setting. More crucially, I was never able to become deeply engaged with my courses by discussing, questioning, and brainstorming ideas with my peers and professors. At my summer field camp with SDSMT, I gained access to all these benefits and more. The course was rigorous and emphasized not just proper field geology technique, but proper work ethic and organizational skills, which I consider to be just as valuable. As a California resident, I had the chance to meet students from across the United States. When we weren't having late-night study sessions or debates about map interpretations, we were teaching each other about the geology and culture of our hometowns and regions. Even car rides to field sites were spent

taking in words of wisdom from our incredible professor, a leading expert in his field of deep marine sedimentary systems.

I am incredibly grateful for the support and guidance offered by the Geological Society of America through their J. David Lowell Field Camp Scholarship. The funding and gifted Brunton compass allowed me to put all my focus into the course without the financial burden of tuition or gear shopping. This field camp was a truly memorable experience, and I recommend it to any student in the earth sciences looking to advance their skills.

Note: If you are able to help students like Leyla attend field camp and pursue their geoscience training, you can make a gift now at **https://gsa-foundation.org/fund/field-camp-opportunities** or contact Debbie Marcinkowski at +1-303-357-1047, dmarcinkowski@geosociety.org, for more information. To apply for a J. David Lowell Field Camp Scholarship, go to **www.geosociety.org/field-experiences.** Questions? Please contact Jennifer Nocerino, jnocerino@geosociety.org.

J. David Lowell Field Camp Scholarships

GSA and the GSA Foundation are proud to announce that J. David Lowell Field Camp Scholarships will be available to undergraduate geology students for the summer of 2023. These scholarships will provide students with US$2,000 each to attend the field camp of their choice. Applications are reviewed based on diversity, economic/financial need, and merit. **Application deadline:** 31 Mar. 2023.

Learn more at **www.geosociety.org/field-experiences**. Questions? Contact Jennifer Nocerino, jnocerino@geosociety.org.

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Alec Siurek, a 2022 J. David Lowell Field Camp Scholarship awardee.

Progressive Failure of Brittle Rocks (PRF2022)

20–24 June 2022 | Flat Rock, North Carolina, USA

CONVENERS

Matt Brain, Dept. of Geography, Durham University, matthew.brain@durham.ac.uk
Martha-Cary (Missy) Eppes, Dept. of Geography & Earth Sciences, University of North Carolina at Charlotte, meppes@uncc.edu
Kerry Leith, GNS Science, New Zealand, kerryleith@gmail.com
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OVERVIEW

At PRF2022, a wealth of research and energetic discussion by a diverse group of attendees explored and supported the idea that rates of crack growth in rock in the natural and built environment are typically non-linear, manifest as slow, progressive ("subcritical") deformations that can accelerate without obvious warning toward rapid and hazardous macroscale critical rock failure—i.e., Progressive Rock Failure, or PRF. The full conference program with extended abstracts is online at **https://gsa.confex.com/gsa/2022PR/meetingapp.cgi/Home/0.**

A common theme throughout the conference was that there has been a fundamental lack of recognition and/or misunderstanding of how PRF applies to earth-surface processes. In parallel, many noted that engineers have long recognized that PRF-driving molecular bond-breaking is strongly linked to crack-tip environment, and fracture can proceed at stresses much lower than a rock's critical strength. PRF2022 served to join these two frameworks that have been, in the past, constrained by traditional disciplinary divides.

The research presented at PRF2022 made clear the value of surface-process problems for field-validation of rock mechanics experiments and theory, and vice versa. Geomorphology has of late turned its eye more directly to the key roles fractures play in a myriad of earth-surface systems, and a range of hypotheses were presented that cannot be fully tested without rock physics experiments and theory. Similarly, PRF2022 allowed rock physicists and other fracture-focused scientists (such as seismologists and structural geologists) to more fully recognize opportunities to embrace potential applications—and critique—of their work in the cognate geoscience subdiscipline of earth and planetary surface processes.

At the end of PRF2022, all participants agreed that the catchall *progressive rock failure science* should be used to help communicate and unify fracture-focused research across traditional disciplines, just as previous terms such as *ecohydrology*, *hydrometeorology*, and *critical zone science* have been coined in the past to drive forward transdisciplinary approaches. We argue that PRF science is not just limited to the shallow subsurface, which is what most of the conference focused on, but rather on all water-catalyzed and time-dependent deformation in the brittle lithosphere on Earth and beyond.

CONFERENCE DETAILS

The conference took place at the lovely and relaxing Highland Inn Lake and Resort, Flat Rock, North Carolina, USA, from 20–25 June 2022, and hosted 85 attendees from 12 countries.

Financial support from the Geological Society of America and the National Science Foundation, plus generous sponsorship from Durham University, Psylotech Inc., and the University of North Carolina at Charlotte (Colleges of Arts + Architecture and Liberal Arts & Sciences, and the Office of Research and Economic Development) allowed for us to ensure that financial need was not a barrier to attendees traditionally underrepresented in the geosciences, including women, those with disabilities, and LGBTQ+, minority ethnic, early-career, and first-generation researchers. We provided 24 conference scholarships that directly served to boost representation from key groups. While there is much work still to do on diversity, equity, and inclusion in the geosciences generally, we are pleased to report the following (based on information provided by conference attendees):

- 46% of attendees identified as female (only 36% of initial applicants were female);
- 21% of attendees were from minority groups, including ethnic, LGBTQ+, and persons with disabilities;
- 52% of attendees described themselves as early career (research students; postdoctoral researchers; and those <5 years since their first permanent position); and
- 11% of attendees took non-traditional academic paths and/or were first-generation scholars.

The conference began with an icebreaker event that focused on early-career researchers, providing mentoring and advice on both integrating with more senior colleagues during the conference and broader goals, including career development and networking.

During three days of technical sessions, our invited keynote speakers discussed PRF from the perspective of their own subdisciplines of engineering geology, rock physics, rock mechanics, critical zone science, reservoir geology, geomorphology, and rock weathering. The key themes identified in these talks were further explored, exemplified, and/or critiqued in 41 oral and 29 poster presentations. These presentations added perspective from field, laboratory, and/or modeling studies that considered the spatial spectrum from microscale to the macroscale. They also considered a wide range of environmental settings that varied in temperature, moisture, and pressure conditions. The scientific sessions ended with a clear commitment to the development of PRF as a collaborative and multidisciplinary research discipline over the next five years, as evidenced by pledges to develop and run a PRF mailing list (email us to be added), social media sites, and scientific sessions at key geoscience conferences, culminating in the next PRF conference in 2027.

A one-day field trip to Hickory Nut Gorge provided insight into how fractures in the geological record can be generated over multiple spatial and temporal scales and how isolating the cause and mechanisms of fracture growth (particularly whether subcritical or critical) is a difficult, time-consuming but fundamental endeavor in both pure and applied geology.

The excellent contributions by all presenters were recognized in a conference award ceremony, with winners voted for by attendees in a broad range of categories; unique prizes were hand-crafted

Group photo of conference attendees (drone image taken by Dylan Ward).

and donated by our vibrant early-career attendees. The conference ended with a performance by the PRF2022 artist-in-residence, dancer and choreographer Melissa Riker (of the Kinesis Project Dance Theater), who expressed the key concepts discussed at the conference in a new, entertaining way, bridging the gap between our science and wider public engagement. Melissa also participated throughout the conference via some insightful and thought-provoking discussions and through live and collective interpretations of rock cracking and failure.

EMERGENT THEMES

PRF2022 highlighted a potential paradigm shift in how surface-process researchers consider rock fracture and in how those from rock mechanics, structural geology, and rock physics disciplines view their prior assumptions regarding the origins and evolution of fractures in outcrops and near-surface environments. The breadth of perspectives for considering very similar questions during the conference was both striking and encouraging, allowing (and, in some cases, forcing) attendees to take stock of their own disciplinary biases and to extend their thinking beyond conventional research boundaries. By the end of the conference, the following of cross-cutting research themes and opportunities emerged:

1. **Universality.** The ubiquitous and dominant nature of PRF processes and effects was emphasized throughout the conference, with examples including fatigue-related failure of asteroids, large-scale fracture features described on planetary surfaces, tree-root controls on near-surface fracture, and fracture generation in reservoirs and hazardous rock slopes. There was conference-wide consensus that fractures progressively grow in response to relatively small stresses long after rocks are exhumed from the deep subsurface.
2. **Moisture dependence.** Barring, possibly, the extraterrestrial, every example of time-dependent rock failure emphasized the importance of access to water in driving fracture. PRF2022 served to bring more general attention to the vital importance of water on driving fracture rates, and thus increasing permeability, reactive surface area, rates of sediment cycling, and more. Another key consensus of the conference was that water feedbacks and effects must be considered to fully understand the architecture and behavior of the lithosphere from the earth surface down, perhaps even to the Mohorovičić Discontinuity.
3. **Time dependence.** Another key theme repeated in talks was that subcritical cracking in surface environments likely varies in rate over time and could be considered "critical" (driven by critical stresses or stress-intensities) on some spatial scale and for some duration. Based on the broad range of examples and settings presented, there is a clear continuum in cracking rates over time from an incremental and continuous process to one that is highly episodic. Where the growth of any particular crack sits on that continuum is a function of a myriad of factors; this has profound implications for our understanding of rates of earth-surface change.

CHALLENGES AND LOOKING FORWARD

1. **Terminology.** There was considerable discussion of terminology to ensure that all attendees were on the same page with respect to the meaning of many terms—including "fracture" itself! These disciplinary differences will not disappear, and, therefore, a key component of all future PRF work must be in clearly defining all fracture-related terminology in every publication.
2. **Rethinking 4D observations.** Some laboratory-scale process studies of chemical weathering have been transferred successfully to the field (in critical zone science, for example). In contrast, broader mechanical linkages between process and form has been lacking, particularly over time and across space. Furthermore, how do chemo-physical state-and-rate effects and feedbacks operate as fractures grow? We have likely been treating a dynamic problem too statically as it relates to both chemical and physical processes. A range of multiscale studies must address this key knowledge gap, with important future roles for novel remote-sensing approaches that can help to link across scales.
3. **Spreading the word.** Publishing, and obtaining funding for, fundamental multidisciplinary PRF work can be difficult, as confirmed by several attendee anecdotes of manuscript and grant reviews. Peer-review comments often suggest that not all scientists across the disciplinary spectrum have accepted and adopted a full understanding of PRF in the context of surface processes and/or fracture mechanics problems, and a range of deep-seated misconceptions and misunderstandings are evident in peer reviews. To continue to develop PRF as a key explanatory component of geoscience, PRF2022 attendees noted the need to continue to communicate and exemplify PRF as widely as possible. We assert that the only way to fully disentangle PRF, and the factors that contribute to it, will be to continue along this tortuous, but exciting, multidisciplinary path paved with a wide range of perspectives, spatial and temporal scales, and methods.

ACKNOWLEDGMENTS

Becky Sundeen, GSA meeting manager, provided invaluable help and enthusiasm with administrative and organizational support. The staff at the Highland Lake Inn and Resort, particularly Kimbrell Arrowood, kept us well-fed and housed. Funding from the Geological Society of America and the National Science Foundation (award #2134366) and generous sponsorship from Durham University, Psylotech Inc., and the University of North Carolina (UNC) Charlotte kept the conference affordable and increased its diversity. UNC Charlotte students April Ryley and Nora Vaughan assisted with snacks and water during the field trip. Marek Ranis, professor of art at UNC Charlotte, provided works of art that served as backdrops to all conversations and presentations.

Attendees

Italic text indicates keynote speaker: Rodrigo Alcaino-Olivares, Jennifer Aldred, Alison Anders, Alex Arzoumanidis, Jennifer

Bauer, Mariam Ben Hammouda, Matan Ben-Asher, Erin Bessette-Kirton, Eric Bilderback, Andy Bobyarchick, Matt Brain, Kristin Chilton, Danilo D'Angiò, Maxwell Dahlquist, Marco Delbo, Vrinda Desai, William Dietrich, *Erik Eberhardt*, Peter Eichhubl, Terry Engelder, Martha Cary (Missy) Eppes, Riley Finnegan, Henry Gage, José Gámez, Benjamin Gilbert, Bradley Goodfellow, Guglielmo Grechi, Xin Gu, Brian Gulick, William Hefner, Mengsu Hu, Mong-han Huang, Marius Huber, Berit Hudson-Rasmussen, Ignacio Ibarra, Michelle Ives, Samuel Johnstone, Russell Keanini, Sophie Kenmare, Eric Kirby, Jennifer Lamp, Jackie Langille, Jeffrey Larimer, *Stephen Laubach*, Thomas Lees, Karin Lehnigk, Kerry Leith, Gian Marco Marmoni, *Jill Marshall*, Salvatore Martino, Justin Mattheis, Nicholas McCarroll, Mauri McSaveney, *Philip Meredith*, *Seulgi Moon*, Faye Moser, Amit Mushkin, Mariel Nelson, Nicolas Oestreicher, Marisa Palucis, Lyman Persico, Nathan Peters, Elizabeth Petrie, Regina Pläsken, *Laura Pyrak-Nolte*, Monica Rasmussen, Miles Reed, Melissa Riker, Alex Rinehart, Estefania Roland Nicolau, Shahrzad Roshankhah, Maryn Sanders, Ira Sasowsky, Behnoush Honarvar Sedighian, Uri Shaanan, Sophie Silver, Carl Steefel, Matthew Struve, Lisa Tranel, Priya Tripathi, Apostolos Vasileiou, *Heather Viles*, Anne Voightlaender, Liang Wang, Dylan Ward, Cheryl Waters-Tormey, Chenxi Zhao, Martin Ziegler, Jesse Zondervan.

Field Trip Leaders

Rick Wooten, North Carolina Geological Survey; Burt Cattanach, North Carolina Geological Survey; David Korte, North Carolina Geological Survey; Jennifer Bauer, Appalachian Landslide Consultants; Philip Prince, Appalachian Landslide Consultants; Cheryl Waters-Tormey, Western Carolina University; Karl Wegmann, North Carolina State University.

2022 Outstanding Earth Science Teacher Awards

The National Association of Geoscience Teachers (NAGT) has announced the 2022 Outstanding Earth Science Teacher (OEST) Awards. This annual award recognizes excellence in earth-science teaching at the pre-college level. GSA awards the section recipients US$700 in travel money to attend a GSA meeting and complimentary membership in GSA for three years. State winners receive a one-year complimentary GSA membership.

SECTION WINNERS

Central Section: Yvonne Garrison, Mason County High School
Eastern Section: Wendy Grimshaw, Andrew Lewis Middle School
Far Western: Lorraine Cathey, San Francisco Bay Area
New England: Joanna Latham, Milton Academy
Southeastern Section: Amanda Savrda, Auburn High School
Pacific Northwest: Kerry Lockwood, Coquitlam, British Columbia, Canada

STATE WINNERS

Alabama: Amanda Savrda
Louisiana: Sandra Saye Foucqueteau
Maryland: Sara Snook
Mississippi: Veronica Wylie
Nevada: Michele Laverty
New York: Zachary Miller
North Carolina: Stefan Klakovich
Oregon: Nichole Erwin
South Carolina: Christopher Willis
Virginia: Wendy Grimshaw
Wisconsin: Beth Allcox

Biographies are online at **https://nagt.org/nagt/awards/oest/2022_oest.html.**

NAGT

Robert Dietz: From Ocean Floor Mapping to Chasing Meteorite Impacts

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Robert Dietz in 1961, the year his *Nature* paper on sea-floor spreading was published (courtesy of the Univ. of California San Diego Library).

"Life is a rocky road, but along its highways and byways I never met a rock I did not like." —Robert Dietz (1994)

In his autobiography published shortly before his death, Robert S. Dietz recommends "a scientific career as the best of all possible pursuits." His life perhaps bears the best testimony to this recommendation: He sailed all the seven oceans, flew over a million miles as a pilot and into the stratosphere, traveled more than a mile deep in the oceans, and his geologic research took him to seven continents.

FROM NEW JERSEY TO ILLINOIS

Robert (Bob) Sinclair Dietz was born on 14 September 1914 in Westfield, New Jersey, USA. His father, Louis, was a civil engineer who struggled to provide for his family during the Great Depression.

His mother, Bertha (née Staiger), was a devout Christian Scientist who died at age 53 while Dietz was in high school, by which time he had rejected all religious beliefs.

Dietz was the sixth child of seven, with a sister and five brothers. His sister, Helen, whom Dietz described as a surrogate mother, worked in a public library. Through her, Dietz became a bookworm and read the popular works of H.G. Wells and James Jeans. He and his classmate, Ralph Hall, who later became a science writer, shared a mutual interest in rockhounding and other aspects of the natural world.

Raised in a penurious way, Dietz developed rat-like instincts for survival. After working two summers at a hotel on the New Jersey coast, he hitchhiked west to the University of Illinois at Urbana during the 1933 Chicago World's Fair.

For two years at Illinois, he lived in a boarding house for US$5 a month. His accommodations: a small, windowless room at the end of a hallway. Working part-time for 25 cents an hour with funds provided by President Franklin Roosevelt's National Youth Administration helped Dietz survive while also influencing his liberal political leanings. He supplemented his income during junior year by signing up for the Army Reserve Officers Training Corps (ROTC) to earn an extra US$16 a month. His favorite subjects were geology and astronomy. In his quest for good grades—he graduated Phi Beta Kappa in 1937—he studiously avoided advanced courses in physics, chemistry, and mathematics. Dietz later lamented that this strategy had stunted his education.

THE SHEPARD FACTOR

Dietz had picked the right time and place for a career in marine geology. In his junior year at Illinois, Dietz started a life-long friendship with fellow student Kenneth Orris (K.O.) Emery (1914–1998), who introduced him to professor Francis P. Shepard (1897–1985), a pioneer in marine geology. Emery and Dietz became Shepard's first graduate students and continued in his footsteps.

In 1936, Shepard received a US$10,000 grant (a huge sum at that time) from the Penrose Bequest of the Geological Society of America for bathymetric mapping and locating submarine canyons offshore California. Shepard and his students cruised aboard the 96-foot schooner *E.W. Scripps* of the Scripps Institution of Oceanography for six months. Roger Revelle (1909–1991), later the director of Scripps, was also on board. The seafloor was then terra incognita, and those late 1930s voyages of the *E.W. Scripps* generated pioneering results.

Shepard was meticulous: "He preferred to count the lion's teeth than consult Aristotle," as Dietz later recalled. For his M.S. thesis (1939), Dietz researched the submarine phosphorite deposits off the coast of California. For his Ph.D. (1941), he wrote a thesis on the mineralogy of deep-sea clay sediments collected from the same area. This work also described the value of manganese nodules as potential ores of copper, nickel, and cobalt.

SEAFLOOR MAPPING AND PLATE TECTONICS

In 1946, Dietz joined the Navy Electronics Laboratory (NEL) in San Diego. His first job was to study the seafloor as part of Admiral Byrd's fourth and last expedition to Antarctica. At NEL, Dietz also met and hired Henry William Menard (1920–1986), who later chronicled the seafloor mapping that led to plate tectonics in *The Ocean of Truth* (1986). Menard and Dietz produced the first contoured bathymetric map of the Gulf of Alaska. They also described the Mendocino Fracture Zone, the first of many such features now known to populate the world's ocean floors at oceanic rift zones. "We wrongly interpreted the nature of this prototype feature which only became apparent some years later in terms of plate tectonics," Dietz would later observe.

Dietz' next focus was guyots, which he called flattened seamounts. In 1950, Dietz co-led the joint Navy-Scripps Mid-Pacific Expedition and dredged several of them to test whether they were of Precambrian age. The fossils they recovered dated to the

Robert Dietz as a graduate student in 1938 (courtesy of University of California San Diego Library).

Cretaceous. "This was one of several surprises in marine geology that conditioned some of us in the mid-1950s to become mobilists, eventually accepting continental drift," he later commented. In 1953, Dietz was a Fulbright Fellow in Japan. This visit resulted in his 1954 *GSA Bulletin* paper, which included a description of a range of drowned seamounts trending northwest from near Midway Island to the Kamchatka Trench, which he named the Emperor Seamounts, each after a Japanese emperor. Dietz later mentioned that he had become a "mobilist" in 1953 in Japan when he became convinced that "trenches were underthrusts on a giant scale."

From 1954 to 1958, Dietz was assigned to the U.S. Office of Naval Research in London, where he reported on scientific advances in Europe. While in Europe, he met Jacques Piccard (1922–2008), who was developing the bathyscaphe *Trieste*. Dietz collaborated with Piccard to prepare the bathyscaphe for a dive into the Mariana Trench in 1960. This fascinating story is given in the popular book *Seven Miles Down* (1961) co-written by Piccard and Dietz.

Also in 1961, Dietz published his most famous paper on "seafloor spreading" in the journal *Nature*. Independently, Harry Hess (1906–1969) of Princeton University had also recognized seafloor spreading based on oceanographic mapping of the 1950s. In later years, Dietz continued to contribute to our understanding of ocean floor features, especially continental shelf-slope-rise changes. In the early 1970s, Dietz and John C. Holden, a geologist and artist, published several seminal papers on the breakup of Pangea and continental drift, creatively illustrated by Holden.

IMPACT CRATERS AND STRUCTURES

Dietz also pioneered research on the interpretation of lunar craters as impact in origin and the recognition of asteroid impact scars on Earth. Since the 1940s, Dietz actively researched meteorite impacts. Indeed, he intended to write his Ph.D. thesis on his idea about the impact origin the lunar craters. He related what happened in his 1994 autobiographical essay: "As a graduate student I proposed writing my Ph.D. thesis about the surface features of the Moon, but it was turned down as not a subject suitable for scientific contemplation," he wrote. "The idea was chided as totally bizarre and besides, 'there was no one to check my field work.'"

From 1941 to 1945, during World War II, Dietz served as an officer in the U.S. Army Air Corps. He attended military flight school in Hondo, Texas, where he also became an instructor. While based in Texas, he flew repeatedly to Meteor Crater in Arizona. The crater's origin as an asteroid-impact feature convinced him that others surely existed elsewhere on Earth. Dietz later recalled, "Flying around up there, you feel like God looking down and you try to apply geology to what you see. I was fascinated with the aerial view of the Earth which was then quite new."

In 1946, Dietz published his idea about lunar craters, though the controversy persisted until lunar landings. In 1947, he published, in *Science*, the first of about 20 papers advocating that asteroids have blasted the Earth with craters, too. With geologic uniformitarianism ruling the day, his papers smacked of unholy catastrophism. But Dietz steadily built his case for what he called terrestrial "astroblemes" (star wounds). From 1958 and into the 1980s, he described impact craters and scars in Australia, Germany, India, North America, Russia, and South America.

SCIENTIFIC REVOLUTIONARY

Dietz participated in the two great geological revolutions of the twentieth century. He promoted impacting asteroids as an important geologic process shaping the surfaces of both the Moon and Earth. His seafloor spreading advocacy helped install plate tectonics as the central organizing principle of geology. In doing so he earned some of the highest awards in geoscience including the Penrose Medal of the Geological Society of America (1988).

Dietz died on 19 May 1995 in Tempe, Arizona. His last wish was "to be struck by a meteorite and then fossilized," but then he would add, "that apparently happened to an Ordovician cephalopod in Sweden."

SUGGESTIONS FOR FURTHER READING

Bourgeois, J., and Koppes, S., 1998, Robert S. Dietz and the recognition of impact structures on Earth: Earth Science History, v. 17, p. 139–156.

Dietz, R.S., 1946, The meteorite impact origin of the Moon's surface features: Journal of Geology, v. 54, p. 359–375.

Dietz, R.S., 1961, Continent and ocean basin evolution by spreading of the sea floor: Nature, v. 190, p. 854–857.

Dietz, R.S., 1994, Earth, sea, and sky: Life and times of a journeyman geologist: Annual Review of Earth and Planetary Sciences, v. 22, p. 1–32.

Welcome New GSA Members!

The following new members joined between 24 Feb. and 4 Aug. 2022 and were approved by GSA Council at its fall meeting.

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Sarah Grace Davis
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Jacob William Clements
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Adam Dubinsky
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- Early-Career Professionals—11%
- Students—67%
- K-12 Teachers—1%
- Affiliates—4%

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Annabella Charlotte Kennedy
Abbegail Suzanne King
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Grace Lamyman
Samuel Thomas Lavin
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Maximilian Pankowski
Nidhi Utkarshbhai Patel
Luke Joseph Philip Rose
Minyoung Son
Edward Joseph Spagnuolo
Karrah Spendlove
Redmond Stein
Obrine Tamon Tamon
Ian Alexander Taylor
Alexandria Thompson
Chelsea Scott Trenbeath
Fortune E. Uchechukwu
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Anna Viktoria Calderon
Hanzhang Chen
Grace Olivia Fanson
Erin Fragoso
Matthew Donovan Gordon
Kyla Serica Gray

Top Professional Interests of New Student Members:

- MGPV
- Environmental
- Paleo Sciences
- Hydrogeology
- Structural Geology/ Tectonics

Brian Gulick
Patrick Harper
Cassaundra Huggins
Emma Rose Jones
Sabrina Yasmeen Khan
An Li
Barbara Lyon
Mackenzie Mills
Roy Naor
Mareli Stella Paredes
Ari Quasney
Madeline Raith
Jessica Rowshandel
Lauren Schwartz
Martin Hugo Senger
Garima Sodha
Caleb Aaron Strom
Katrina Mackenzie Taylor
Madison Turner
Robin Van Auken
Sarah Anne Walton
Katya Lorena Yanez
Jacob Yates
Sophia Zipparo

Policy/Regulatory
Emily Bengston
Christopher Lee Shannon

Quaternary Geology/ Geomorphology
Alla Ahmaed Alnoubi
Holden Aronson
Adrian Aviles
Allie Balter-Kennedy
Rachel Barnett
David Cavagnaro
Leo George Urnau Collier
Corey Crowder
Grace Guryan
Md Saddam Hossain
Tingan Li
Elena Lowe
Mishel Milagros Melendez-Bernardo
Chelsea Moran

Samantha Louise Motz
Christopher Norcross
Audrey Parnell
Nicholas Ross Patton
Charis B.K. Peever
Ethan Pierce
Emily C. Polizzi
Cornelis Reijm
Kristen Elizabeth Smith
Ivan Tochimani-Hernandez
Jackson Wade
Karina Zyatitsky

Seismology
Gabrielle Karece Davy

Soil Science
Terrence Anthony Carbon
Jason Phan Dahlberg
Johnna Elyse Green
Eli Finn Gundersen
Alicia M. Hernández
Laysen Keel
Loryssa Lake
Declan Martin
Andrew Wayne Rupiper
Ahmad Tourei

Stratigraphy/Sedimentology
Sreetama Aich
Rawan Alasad
Nicolas Bell
Hope Elizabeth Burbank
Candice Tatyana Galindo
Ian Gillette
Matthew David Gonzalez
Seounghun Ham
Bronte Heerdink
Amy Hsieh
Kelly Lynn Johnson
Cassandra L. Kenyon
Hanna Konavaluk
Binbing Li
David Bruin Luffman
Mahdi Maaleki Moghadam
Andrew J. Moreland
Molly O'Halloran
Abdul Qudus
Samuel Alejandro Ramirez
Luke D. Romang
George Rump
Melanie Schwarz
Samuel Madison Thompson
Evelyn Hope Usher
Guanghui Wu
Samantha Stanek Zink

Structural Geology/Tectonics
Anneke Avery
Alaura Lynn Beck
Zachary Andrew Betta
Erick Bora
Ariel J. Borsook
Sedona Boyle
Daniel James Brenneman
Summer Donyelle Brooks
Anna Rose Chanar
Zhe Chen
Elizabeth Rose Curtiss
Yannan Du
Joshua Patrick Frank
Alana Marie Gabriel
Ian Gannon
Joseph Frank Gunter
Richardjames Kemble
Natthakorn Konguthaithip
Joseph Lane
Katherine Langfield
Terry WaiHo Lee
Yanying Li
Joshua S. Love
Jiannan Meng
Michelle Nishimoto
Emuobosa Patience Ojoboh
Daniel Ortega-Arroyo
William H. Priakos
Steven Daniel Ramirez
Johnathann Christopher Renna Reyes
Andrew Robillard
Ronny Y. Rodriguez
Emily Ross
Melissa Jean Schmidt
Roxanne Elizabeth Schulman
Ananya Singha
Kawner Fred Sistrunk
Julia L. Stevens
Holli L. Swarner
Rongshu Wang
Samuel Joseph White

Other Professional Interests
Adonia Penelope Alexopoulos
Iona MacCallum Baillie
Anah Victoria Bogdan
Hayden Douglas Bowman
Nicholas Andrew Brack
Teagan Riley Cox
Amy Crook
Joshua Deen
Jesse Do
Cody Fehringer
Sofia Garza
Alexander Goff
Elena Gonzalez
Cameryn Jane Greenough
Easton Jack Hitchens
Hannah Jackson
Ryan J. Johnston
Kathryn C. Josten
Nathan Sherwood Liang
Zhikang Luan
Kitsel Lusted
Richard Jeremy Molina
Matthew Mollica
Mahima Quazi
Nelofar Quilzada
Lily Reed
Iliomar Rodriguez Ramos
Lizbet Salcedo
Leah Shadle
Elizabeth Grace Sjovold
Evelyn Solis Cabrera
Darby Steindorf
Elizabeth R. Sullivan
Breanna H. Taylor
Raheem Taylor
Henry Urschel
Kathryn Irene Utter
John Xaiver Wagner

K–12 TEACHERS
Keith Barnes
Jacqueline Boyle
Olivia Cruz
Laura Cruz-Gomez
Jo Hamilton
Deb Jess
Carla Kuhn
Lisa Leonard
Demetrius Lutz
Jomhara Palacios
Jonathon Snyder
Leishawn Spotted Bear
Kongyou Wu

AFFILIATES
Elesi Ameko
James Binkley

Top Employment Sectors of New Members (Excluding Students):
- Four-Year University
- Federal
- Environmental

James Burrall
Joyce Chung
Anthony Clevenger
Scott Clifton
Mark Fiege
Maryann Foster
Jenny Gholson-Morris
Brent Hege
Helene Hendrix
Melissa Hendrix
Tyler Hintz
Beazley Holly
Roland Kilcher
Eileen Kramer
Jayme Lopko
Rachael Lyle
Lisa Mattox
Phoebe McMellon
Celia Mojica
Marcelino Montas Jimenez
David Morgans
John Nash
John Norton
Corey Owen
Maximilian Pankowski
Raymond Perry
Deborah Phillips
Joanna Pitsikoulis
Leila Poullada
Deborah Prusia
Galen Randall
Jay Reid
Timothy Ridlon
Ted Snelling
William Taylor
Derek Turner
Jesse Van Gerven
Greg Walker
Russell Warner
Derek Watson
Van Wilshire
Zachary Zuccaro

GeoCareers Programs at the 2023 Section Meetings

GEOSCIENCE CAREER WORKSHOPS

Part 1: Career Planning and Networking. Your job-hunting process should begin with career planning, not when you apply for jobs. This workshop will help you begin this process and practice your networking skills. Highly recommended for freshmen, sophomores, and juniors—the earlier you start your career planning the better.

Part 2: Geoscience Career Exploration. What do geologists in various sectors earn? What do they do? What are the pros and cons of working in academia, government, and industry? Workshop presenters and professionals in the field will address these issues.

Part 3: Cover Letters, Résumés, and CVs. How do you prepare a cover letter? Does your résumé need a good edit? Whether you are currently in the market for a job or not, learn how to prepare the best résumé possible. You will review numerous examples to help you learn important résumé dos and don'ts.

MENTOR PROGRAMS

GSA student members will have the opportunity to discuss career prospects and challenges with applied geoscientists from various sectors. Not a member? Join at **www.geosociety.org/join** today!

South-Central Section Meeting
13–14 March, Stillwater, Oklahoma, USA
Shlemon Mentor Program: Monday, 13 March
Mann Mentors in Applied Hydrology Program: Tuesday, 14 March

Southeastern & Northeastern Joint Section Meeting
17–19 March, Reston, Virginia, USA
Shlemon Mentor Program: Friday, 17 March
Mann Mentors in Applied Hydrology Program: Saturday, 18 March

North-Central Section Meeting
4–5 May, Grand Rapids, Michigan, USA
Shlemon Mentor Program: Thursday, 4 May
Mann Mentors in Applied Hydrology Program: Friday, 5 May

Cordilleran Section Meeting
17–19 May, Reno, Nevada, USA
Shlemon Mentor Program: Wednesday, 17 May
Mann Mentors in Applied Hydrology Program: Thursday, 18 May

Rocky Mountain Section Meeting
23–25 May, Fort Collins, Colorado, USA
Shlemon Mentor Program: Tuesday, 23 May
Mann Mentors in Applied Hydrology Program: Thursday, 25 May

SECOND ANNOUNCEMENT AND CALL FOR PAPERS

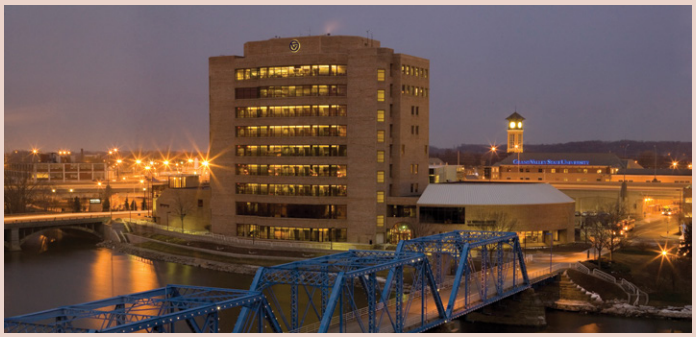
North-Central Section

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

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

www.geosociety.org/nc-mtg

A Meeting in the Mitten: Water, Rock, Wonderland



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

LOCATION

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

REGISTRATION

Early registration deadline: 27 Mar.
Cancelation deadline: 3 Apr.

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

REGISTRATION FEES (all fees are in U.S. dollars)

Member Type	Early		Standard	
	Full Mtg.	One Day	Full Mtg.	One Day
Professional Member	$280	$170	$310	$185
Professional Member 70+	$165	$100	$180	$110
Professional Nonmember	$335	$200	$360	$220
Early-Career Professional Member	$205	$120	$225	$135
Student Member	$80	$50	$90	$55
Student Nonmember	$125	$75	$135	$80
K–12 Professional	$85	$50	$95	$55
Guest or Spouse	$65	n/a	$75	n/a
Field Trip/Workshop Only	$45	n/a	$50	n/a

ACCOMMODATIONS

Hotel registration deadline: 18 Apr., 5 p.m. EST

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

Courtyard by Marriott, Downtown Grand Rapids: 11 Monroe Ave. NW, Grand Rapids, Michigan 49503, USA. The meeting rate is US$149 per night plus tax for single/double/triple/quad occupancy. Reservations can be made by calling +1-616-242-6000. Please be sure to identify yourself with the group code "GSA–North Central Section" and that you are attending the GSA North-Central Section Meeting.

Holiday Inn Grand Rapids Downtown: 310 Pearl Street NW, Grand Rapids, Michigan 49504, USA. The meeting rate is US$125/night for one to two queen beds, single-quad occupancy; US$135/night for a king standard, single-double occupancy; and US$165/night for a king executive room (hospitality room) plus tax. Reservations can be made by calling +1-616-235-7611.

DASH around Downtown Grand Rapids

Grand Rapids has a downtown area shuttle called DASH. It is a system of small buses that link downtown neighborhoods and

destinations. This service is free and provides convenient connections to all parts of the urban core. For details and routes, go to https://downtowngr.org/get/dash.

CALL FOR PAPERS

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

TECHNICAL PROGRAM

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

T1. **Teaching Geoscience at 2YC: Working to Engage Students and Broaden Participation.** *Endorsed by GSA Energy Geology Division; GSA Geoscience Education Division*; *National Association of Geoscience Teachers (NAGT); National Association of Geoscience Teachers (NAGT) Geo2YC Division.* Tari Noelani Mattox, Grand Rapids Community College, tmattox@grcc.edu; Andrea Bair, Delta College, andreabair@delta.edu.

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

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

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

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

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

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

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

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

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

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

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

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

T14. **Geobiology of the Great Lakes.** *Endorsed by GSA Marine and Coastal Geoscience Division.* Cecilia Howard, University of Michigan, howardcm@umich.edu; Diana Velazquez, University of Michigan, dvelaz@umich.edu.

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

T16. **Geoscience and Hydrology of Your Federal and Other Public Lands: STEM Internships, Research, Science,**

Mapping, Resource Management, and Education. *Endorsed by GSA Energy Geology Division.* Matt Dawson, Geological Society of America, mdawson@geosociety.org.

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

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

T19. **Aqueous and Environmental Geochemistry.** *Endorsed by GSA Marine and Coastal Geoscience Division; International Association of Geochemistry.* David T. Long, Michigan State University, long@msu.edu; W. Berry Lyons, The Ohio State University, lyons.l42@osu.edu.

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

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

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

T23. **Undergraduate and Graduate Geoscience Student Showcase.** *Endorsed by GSA Energy Geology Division; GSA Marine and Coastal Geoscience Division; Council on Undergraduate Research Geosciences Division.* Ken Brown, DePauw University, kennethbrown@depauw.edu; Claire McLeod, Miami University, mcleodcl@miamioh.edu; Robert Shuster, University of Nebraska Omaha, rshuster@unomaha.edu.

T24. **Undergraduate Research Poster Session.** *Endorsed by GSA Energy Geology Division; Council on Undergraduate Research Geosciences Division.* Robert Shuster, University of Nebraska Omaha, rshuster@unomaha.edu; Ginny Peterson, Grand Valley State University, petersvi@gvsu.edu.

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

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

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

T28. **Critical Minerals in the North-Central United States: Exploration, Mining, and Processing**. Snehamoy Chatterjee, Michigan Technological University, schatte1@mtu.edu; Tim Eisele, Michigan Technological University, tceisele@mtu.edu.

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

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

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

T32. **Lithospheric and Crustal Studies of the Midcontinent Using Geophysics.** *Endorsed by GSA Geophysics and Geodynamics Division; GSA Energy Geology Division.* Kevin Mickus, Missouri State University, kevinmickus@missouristate.edu.

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

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

T35. **Imaging the Subsurface.** *Endorsed by GSA Energy Geology Division.* Harry Jol, University of Wisconsin Eau Claire, jolhm@uwec.edu.

T36. **Remembering Our Colleague, Al Kehew: His Contributions to Glacial Geomorphology, Midwestern Glacial Geology, and Geologic Mapping.** Kevin Kincare, U.S. Geological Survey, kkincare@usgs.gov; Andrew Kozlowski, New York State Museum, andrew.kozlowski@nysed.gov; John Yellich, Michigan Geological Survey, john.a.yellich@wmich.edu.

FIELD TRIPS

For additional information, please contact the field trip co-chairs: Peter Wampler, wamplerp@gvsu.edu, or Ed Hansen, hansen@hope.edu.

Pre-Meeting

FT1. **Michigan Geological Repository for Research and Education (MGRRE) Tour—Michigan Subsurface Geology Using Borehole Core Samples.** Wed., 3 May. Departs Eberhard Center 9 a.m.; returns 4 p.m. Cost: US$110. Max. participants: 40. Leaders: Peter Voice, Western Michigan University, peter.voice@wmich.edu; William B. Harrison III, Western Michigan University, william.harrison_iii@wmich.edu; Jennifer Trout, Western Michigan University, jennifer.l.trout@wmich.edu; Robb Gillespie, Western Michigan University, robb.gillespie@wmich.edu.

FT2. **Tour of PFAS Disposal and Treatment Sites in Northern Kent County.** Wed., 3 May. Departs Eberhard Center 1 p.m.; returns 5 p.m. Cost: US$60. Max. participants: 40. Leaders: Richard Rediske, Grand Valley State University, redisker@gvsu.edu; Karen Vorce, Michigan Department of the Environment, Great Lakes, and Energy, vorcek@michigan.gov.

Mid-Meeting

FT3. **Riverwalk Tour—Revitalizing the Rapids in Grand Rapids.** Thurs., 4 May. Departs Eberhard Center 11 a.m.; returns 1 p.m. Cost: US$30. Max. participants: 90. Leaders: Wendy Ogilvie, Grand Valley Metro Council/Lower Grand River Organization of Watersheds, wendy.ogilvie@gvmc.org; Matt Chapman, Grand Rapids Whitewater, matt@grandrapidswhitewater.org; Michael Staal, City of Grand Rapids, mstaal@grand-rapids.mi.us.

FT4. **Collections Tour of the Grand Rapids Public Museum.** Fri., 5 May. Departs Eberhard Center 11 a.m.; returns 1:30 p.m. Cost: US$35. Max. participants: 24. Leader: Cory Redman, Grand Rapids Public Museum, credman@grpm.org.

FT5. **Mississippian Gypsum Mine Geology and Paleontology Field Trip.** Fri., 5 May. Departs Eberhard Center 6 p.m.; returns 9 p.m. Cost: US$50. Max. participants: 20. Leaders: John Van Regenmorter, Grand Rapids Community College, johnvanregenmorter1@grcc.edu; Peter Wampler, Grand Valley State University, wamplerp@gvsu.edu.

Post-Meeting

FT6. **Coastal Dunes of Southern Lake Michigan.** Sat., 6 May. Departs Eberhard Center 8 a.m.; returns 6 p.m. Cost: US$120. Max. participants: 30. Leaders: Suzanne DeVries-Zimmerman, Hope College, zimmerman@hope.edu; Erin Argyilan, Indiana University Northwest, eargyila@iun.edu; Todd Thompson, Indiana Geological and Water Survey, Indiana University, tthomps@indiana.edu.

FT7. **Mid-Michigan's Outdoor Classroom: Pennsylvanian Marginal-Marine Strata at Grand Ledge, Michigan.** Sat., 6 May. Departs Eberhard Center 8 a.m.; returns 5 p.m. Cost: US$160. Max. participants: 30. Leaders: Danita Brandt, Michigan State University, brandt@msu.edu; Melinda Higley, Calvin University, mchigley@calvin.edu; Madeline Marshall, Albion College, mmarshall@albion.edu; Heather L. Petcovic, Western Michigan University, heather.petcovic@wmich.edu; Michael Velbel, Michigan State University, velbel@msu.edu; Peter J. Voice, Western Michigan University, peter.voice@wmich.edu; Ian Winkelstern, Grand Valley State University, winkelsi@gvsu.edu.

FT8. **Geology, Age, and Shock Metamorphism of The Kentland, Indiana, Impact Structure.** Sun., 7 May. Departs Eberhard Center 7:30 a.m.; returns 5 p.m. Cost: US$200. Max. participants: 40. Leader: John Weber, Grand Valley State University, weberj@gvsu.edu.

SHORT COURSES

For additional information, please contact the short course organizer, Tara Kneeshaw, kneeshta@gvsu.edu, or the short course leaders listed below.

SC1. **Practical High-Energy Injection in Overburden and Bedrock: Preparation, Tools, Design, Distribution, and Evaluation Illustrated by Case Studies.** Wed., 3 May, 8 a.m.–noon. Cost: US$25 students/US$80 professionals. Max. participants: 30. Leader: Edward Winner, RPI Group, ed@trapandtreat.com.

SC2. **Near Subsurface Microbiology: It's the Little Things That Count.** Wed., 3 May, 1–5 p.m. Cost: US$25 students/US$80 professionals. Max. participants: 30. Leader: Edward Winner, RIP Group, ed@trapandtreat.com; Aaron Peacock, Microbac Laboratories, aaron.peacock@microbac.com.

SC3. **Stratigraphic Imaging of Geomorphic, Geologic, and Geoarchaeological Landscapes.** Wed., 3 May, 1–5 p.m. Cost: US$25 students/US$80 professionals. Max. participants: 30. Leader: Harry Jol, University of Wisconsin Eau Claire, jolhm@uwec.edu.

OPPORTUNITIES FOR STUDENTS AND EARLY-CAREER PROFESSIONALS

Career Mentoring Luncheons

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

Career Workshop Series

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

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

STUDENT VOLUNTEERS

Earn free registration and get an insider's view when you volunteer to work at the meeting. For more information, contact Caitlin Callahan, callahca@gvsu.edu, or Melinda Higley, mcc4@calvin.edu.

TRAVEL GRANTS

Deadline to apply: 27 Mar.

The North-Central Section is pleased to offer support for the cost of student travel to the meeting. For more information, go to **www.geosociety.org/travel-grants** and click on North-Central.

PROFESSIONALS

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

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

LOCAL COMMITTEE

Meeting Co-Chairs: Tara Kneeshaw, kneeshta@gvsu.edu; Ginny Peterson, petersvi@gvsu.edu
Technical Program Chair: Kevin Mickus, kevinmickus@missouristate.edu
Field Trip Co-Chairs: Peter Wampler, wamplerp@gvsu.edu; Ed Hansen, hansen@hope.edu
Exhibits Chair: Steve Mattox, mattoxs@gvsu.edu
Short Course Chair: Tara Kneeshaw, kneeshta@gvsu.edu
Budget/Finance Chair: Ginny Peterson, petersvi@gvsu.edu
Sponsorship Co-Chairs: Peter Riemersma, riemersp@gvsu.edu; Ian Winkelstern, winkelsi@gvsu.edu
Student Volunteer Co-Chairs: Caitlin Callahan, callahca@gvsu.edu; Melinda Higley, mcc4@calvin.edu

THE GEOLOGICAL SOCIETY OF AMERICA®

Mark Your Calendar for Meetings Closer to Home

South-Central Section

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

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

Joint Southeastern & Northeastern Sections

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

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

North-Central Section

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

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

Cordilleran Section

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

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

Rocky Mountain Section

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

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

2023

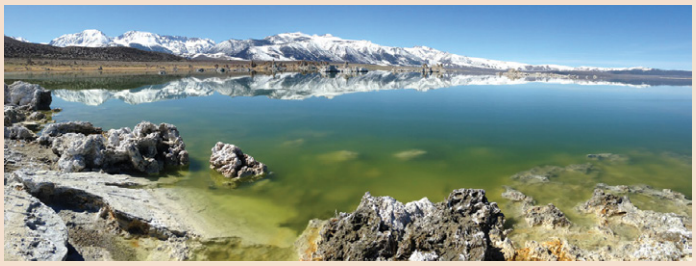
SECOND ANNOUNCEMENT AND CALL FOR PAPERS

Cordilleran Section

119th Annual Meeting of the Cordilleran Section, GSA

Reno, Nevada, USA | 17–19 May 2023

www.geosociety.org/cd-mtg



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

LOCATION

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

REGISTRATION

Early registration deadline: 10 Apr.
Cancelation deadline: 17 Apr.

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

REGISTRATION FEES (all fees are in U.S. dollars)

Member Type	Early		Standard	
	Full Mtg.	One Day	Full Mtg.	One Day
Professional Member	$295	$220	$325	$250
Professional Member 70+	$245	$145	$270	$175
Professional Nonmember	$375	$295	$405	$320
Early-Career Professional Member	$220	$145	$250	$175
Student Member	$120	$85	$145	$110
Student Nonmember	$170	$130	$185	$145
K–12 Professional	$145	$105	$160	$120
Guest or Spouse	$145	$105	$155	$120
Field Trip/Workshop Only	$70	n/a	$95	n/a

ACCOMMODATIONS

Hotel registration deadline: 24 Apr.

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

CALL FOR PAPERS

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

TECHNICAL PROGRAM

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

Theme Sessions

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

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

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

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

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

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

T7. **Advancements in Central Sierra Nevada Structural Geology and Tectonics.** Allison Jones, Sierra College, ajones124@sierracollege.edu; Kurtis Burmeister, California State University Sacramento, k.burmeister@csus.edu.

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

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

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

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

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

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

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

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

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

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

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

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

T21. **Innovative and Novel Applications of Geographic Information Systems (GIS) and Remote Sensing for** Geologic Mapping, Geomorphology, Volcanology, and

Other Fields. Stephen M. Crabtree, University of Minnesota Morris, crabt012@morris.umn.edu.

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

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

T24. **Geoscience and Hydrology of Your Federal and Other Public Lands: STEM Internships, Research, Science, Mapping, Resource Management, and Education (Posters).** Matt Dawson, Geological Society of America, mdawson@geosociety.org.

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

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

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

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

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

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

T31. **From High Grade to Low Grade: A Session Honoring the Contributions of J. Douglas Yule toward Understanding the Growth and Active Deformation of Western North America.** Andrew Meigs, Oregon State University, andrew.meigs@oregonstate.edu; Whitney Behr, ETH Zurich, wbehr@ethz.ch; Kate Scharer, U.S. Geological Survey, kscharer@usgs.gov

FIELD TRIPS

For additional information, please contact the Field Trip co-chairs: Pat Cashman, patriciahcashman@gmail.com, Sue Cashman, smc1@humboldt.edu, or Harvey Kelsey, hmk1@humboldt.edu.

Pre-Meeting

FT1. **Geology along the Yuba Pass and Highway 70 Corridors: A Complex History of Tectonics and Magmatism in the Northern Sierra Nevada.** Tues., 16 May. Cost: US$92. Michelle A. Roberts, U.S. Geological Survey, roberts@usgs.gov; Vicki Langenheim, U.S. Geological Survey, zulanger@usgs.gov.

FT2. **The Blast, The Quake, and the Bomb: An Accessible Tour of High-Energy Events in Western Nevada.** Tues., 16 May. Cost: US$205. John Louie, University of Nevada Reno, louie@unr.edu; Philipp Ruprecht, University of Nevada Reno, pruprecht@unr.edu.

FT3. **Northern Walker Lane Seismic Hazards and State Water Project Dams: Upper Feather River, California, USA.** Tues., 16 May. Cost: US$105. Chad W. Carlson, California Department of Water Resources, chad.carlson@water.ca.gov; Don F. Hoirup, California Department of Water Resources, don.hoirup@water.ca.gov; Christopher Hitchcock, InfraTerra Inc., chitchcock@infraterra.com.

FT4. **Ammonites and Ichthyosaurs in Nevada's Triassic–Jurassic Seaway.** Tues., 16 May. Cost: US$123. Montana Hodges, University of Nevada Reno, montanahodges@unr.edu; Neil Kelley, Vanderbilt University, neil.p.kelley@vanderbilt.edu; Paula Noble, University of Nevada Reno, noblepj@unr.edu.

FT5. **Tufa or Microbialites?** Tues., 16 May. Cost: US$56. Russell Shapiro, California State University Chico, rsshapiro@csuchico.edu; Tom Anderson, University of Nevada Reno; Laura DeMott, U.S. Geological Survey, ldemott@usgs.gov.

Post-Meeting

FT6. **Bodie and Aurora Mining Districts, Mono County California, USA.** Sat., 20 May. Cost: US$132. Gregg

Wilkerson, California State University Bakersfield, gwilkerson1@csub.edu.

FT7. **Miocene Diatomite in Western Nevada—Climate and Tectonic Implications.** Sat., 20 May. Cost: US$287. Michel Houseman, Imerys, mike.houseman@imerys.com; Bill Krebs, Subsurface Consultants, wnkrebs@hotmail.com.

FT8. **From Headwaters to The Terminal Basin: Tracking the Interrelated History of Lake Tahoe, The Truckee River, and Pyramid Lake.** Sat., 20 May. Cost: US$52. Kenneth D. Adams, Desert Research Institute, kadams@dri.edu.

FT9. **Northern Sierra Nevada: Ophiolites and Blueschists to Active Tectonics and Geomorphology.** Sat.–Sun., 20–21 May. Cost: US$210. John Wakabayashi, California State University Fresno, jwakabayashi@csufresno.edu; David Shimabukuro, California State University Sacramento, dhs@csus.edu.

FT10. **The Transition from Walker Lane Transtension to Vertical-Axis Rotation Deformation Styles in Southern Oregon.** Sat., 20 May–TBD. Cost: US$441. Andrew Meigs, Oregon State University, Andrew.Meigs@oregonstate.edu; Katherine Alexander, U.S. Geological Survey; Colin Amos, Western Washington University, amosc2@wwu.edu; Trevor Waldien, South Dakota School of Mines, trevor.waldien@sdsmt.edu.

FT11. **Emplacement of the Sage Hen Flat Pluton: Use of Strabo-Spot and Uncertainty Rankings.** Sat.–Sun., 20–21 May. Cost: US$197. Basil Tikoff, University of Wisconsin Madison, basil@geology.wisc.edu; Sven Morgan, University of Michigan Dearborn, svenmor@umich.edu; Ellen Nelson, University of Wisconsin Madison, emnelson8@wisc.edu; Tim Shipley, Temple University, thomas.shipley@temple.edu.

SHORT COURSES

For additional information, please contact the short course chair: Rich Koehler, rkoehler@unr.edu.

SC1. **Basics of Electron Backscatter Diffraction (EBSD) Analysis Related to Structural and Petrochronology Studies.** Tues., 16 May, 9 a.m.–4:30 p.m. Cost: US$15 students/US$20 all others. Joel DesOrmeau, University of Nevada Reno, jdesormeau@unr.edu; Zach Michels, University of Arizona, zacharymichels@arizona.edu; Drew Levy, University of Nevada Reno, drewlevy@nevada.unr.edu.

SC2. **Solving Geomorphic Puzzles for Paleoflood Analyses: It's Just Water and Dirt, Right?** Tues., 16 May, 8 a.m.–5 p.m.. Cost: US$99. Keith Kelson, USACE National Paleoflood Lead, keith.i.kelson@usace.army.mil.

OPPORTUNITIES FOR STUDENTS AND EARLY-CAREER PROFESSIONALS

Best Student Posters and Papers

Awards for the best student posters and presentations are supported by the GSA Cordilleran Section. To be eligible, students must be lead authors and presenters and should be capable of answering detailed questions about their research. Judging will take place during the conference, and awards will be announced after the meeting.

Career Mentoring Luncheons

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

Career Workshop Series

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

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

STUDENT VOLUNTEERS

Take advantage of work opportunities to earn free registration. Students interested in helping with the various aspects of the meeting should contact Wenrong Cao, wenrongc@unr.edu.

PROFESSIONALS

Interested in sharing information about your applied geoscience or hydrology career with students, or interested in earning CEUs by attending the meeting? Being a mentor is a rewarding experience. To learn more about serving as a mentor at the meeting, contact Jennifer Nocerino at jnocerino@geosociety.org.

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

ORGANIZING COMMITTEE

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

SECOND ANNOUNCEMENT AND CALL FOR PAPERS

Rocky Mountain Section

72nd Annual Meeting of the Rocky Mountain Section, GSA

Fort Collins, Colorado, USA | 23–25 May 2023

www.geosociety.org/rm-mtg

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

LOCATION

The 2023 GSA Rocky Mountain Section Meeting will be held in Fort Collins, Colorado, USA, on the campus of Colorado State University. This meeting site is near the foothills of the geologically diverse Front Range, which includes complex Proterozoic rocks and shear zones, well-exposed Pennsylvanian to Cretaceous strata, spectacular Laramide structures, Late Cretaceous–Paleogene intrusive bodies and associated mineral deposits, and a wide range of geomorphic features. Fort Collins is about a one-hour drive from Denver International Airport and is a small, dynamic city with a nationally renowned and very walkable downtown, arts, restaurants, and outdoor recreational scene (including numerous noteworthy breweries).

REGISTRATION

Early registration deadline: 17 Apr.
Registration cancelation deadline: 24 Apr.

For further information or if you need special accommodations, please contact the organizing chair, Rick Aster, rick.aster@colostate.edu.

REGISTRATION FEES (all fees are in U.S. dollars)

Member Type	Early		Standard	
	Full Mtg.	One Day	Full Mtg.	One Day
Professional Member	$350	$250	$400	$275
Professional Member 70+*	$225	$140	$250	$170
Professional Nonmember	$400	$275	$450	$300
Early-Career Professional Member	$225	$100	$250	$125
Student Member	$125	$90	$150	$110
Student Nonmember	$150	$100	$175	$120
K–12 Professional	$225	$90	$250	$110
Guest or Spouse	$75	n/a	$75	n/a
Field Trip/Workshop Only	$40	n/a	$40	n/a

*70 years of age or older and a member for 30 or more years.

ACCOMMODATIONS

Hotel registration deadline: 2 May

A block of rooms has been reserved at the Fort Collins Hilton located next to the Colorado State University campus and within easy walking distance of the Lory Center meeting venue. The meeting rate is US$189 per night plus tax (single or double), US$199 (triple), and US$209 (quad). 10% of rooms will be offered at the prevailing federal government per diem rate. The convention center is just steps away. Reservations can be made by calling +1-970-482-2626. Please reference group code **NNR1.**

CALL FOR PAPERS

Abstract deadline: 28 Feb. 2023
Submit online at **www.geosociety.org/rm-mtg**

Abstract submission fee: GSA members: professionals, US$35; students, US$20. Non-members: professionals, US$60; students, US$35. If you cannot submit an abstract online, please contact Heather Clark, +1-303-357-1018, hclark@geosociety.org.

TECHNICAL PROGRAM

Technical Sessions

Technical session and short course meeting co-chairs: Ken Sims, ksims7@uwyo.edu, and Rick Aster, rick.aster@colostate.edu.

T1. **The Laramide Belt: End to End.** *Endorsed by GSA Structural Geology and Tectonics Division; GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division.* Jacob O. Thacker, Montana State University Billings, jacoboliverthacker@gmail.com; Carla Eichler, Oklahoma Geological Survey, carla.eichler@ou.edu; Nikki M. Seymour, Stanford University, nseymour@stanford.edu; Brian Hampton, New Mexico State University, bhampton@nmsu.edu.

T2. **Planning to Reduce Landslide Hazard Losses.** *Endorsed by GSA Environmental and Engineering Geology Division; GSA Quaternary Geology and Geomorphology Division.* Stephen L Slaughter, U.S. Geological Survey, sslaughter@usgs.gov; Jonathan Godt, U.S. Geological Survey, jgodt@usgs.gov.

T3. **Past and Present Glaciation of Western North America.** *Endorsed by GSA Quaternary Geology and Geomorphology Division.* Keith Brugger, University of Minnesota Morris, bruggeka@morris.umn.edu; Jordan Dahle, North Dakota State University, jordan.dahle@ndsu.edu; Eric Leonard, Colorado College, eleonard@coloradocollege.edu.

T4. **Geophysical Studies of Crust-Mantle Structure and Surface Deformation in the Rocky Mountains.** *Endorsed by GSA Geophysics and Geodynamics Division.* Brandon Schmandt, University of New Mexico, bschmandt@unm.edu;

Julien Chaput, University of Texas at El Paso, jchaput82@gmail.com.

T5. **Drivers of Continental Magmatism.** *Endorsed by GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division.* Pamela Kempton, Kansas State University, pkempton@ksu.edu; Claudia Adam, Kansas State University, cadam@ksu.edu; Matthew Brueseke, Kansas State University, brueseke@ksu.edu.

T6. **Integrated Science Approaches to Addressing Complex Earth Science Challenges.** *Endorsed by GSA Geology and Society Division; GSA Hydrogeology Division; GSA Environmental and Engineering Geology Division; GSA Soils and Soil Processes Division; GSA Geoscience Education Division; GSA Geoinformatics and Data Science Division.* Jason Alexander, U.S. Geological Survey, jalexand@usgs.gov; Rebecca Frus, U.S. Geological Survey, rfrus@usgs.gov; Patrick Anderson, U.S. Geological Survey, andersonpj@usgs.gov; Joseph Hevesi, U.S. Geological Survey, jhevesi@usgs.gov; Adrian Monroe, U.S. Geological Survey, amonroe@usgs.gov; Sharon Qi, U.S. Geological Survey, slqi@usgs.gov; Katharine Dahm, U.S. Geological Survey, kdahm@usgs.gov.

T7. **Geoscience, Hydrology, and Water Management of Our Public Lands.** *Endorsed by GSA Hydrogeology Division.* Forrest "Ed" Harvey, National Park Service–Water Resources Division, forrest_harvey@nps.gov; Steve Rice, National Park Service, steven_rice@nps.gov; Tyler Gilkerson, National Park Service, tyler_gilkerson@nps.gov; Nicole O'Shea, National Park Service, nicole_oshea@nps.gov; Erin White, National Park Service, erin_white@nps.gov; Matt Dawson, The Geological Society of America, mdawson@geosociety.org.

T8. **The Yellowstone Hotspot Geologic Province: Examining the Effects of Yellowstone Volcanism on the North American West.** *Endorsed by GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division.* Cole Messa, University of Wyoming, cmessa@uwyo.edu; Mark Stelten, U.S. Geological Survey, mstelten@usgs.gov; Kenneth Sims, University of Wyoming, ksims7@uwyo.edu.

T9. **Tectonism and Magmatism in the Rio Grande Rift.** *Endorsed by GSA Structural Geology and Tectonics Division; GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division.* Greg Stark, University of Wyoming, gstark2@uwyo.edu; John Singleton, Colorado State University, John.Singleton@colostate.edu; W. Scott Baldridge, Los Alamos National Laboratory, sbaldridge@lanl.gov; Kenneth Sims, University of Wyoming, ksims7@uwyo.edu.

T10. **Past and Present Stable Isotopes of the Western U.S. and Beyond.** *Endorsed by GSA Quaternary Geology and Geomorphology Division.* Jeremy Rugenstein, Colorado State University, jeremy.rugenstein@colostate.edu; Tyler Kukla, Colorado State University, Tyler.Kukla@colostate.edu; Daniel E. Ibarra, Institute at Brown for Environment and Society, Brown University, daniel_ibarra@brown.edu.

T11. **A Changing Cryosphere: The Rocky Mountains and Beyond.** *Endorsed by GSA Quaternary Geology and Geomorphology Division; GSA Hydrogeology Division.* Randall Bonnell, Colorado State University, rbonnell@colostate.edu; Lucas Zeller, Colorado State University, lucas.zeller@colostate.edu; Sierra Melton, Pennsylvania State University, smm1084@psu.edu; Wyatt Reis, Colorado State University, wyatt.reis@colostate.edu.

T12. **Geohydrobiology of the Yellowstone Hydrothermal System.** *Endorsed by GSA Hydrogeology Division; GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division.* Andrew E. Miller, University of Wyoming, amille78@uwyo.edu; Kenneth Sims, University of Wyoming, ksims7@uwyo.edu; Daniel Colman, Montana State University, daniel.colman@montana.edu; Eric Boyd, Montana State University, eboyd@montana.edu.

T13. **Post-Wildfire and Other Debris Flows.** *Endorsed by GSA Environmental and Engineering Geology Division.* Jonathan Lovekin, Colorado Geological Survey, jlovekin@mines.edu; Amy Crandall, Colorado Geological Survey, acrandall@mines.edu; Kassandra Lindsey, Colorado Geological Survey, kolindsey@mines.edu.

T14. **Geologic and Geohazard Mapping: Recent Advances in Mapping and Age-Dating Techniques and Use of Lidar.** *Endorsed by GSA Environmental and Engineering Geology Division.* Kassandra Lindsey, Colorado Geological Survey, kolindsey@mines.edu; Steve Keller, Colorado Geological Survey, skeller@mines.edu; Amy Crandall, Colorado Geological Survey, acrandall@mines.edu; Jonathan Lovekin, Colorado Geological Survey, jlovekin@mines.edu.

T15. **Geologic Mapping in the Rocky Mountains: Evolving Techniques and Challenges (Posters).** Nathan Hopkins, Idaho Geological Survey, nhopkins@uidaho.edu; Russ Di. Fiori, Idaho Geological Survey, russelld@uidaho.edu.

T16. **Intraplate Seismicity: Ancient and Modern.** *Endorsed by GSA Geophysics and Geodynamics Division.* Kyren Bogolub, Colorado Geological Survey, kbogolub@mines.edu; Matthew Morgan, Colorado Geological Survey, mmorgan@mines.edu; Anne Sheehan, University of Colorado Boulder, anne.sheehan@colorado.edu; James P. McCalpin, GEO-HAZ Consulting, Inc., mccalpin@geohaz.com.

T17. **Landscape Evolution across Time Scales from the High Plains to the Colorado Plateau.** *Endorsed by GSA Quaternary Geology and Geomorphology Division.* Sean Gallen, Colorado State University, sean.gallen@colostate.edu; Eyal Marder, Indiana University, emarder@iu.edu.

T18. **Crust Formation, Deformation, Metamorphism, Plutonism, and Thermal Evolution of the Rocky Mountains: Proterozoic to Present.** *Endorsed by GSA Structural Geology and Tectonics Division; GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division.* Andreas Möller, University of Kansas, amoller@

ku.edu; Graham Baird, University of Northern Colorado Greeley, Graham.Baird@unco.edu; Timothy P. Grover, University of Northern Colorado Greeley, timothy.grover@unco.edu; A. Kate Souders, U.S. Geological Survey, asouders@usgs.gov.

T19. **The Field Fellows: A Network of Diversity and Inclusion Champions within the Earth Sciences.** Gillian Bowser, Colorado State University, gbowser@colostate.edu; Lisa White, University of California Berkeley; Philip Haliwell, Colorado State University.

T20. **Quaternary Paleoclimate Records of the Rocky Mountain Region.** *Endorsed by GSA Quaternary Geology and Geomorphology Division.* Shannon Mahan, U.S. Geological Survey, smahan@usgs.gov; Tammy Rittenour, Utah State University, tammy.rittenour@usu.edu; Peter Fawcett, University of New Mexico, fawcett@unm.edu.

T21. **Data Preservation for the Geosciences: Recent Advances in Geo-Databases, Repository Practices, and Big Data Applications.** Amy Atwater, U.S. Geological Survey, aatwater@usgs.gov; Kelly Thomson, U.S. Geological Survey, kthompson@usgs.gov; Victoria Crystal, U.S. Geological Survey, vcrystal@usgs.gov.

FIELD TRIPS

Field trip co-chairs: John Singleton, john.singleton@colostate.edu; Yvette Kuiper, ykuiper@mines.edu; and Jonathan Caine, jscaine@usgs.gov.

Pre-Meeting

FT1. **Why is Kilometer-Scale Exhumation Diachronous across the Colorado Rockies and Great Plains?** *Endorsed by GSA Structural Geology and Tectonics Division; GSA Geochronology Division.* Sat.–Mon., 20 May–22 May. Cost: US$422. Lon Abbott, University of Colorado, lon.abbott@colorado.edu; Rebecca Flowers, University of Colorado, rebecca.flowers@colorado.edu; James Metcalf, University of Colorado, james.metcalf@colorado.edu; Sabrina Kainz, University of Colorado, sabrina.kainz@colorado.edu.

FT2. **After the Asteroid: Stratigraphy and Paleontology of the K-Pg Succession at Corral Bluffs, Colorado, USA.** Mon., 22 May. Cost: US$33. James Hagadorn, Denver Museum of Nature & Science, jwhagadorn@dmns.org; Gussie MacCracken, Denver Museum of Nature & Science, gussie.maccracken@dmns.org.

FT3. **An Examination of Late Paleozoic Stratigraphy, Laramide Folds, and the Rocky Mountain Erosion Surface.** Mon., 22 May. Free. Michael Kendrick, Retired Petroleum Geoscientist, mkendrick9@icloud.com; John Singleton, Colorado State University, john.singleton@colostate.edu.

FT4. **Overview and Geologic History of Quaternary Fluvial and Eolian Deposits in the Northern Colorado Piedmont.** *Endorsed by GSA Quaternary Geology and Geomorphology Division.* Mon., 22 May. Cost: US$170. Stephen M. Keller, Colorado Geological Survey, skeller@mines.edu; Michael K. O'Keeffe, Colorado Geological Survey, okeeffe@mines.edu; Kassandra O. Lindsey, Colorado Geological Survey, kolindsey@mines.edu; Alexander E. Marr, Colorado Geological Survey, alexmarr131@gmail.com; Matthew L. Morgan, Colorado Geological Survey, mmorgan@mines.edu.

Mid-Meeting

FT5. **A VIP Behind-The-Scenes Tour at the Denver Museum of Nature & Science.** Tues., 23 May. Cost: US$10. James Hagadorn and others, Denver Museum of Nature & Science, jwhagadorn@dmns.org.

Post-Meeting

FT6. **Proterozoic Tectonics of the Northern Colorado Front Range.** *Endorsed by GSA Structural Geology and Tectonics Division; GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division.* Fri., 26 May. Cost: US$50. Graham Baird, University of Northern Colorado, graham.baird@unco.edu; Tim Grover, University of Northern Colorado, timothy.grover@unco.edu; Kevin Mahan, University of Colorado Boulder, kevin.mahan@colorado.edu.

FT7. **Stratigraphy and Structural Geology of the Front Range near Fort Collins, Colorado, USA.** Fri., 26 May. Free. John Singleton, Colorado State University, john.singleton@colostate.edu; Jeremy Rugenstein, Colorado State University, jeremy.rugenstein@colostate.edu.

FT8. **Geomorphology and Structures in the Epicentral Area of the 1882 M6.6 Earthquake.** Fri., 26 May. Cost: US$90. James P. McCalpin, GEO-HAZ Consulting, Inc., mccalpin@geohaz.com.

FT9. **Cenozoic Geology and Geomorphology of the Laramie Mountains, Wyoming, USA.** *Endorsed by GSA Quaternary Geology and Geomorphology Division; Wyoming Geological Survey.* Fri.–Sat., 26–27 May. Cost: US$119. Emmett Evanoff, University of Northern Colorado, emmett.evanoff@unco.edu.

FT10. **From Mantle to Mountain Top—Palinspastic Restoration of the I-70 Transect across the Basement Uplifts of Central Colorado.** *Endorsed by GSA Structural Geology and Tectonics Division.* Fri.–Sat., 26–27 May. Cost: US$480. Ned Sterne, independent geologist, nedsterne@aol.com; Bob Raynolds, Denver Museum of Nature & Science, bobraynolds1@gmail.com; Jim Granath, consulting structural geologist, jwgranath@q.com.

FT11. **Introduction to the Stratigraphy and Depositional Settings of the Classic Outcrops of the Book Cliffs.** Fri.–Mon., 26–29 May. Cost: US$700. Howard Feldman, Colorado State University, howard.feldman@colostate.edu; Vitor Abreu, Act Geosciences, vitor@act-geo.com.

SHORT COURSES

SC1. **Practical Python for Earth Scientists.** *Endorsed by Rocky Mountain Association of Geologists.* Matthew W. Bauer,

P.G., Colorado School of Mines and V.P. Data Science & Analytics, Energy Royalty Partners, matthew.w.bauer.pg@gmail.com. Mon., 22 May, 9 a.m.–4 p.m., Colorado State University. US$15 student; $50 professional.

SC2. **Core Workshop: Recent Advances in Stratigraphy and Origin of Mid-Carboniferous Strata, Heath and Tyler Formations, Central Montana, USA.** Richard J. Bottjer, Denver Museum of Nature & Science, rjbottjer@coalcreekresources.com; Christopher R. Fielding, University of Connecticut; Mercedes Di Pasquo, Laboratorio de Palinoestratigrafía y Paleobotánica, CONICET, Buenos Aires, Argentina. Mon., 22 May, 8:30 a.m.–3:30 p.m. Cost: US$25 if attended in association with meeting registration; US$40 for the short course only. (lunch included).

SC3. **Luminescence (OSL) Dating Short Course: Essential Guide for Sampling and Dark Secrets behind the Technique.** *Endorsed by GSA Quaternary Geology and Geomorphology Division; GSA Geochronology Division.* Shannon Mahan, U.S. Geological Survey, smahan@usgs.gov; Tammy Rittenour, Utah State University, tammy.rittenour@usu.edu. Mon., 22 May, 9 a.m.–4 p.m., Colorado State University. Max. participants: 35. US$25 if attended in association with a meeting registration; US$40 for the short course only.

OPPORTUNITIES FOR STUDENTS AND EARLY-CAREER PROFESSIONALS

Career Mentoring Luncheons

Ask your career-related questions and learn about non-academic pathways in the geosciences while networking with professionals at the Roy J. Shlemon and John Mann Mentor Luncheons on Tuesday, May 23, and Thursday, May 25, respectively. All GSA student members are welcome.

Career Workshop Series

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

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

TRAVEL GRANTS

Application deadline: 17 Apr.

Students who are GSA members and who register for the meeting are eligible to apply for travel grants from their respective sections. For further information, go to **www.geosociety.org/travelgrants** and click on Rocky Mountain.

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 meeting organizer Rick Aster at rick.aster@colostate.edu.

PROFESSIONALS

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

This 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 can be downloaded from the meeting website after the meeting.

LOCAL COMMITTEE

Organizing Chair: Rick Aster, Colorado State University, rick.aster@colostate.edu

Technical Program Co-Chairs: Ken Sims, University of Wyoming, ksims7@uwyo.edu; Rick Aster, Colorado State University, rick.aster@colostate.edu

Field Trip Co-Chairs: John Singleton, Colorado State University, john.singleton@colostate.edu; Yvette Kuiper, Colorado School of Mines, ykuiper@mines.edu; Jonathan Caine, U.S. Geological Survey, jscaine@usgs.gov

The Energy of Corporate Partnerships

Sonia Scarselli, vice president, BHP Xplor.

"There is the passion to look for something new, the passion to find something new that nobody thought about before, and how to move that forward to people who need it." This remark from Sonia Scarselli, vice president of BHP Xplor, in the summer of 2022 described the company's driving purpose, which led them to participate in events like GSA Connects later that fall.

BHP Xplor contacted us just after opening applications for their inaugural submission process to make grants up to US$500,000 in their global search for explorers, entrepreneurs, researchers, teams, or companies with bold, new ideas in exploration. They are seeking people with concepts that are "ready to think about the earth's mineral systems differently to unlock copper, nickel, and other critical mineral deposits" (https://www.bhp.com/xplor). Specifically, as BHP Xplor program manager Charlee Johnson described in our first call, exploration concepts in early stages that could use support to get from the idea to the exploration operation. This accelerator program launched by BHP will offer not only funding, but mentorship, in-kind services from legal to land and finance support, training, a network of support and connections, and an ecosystem of global partners.

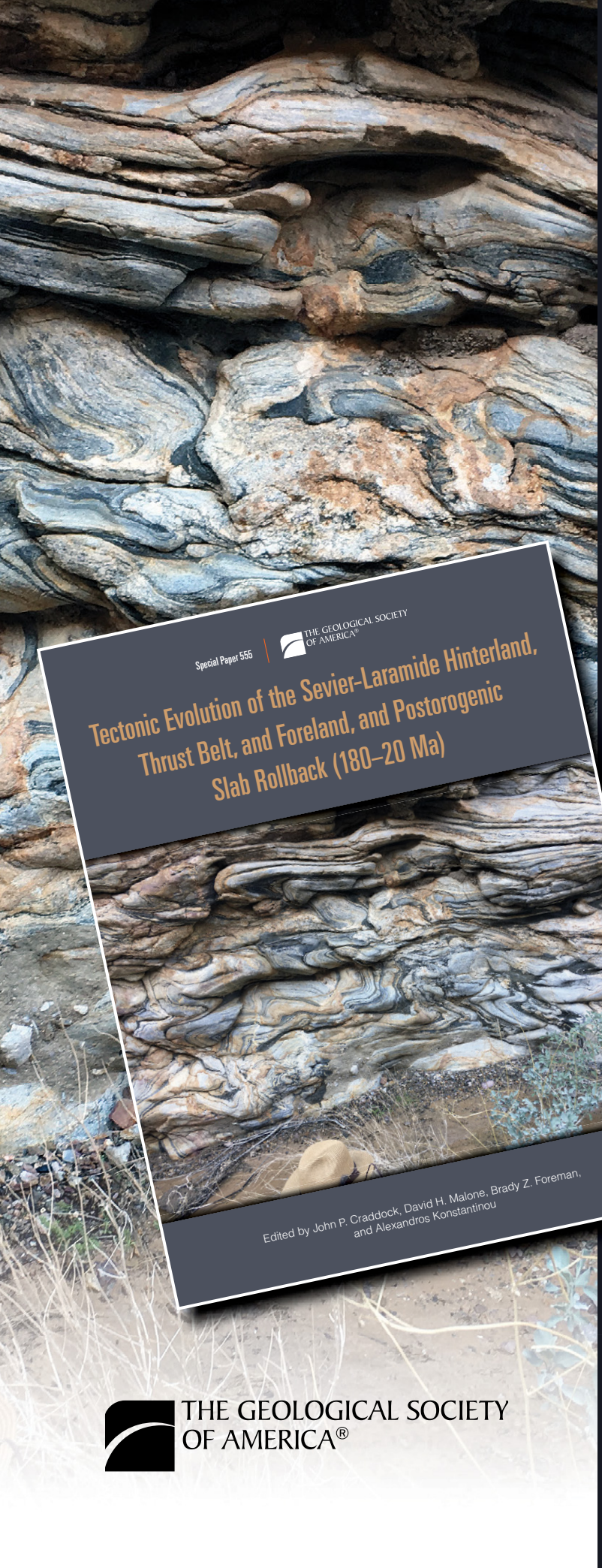
GSA Connects 2022 provided a relevant forum to spread news of this opportunity and talk with others interested in the same movement toward an energy transition, and the timing was serendipitous to meet GSA's membership leading into the next GSA Connects. One of the themes for the 2023 meeting is "Climate and Energy Transition." BHP Xplor interacted with attendees in a number of ways, including a booth in the Resource & Innovation Center, sponsorship of the 2022 Presidential Address & Awards Ceremony, and pre-meeting messaging to relevant GSA Divisions.

"We believe that building a better future is a responsibility we all share and that is why we are committed to accelerating exploration of critical resources needed for the energy transition." Dr. Scarselli describes BHP Xplor's inspiring venture with the kind of zeal we are eager to join in with our corporate partners. It is an exciting time for the Society and for the GSA Foundation's continued work to support GSA programs as geoscientists leap into the future, working on the pressing challenges facing our world.

We appreciate BHP Xplor's support of, and participation in, GSA Connects 2022 in Denver, Colorado, USA.

Please contact Debbie Marcinkowski, dmarcinkowski@geosociety.org, +1-303-357-1047, if your company or employer might be interested in joining GSA's family of corporate partners. Together, we can make a difference in the world around us.

www.gsa-foundation.org



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Edited by John P. Craddock, David H. Malone, Brady Z. Foreman, and Alexandros Konstantinou

This Special Paper focuses on the evolution of the crust of the hinterland of the orogen during the orogenic cycle, and describes the evolution of the crust and basins at metamorphic core complexes. The volume includes a regional study of the Sevier-Laramide orogens in the Wyoming province, a regional seismic study, strain analysis of Sevier and Laramide deformation, and detrital zircon provenance from the Pacific Coast to the foreland between the Jurassic and the Eocene.

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OPEN POSITIONS

Assistant Specialist in Geoscience Education and Outreach, University of Hawai'i

The Department of Earth Sciences in the School of Ocean and Earth Sciences and Technology, University of Hawai'i at Mānoa seeks to fill a tenure-track faculty position at the level of Assistant Specialist in the area of Geoscience Education and Outreach (GEO).

We seek a talented scientist and educator with the capacity for excellence in teaching and mentoring, including creative approaches for enhancing student learning, engaging undergraduate students from diverse backgrounds in research, and promoting their academic success. The successful candidate is expected to assist with the development, coordination, assessment, and day-to-day management of our undergraduate program in the Earth Sciences, including academic advising, research experiences, outreach, recruitment and retention, and career development and planning. The successful candidate will pursue funding individually or collaboratively with other faculty to support the undergraduate program and the success of our students. They will produce scholarly work to present at professional meetings and/or in peer-reviewed publications on assessment activities, Geoscience Education research, and/or Earth Science research. All of the above will be done in keeping with best practices for an institution that serves a culturally diverse student body, including a large number of Native Hawaiians and Pacific Islanders. A willingness to engage with faculty, staff, and students in a collaborative fashion that supports diversity and inclusivity is an essential value of our Department, and is a required characteristic of the successful candidate.

The Department of Earth Sciences (http://www.soest.hawaii.edu/GG/) is one of thirteen research units and four academic departments within the School of Ocean and Earth Science and Technology (SOEST) (https://www.soest.hawaii.edu/soestwp/), a world-class research and academic institution focused on informing solutions to some of the world's most vexing problems. The Department has 18 tenured or tenure-track faculty as well as many additional cooperating graduate faculty in the Hawai'i Institute of Geophysics and Planetology (https://www.higp.hawaii.edu/). Together these faculty instruct and advise approximately 50 graduate students and 60 undergraduate majors.

The University of Hawai'i at Mānoa is one of 146 Research 1 Universities in the country, and is one of only a handful of land-, sea-, space-, and sun-grant institutions. It is a world leader in Earth and Environmental Sciences, consistently ranked among the top universities internationally. UH Mānoa is proud of its diverse, multiethnic heritage. Located in Hawai'i's capital city of Honolulu at the crossroads of the Pacific, the campus is home to students, faculty and staff from Hawai'i, the U.S. mainland, and more than 100 countries around the world. UH Mānoa's programs often rank among the nation's most diverse. We seek applicants who will embrace this diversity, and further welcome candidates whose professional or personal perspectives enrich the communities within the University, SOEST, the Department, as well as the public we serve.

Apply online at https://www.governmentjobs.com/careers/hawaiiedu. Search for the position #85998 and click on the "Apply" (top right corner of the screen). If this is your first time using NEOGOV you will need to create an account. This link provides the complete vacancy announcement, including the duties and responsibilities of the position. Applicants must upload a single-file PDF containing five parts (1) A one-page cover letter; (2) A curriculum vitae with a publication list; (3) Names and contact information of three individuals willing to provide professional reference letters; (4) A two-page (maximum) statement describing experiences in, and approaches to, teaching and mentoring students; (5) A two-page (maximum) statement describing a vision for the development and management of our undergraduate program in the Earth Sciences. Items (4) and (5) should include descriptions of commitment to collaborative engagement with others and support for diversity and inclusivity.

Review and evaluation of applications will begin on March 1, 2023 and continue until the position is filled. Questions may be addressed to Dr. Garrett Apuzen-Ito (gito@hawaii.edu), or Dr. Aaron Pietruszka (apietrus@hawaii.edu).

The University of Hawai'i is an Equal Opportunity/Affirmative Action Institution.

Associate Professor, Economic Geology, Nevada Bureau of Mines and Geology, University of Nevada, Reno

The Nevada Bureau of Mines and Geology (NBMG) at the University of Nevada, Reno (UNR) seeks a renowned individual for a tenure-track faculty position at the Associate Professor level to lead our Economic Geology program. We are looking for individuals with field and lab experience, including research studies related to the genesis, transport, and distribution of metals in the crust, critical minerals, fluid-rock interaction and circulation of fluids, magmatic and/or hydrothermal processes, and/or exploration methods. Research must integrate one or more of the following disciplines: economic geology, structural geology, igneous petrology, and geochemistry. NBMG is a research and public service unit of UNR and serves as Nevada's state geological survey. For further information about NBMG, please consult our website (http://www.nbmg.unr.edu).

Responsibilities for this position will include: 1) managing the industry-funded, Ralph J. Roberts Center for Research in Economic Geology; 2) research on mineral deposits, focusing on the western US and Nevada's enormous mineral wealth; 3) education via supervision of graduate students and teaching courses in Economic Geology; 4) serving as a spokesperson for the Economic Geology program at UNR, requiring effective communication with the public and community leaders regarding the geology of Nevada and its mineral resources; 5) working independently as well as collaborating with NBMG faculty-staff, other geoscience units at UNR and in the region, and others in industry and government in developing funded projects and conducting research; 6) contributing to the development of datasets and reports on Nevada's mineral resources; and 7) public outreach and service within the University and community.

Interested applicants must have a doctorate in geology or a related geoscience field and a demonstrated record of research on topics related to mineral deposits as indicated by peer-reviewed publications and/or industry-related reports. Excellent communication skills, as demonstrated in written application materials; public service; potential for, or established record of publications; and ability to attract funding are essential.

The position will have a base salary that is competitive with other research universities. Starting date will be July 1, 2023 or shortly thereafter, depending on availability of the successful candidate.

To apply, please visit: https://nshe.wd1.myworkdayjobs.com/UNR-external/job/University-of-Nevada-Reno---Main-Campus/Associate-Professor--Economic-Geologist_R0134587-1. To ensure full consideration, all information must be submitted by March 3, 2023.

Equal Employment Opportunity/Affirmative Action. Women and underrepresented groups are encouraged to apply.

Teaching Assistant Professor, Geological Sciences and Engineering, University of Nevada, Reno

Job Description: The Department of Geological Sciences and Engineering at the University of Nevada, Reno invites applications for a full-time (9-month, non-tenure track) Teaching Assistant Professor position starting in Fall 2023.

We are looking for a candidate with broad experience in geological engineering, engineering geology, geotechnical engineering or related applied geology. We are looking for someone who can teach a range of fundamental courses for our Geological Engineering

(GE) undergraduate majors. These potentially include introductory geological engineering, geostatistics, groundwater hydrology, hydrologic fluid dynamics, landslides and slope stability, waste containment, earthquake engineering, geomatics and modern instrumentation for geotechnical engineering, and geological engineering senior design. Many of these also serve graduate students for our MS and planned Ph.D. program in Geological Engineering. The candidate may also teach other courses relevant to undergraduate and graduate students in our programs. Applicants are encouraged to consult our BS in GE curriculum here: https://catalog.unr.edu/preview_program.php?catoid=50&poid=149936&hl=%22BEAP%

The position will also have a strong service component to collect, coordinate, and prepare assessment data in support of our ABET accreditation for the GE program. Information specifically related to GE and ABET accreditation can be found at this website: https://www.unr.edu/mackay/about/geological-engineering-abet-accreditation. We seek someone with an advanced degree from an accredited university who will complement the existing strengths in our department, and who will develop connections with locally based engineering and environmental firms and government agencies. The ideal candidate will demonstrate teaching excellence. The expected teaching load is 5 courses per year and required mode of course delivery is in-person, but will follow temporary alternate operations as adopted by University administration. The applicant is further expected to participate in department, college and university activities, such as curriculum development, curriculum enhancement and mentoring student projects.

The Department is part of the Mackay School of Earth Sciences and Engineering, which also includes two additional teaching Departments, Mining and Metallurgical Engineering and Geography, and two state-funded Earth Science units, the Nevada Bureau of Mines and Geology and the Nevada Seismological Laboratory. We offer BS degrees in Geology, Geophysics, Hydrogeology and Geological Engineering. We offer MS degrees in Geology, Geophysics, and Geological Engineering, and Ph.D.'s in Geology, Geophysics and Mineral Resource Engineering (joint with Mining). More information about the Department can be found at http://www.unr.edu/geology.

Qualified individuals are encouraged to apply immediately. Review of applications will begin on January 31, 2023.

Required Qualifications: Applicants must hold a Ph.D., or an MS and equivalent experience, in Geological Engineering, Civil Engineering or a related Earth Science or Engineering field by May 30, 2023. Applicants must be strongly committed to excellence in teaching and student mentoring as well as have a demonstrated interest in innovative teaching.

Preferred Qualifications: A Ph.D. with at least one degree (BS, MS, or Ph.D.) in a GE-related engineering field. Licensed as a Professional Engineer. Two years of college-level teaching (preferably teaching introductory earth science and engineering courses).

For more information, and to apply, please visit: https://nshe.wd1.myworkdayjobs.com/UNR-external/job/University-of-Nevada-Reno---Main-Campus/Teaching-Assistant-Professor--Geological-Sciences-and-Engineering_R0134556

EEO/AA. Women, under-represented groups, individuals with disabilities, and veterans are encouraged to apply.

Visiting Assistant Professor of Geosciences, Trinity University

The Department of Geosciences at Trinity University invites applications for a one-year Visiting Assistant Professor (VAP) in the Department of Geosciences beginning in August 2023. The VAP will teach introductory Geosciences courses such as Volcanology, Earth's Environmental Systems, and/or Oceanography that serve both intended Geosciences and Environmental Studies majors and students taking these courses to satisfy a general-education requirement. In addition, the VAP may teach Geosciences core courses such as Solid Earth Processes. The position is non-renewable.

Trinity University (http://www.trinity.edu) is an independent, coeducational, selective, primarily undergraduate institution founded in 1869. Trinity offers high-quality science, liberal arts, and pre-professional programs to approximately 2400 undergraduate students from the U.S. and many foreign countries. The attractive campus overlooks downtown San Antonio, a city rich in heritage and ethnic diversity. The Geosciences Department, housed in the Center for Sciences and Innovation (http://www.trinity.edu/csi), has granted degrees in the geosciences for over 50 years and is a member of the Keck Geology Consortium.

Candidates must apply through Trinity University's Employment Opportunities Portal, linked here: https://trinity.wd1.myworkdayjobs.com/en-US/Trinity_University/details/Visiting-Assistant-Professor---Geoscience_JR100112. Under "Start your application" select "Apply Manually" and only complete required fields. Candidates should submit all of the following items in pdf format under the Resume/CV file upload portal: a cover letter (1-2 pages, single-spaced); a curriculum vitae; a statement of undergraduate teaching experience and philosophy; documentation of teaching effectiveness; unofficial transcripts from all postsecondary institutions attended; and the names and contact information for three professional references. Candidates must also submit a 250-500-word diversity statement (as a pdf) responding to the prompt: "Trinity University is committed to the value of intentional inclusion. Please provide a brief statement describing your past efforts as well as your future plans to advance diversity, equity and inclusion in your teaching." Review of completed applications will begin on Feb 26, 2023. Questions about the search can be directed to Dr. Benjamin Surpless [geossearch@trinity.edu], Search Committee Chair, Department of Geosciences.

Trinity University is committed to diversity and inclusion and strongly encourages candidates from underrepresented groups to apply. Trinity University is an Equal Opportunity Employer. As such it provides equal opportunity for employment and advancement of all employees without regard to race, color, religion, sex, age, national origin, disability, military/veteran status, sexual orientation, gender identity, gender expression, or any status protected by federal, state or local laws. Trinity welcomes applications from candidates who share those values and who will harness them on behalf of the University's mission.

Assistant Professor in Paleontology, Department of Earth Sciences, College of Letters and Science, Montana State University

The Department of Earth Sciences at Montana State University invites applications for the position of tenure-track Assistant Professor of Paleontology. We seek an active researcher and teacher who brings an innovative perspective to the study of Earth and evolutionary history and has the ability to develop an internationally-recognized research program. Specific areas of research could include but are not limited to vertebrate paleontology, invertebrate paleontology, paleobotany, Earth history and evolution, sedimentary geochemistry as applied to paleontology, deep-time environmental change, and macroevolution and the fossil record. The successful candidate will have a clear vision for launching an innovative research program from our location in Bozeman, Montana. The candidate will be expected to teach courses such as Earth Systems Science, Earth History and Evolution, Invertebrate Paleontology, and contribute to our upper-division and graduate curriculum in their area of expertise. The candidate will provide graduate mentorship in our MSc and Ph.D. programs, and participate as a team player in a highly collegial and student-focused department.

For complete job announcement and application procedures, click on: https://jobs.montana.edu/postings/33545

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Visiting Assistant Professor (3-year), Earth and Oceanographic Science, Bowdoin College

Bowdoin College Department of Earth and Oceanographic Science seeks full time visiting assistant professor to begin July 1, 2023 (3-year position, contingent upon successful first year review). Ph.D. required. Four courses per year (two with weekly labs) intermediate to advanced in solid earth disciplines. Bowdoin warmly welcomes people of all backgrounds. Visit https://careers.bowdoin.edu before Febru-

ary 10 to apply. Bowdoin is committed to equality through Affirmative Action, and is an equal opportunity employer. http://www.bowdoin.edu for more information.

Two Instructional Faculty Positions, Geological Sciences, University at Buffalo, The State University of New York

The Department of Geology, University at Buffalo, seeks to hire 2 Assistant Teaching Professors (official state title: Clinical Assistant Professor 12) who are passionate about teaching and eager to join a growing Department striving to increase diversity in the geosciences. The successful candidates will teach 4 courses per semester or engage in equivalent non-instructional duties, such as service or administrative responsibilities associated with the Department's educational programs; one instructor will be responsible for overseeing our expanding undergraduate introductory lab course. Successful candidates will teach classes related to their areas of research in the undergraduate and graduate curriculum, ensuring that our core undergraduate degree requirements are being met. Opportunities (depending on interest and aptitude) include advancing pedagogy and scholarship through attendance at professional meetings and mentoring student research projects. These are 12-month non-tenure-track appointments that include summer teaching. Successful candidates will have earned a Ph.D. in Geology or a closely related field, with conferral dates no later than the start of the appointment. Demonstrated teaching ability is required, as is the ability to lead field trips for assigned courses. Post-secondary teaching experience, demonstrated computational skills, and the ability to lift and carry up to 30 pounds are preferred. The three-year, renewable appointments can begin as soon as late May 2023 or as late as August 2023. Applications, including cover letter, CV, teaching statement and list of 3 references, must be submitted electronically through UBJobs https://www.ubjobs.buffalo.edu/postings/39270 The positions are open until filled. Direct questions to tgregg@buffalo.edu. University at Buffalo is an affirmative action/equal opportunity employer and, in keeping with our commitment, welcomes all to apply including veterans and individuals with disabilities.

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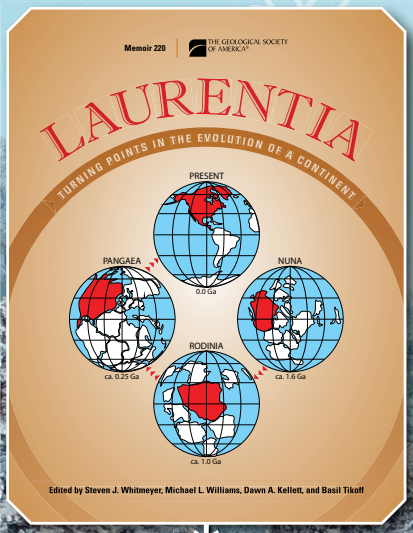

Laurentia: Turning Points in the Evolution of a Continent

Edited by Steven J. Whitmeyer, Michael L. Williams, Dawn A. Kellett, and Basil Tikoff

The North American continent has a rich record of the tectonic environments and processes that occur throughout much of Earth history. This Memoir focuses on seven "turning points" that had specific and lasting impacts on the evolution of Laurentia: (1) The Neoarchean, characterized by cratonization; (2) the Paleoproterozoic and the initial assembly of Laurentia; (3) the Mesoproterozoic southern margin of Laurentia; (4) the Midcontinent rift and the Grenville orogeny; (5) the Neoproterozoic breakup of Rodinia; (6) the mid-Paleozoic phases of the Appalachian-Caledonian orogen; and (7) the Jurassic–Paleogene assembly of the North American Cordillera. The chapters in this Memoir provide syntheses of the current understanding of the geologic evolution of Laurentia and North America, as well as new hypotheses for testing.

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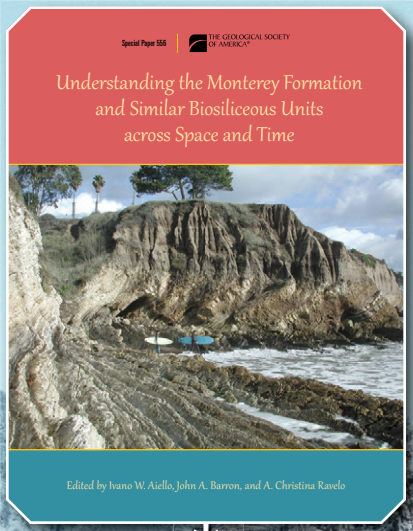

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Edited by Ivano W. Aiello, John A. Barron, and A. Christina Ravelo

The Monterey Formation is a Miocene marine unit that occurs extensively in the Coast Ranges and in the continental margins of California, and analogous biosiliceous deposits are found around the Pacific Rim and elsewhere in the world. Classic studies on the diatomaceous deposits that characterize the hemipelagic/pelagic facies of the Monterey Formation have been key to understanding the oceanographic and tectonic conditions that lead to the preservation of large volumes of organic-rich hemipelagic biosiliceous sediments, and the properties of these sedimentary deposits once they convert into rocks. This volume presents a collection of recent studies on the Monterey and other similar biosiliceous deposits that offer modern and updated interpretations of this classic unit and its analogues. The volume is dedicated to the memory of Professor Bob Garrison.

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Edited by Xiaogang Ma, Matty Mookerjee, Leslie Hsu, and Denise Hills

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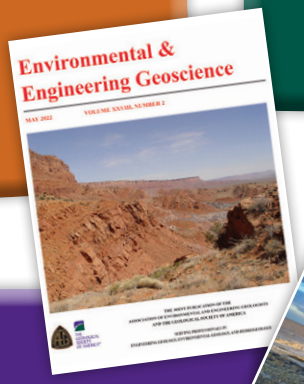

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Science Editor Openings for 2024

GSA seeks applications for science co-editors for GSA Books (two positions), *GSA Bulletin* (one position), and *Geology* (two positions). The four-year terms begin 1 January 2024. Duties include: ensuring stringent peer review and expeditious processing of manuscripts; making final acceptance or rejection decisions after considering reviewer recommendations; and, along with your co-editors, setting the editorial tone of the publication and maintaining excellent content through publication of a diverse range of papers.

POSITION DETAILS

Research interests that complement those of the continuing *GSA Bulletin* editors include but are not limited to: tectonics; tectonophysics; structural geology; low-T thermochronology; deformation; archaeological geology; economic geology; geochronology; geodynamics; paleomagnetism; petrology; Precambrian geology; sedimentary geology.

GSA Books editor duties include soliciting high-quality book proposals and ensuring that proper peer-review procedures are followed by volume editors. Editors handle the entire peer-review process for authored volumes. The successful candidate will have a wide range of interests and expertise, prior editing experience, and a strong publication record.

Research interests that complement those of the continuing *Geology* editors include, but are not limited to: paleontology; paleomagnetism; paleoceanography; marine geology; economic geology; stratigraphy; subsurface geophysics.

> Note: Because of the volume of papers received by *Geology* and the breadth of the topics covered, editors must be willing to handle papers outside of their main disciplines.

Editors work out of their current locations at work or at home. The positions are considered voluntary, but GSA provides an annual stipend and funds for office expenses.

Evaluation Process: The GSA Publications Committee will evaluate applications and make its recommendations to GSA Council based on the combination of how a candidate's disciplinary expertise fits with the needs of the publication and on the candidate's application, which should provide documentation of the required and preferred qualifications listed here.

GSA affirms the value of diverse scientific ideas and the connection between diverse scientific ideas and a diverse group of contributors of those ideas. Accordingly, GSA welcomes applications from all qualified persons and encourages applications that highlight diversity.

To Apply: In a single PDF, submit your curriculum vitae and a letter of application that demonstrates how your interests and experience fulfill the required and preferred qualifications listed below to Bridgette Moore, bmoore@geosociety.org. **Deadline: 1 March 2023.**

REQUIRED QUALIFICATIONS

- Experience as an editor or associate editor for a geoscience journal. Include details of the duties and duration of the position(s) held.
- Demonstrated expertise in two or more fields in the geosciences or in interdisciplinary fields broadly related to the geosciences.
- Demonstrated experience handling a significant editorial workload and ability to make timely decisions.
- Because of the breadth of topics covered in GSA publications, the applicant must clearly express willingness to handle papers outside of their main disciplines.
- Demonstrated ability to communicate clearly and be responsive to author needs.

PREFERRED QUALIFICATIONS

- Experience with a GSA journal as a reviewer, associate editor, or editor.
- Breadth of interdisciplinary experience to complement that of existing editors; demonstrated interest in interdisciplinary research.
- International reputation and connections with the geoscience communities.
- Interest in encouraging innovation; willingness to take risks.
- Ability to support a positive team dynamic; ability to work with GSA staff and other editors to enhance the reputation of the publication.

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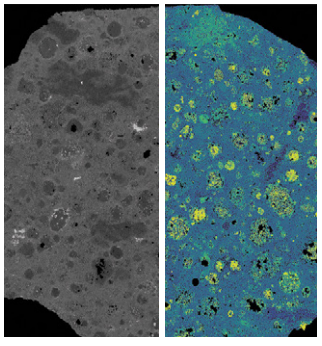

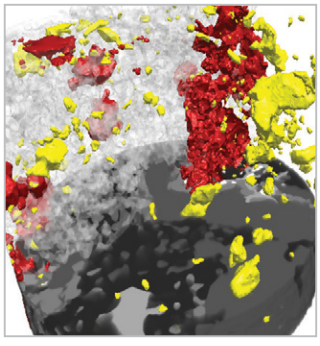

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