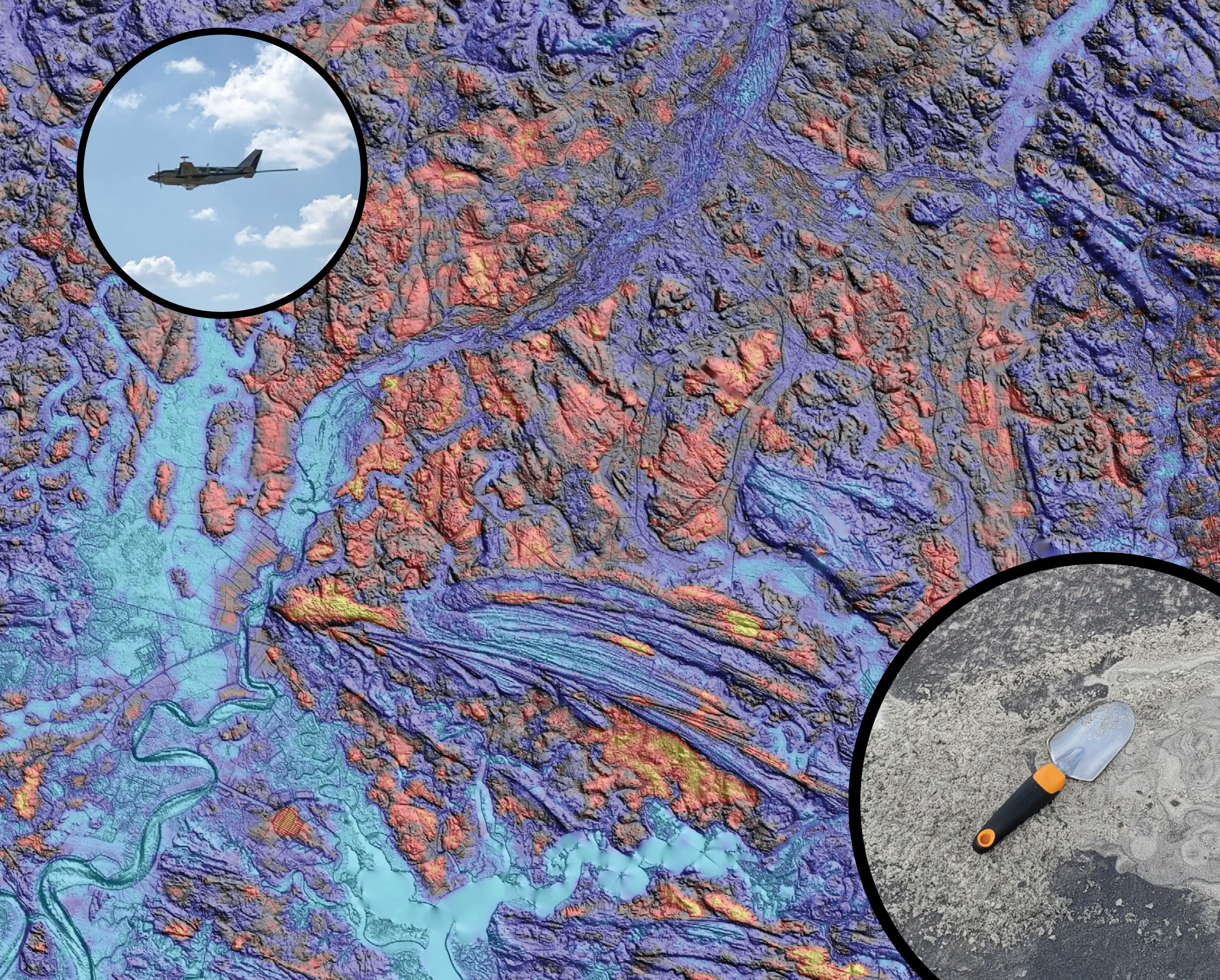
Renew Your Membership Today!

GSA TODAY

THE GEOLOGICAL SOCIETY OF AMERICA®

VOL. 31, NO. 11 | NOVEMBER 2021

Mapping Critical Minerals from the Sky



2022 CALENDAR




BUY ONLINE ▸
rock.geosociety.org/store

ONLY **$9.95**

Splendors & Sojourns

CALENDAR | $9.95

With a variety of splendors on display, GSA's newest calendar offers extraordinary views from sojourns near and far for all to enjoy throughout 2022. This 12-month 11.5" x 8.75" calendar showcases awe-inspiring images of Ten Peaks, Joshua Tree National Park, Elephant Rocks, Steens Mountain, Orocopia Mountains, Cape Pillar, Bishop tuff columns, tessellated pavement, Arches National Park, aragonite crystals, Carpenter Falls, and Bering Glacier.

- Dates of many noteworthy eruptions & earthquakes
- Birthdates of notable geoscientists
- Dates of GSA events & deadlines






THE GEOLOGICAL SOCIETY OF AMERICA®

toll-free 1.800.472.1988 | +1.303.357.1000, option 3 | gsaservice@geosociety.org

NOVEMBER 2021 | VOLUME 31, NUMBER 11

GSA TODAY

GSA TODAY (ISSN 1052-5173 USPS 0456-530) prints news and information for more than 22,000 GSA member readers and subscribing libraries, with 11 monthly issues (March-April is a combined issue). *GSA TODAY* is published by The Geological Society of America® Inc. (GSA) with offices at 3300 Penrose Place, Boulder, Colorado, USA, and a mailing address of P.O. Box 9140, Boulder, CO 80301-9140, USA. GSA provides this and other forums for the presentation of diverse opinions and positions by scientists worldwide, regardless of race, citizenship, gender, sexual orientation, religion, or political viewpoint. Opinions presented in this publication do not reflect official positions of the Society.

Subscriptions: GSA members: Contact GSA Sales & Service, +1-888-443-4472; +1-303-357-1000 option 3; gsaservice@geosociety.org for information and/or to place a claim for non-receipt or damaged copies. **Nonmembers and institutions:** *GSA TODAY* is US$108/yr; to subscribe, or for claims for non-receipt and damaged copies, contact gsaservice@geosociety.org. Claims are honored for one year; please allow sufficient delivery time for overseas copies. Periodicals postage paid at Boulder, Colorado, USA, and at additional mailing offices. Postmaster: Send address changes to GSA Sales & Service, P.O. Box 9140, Boulder, CO 80301-9140.

***GSA TODAY* STAFF**

Executive Director and Publisher: Vicki S. McConnell

Science Editors: Mihai N. Ducea, University of Arizona, Dept. of Geosciences, Gould-Simpson Building, 1040 E 4th Street, Tucson, Arizona 85721, USA, ducea@email.arizona.edu; **Peter Copeland,** University of Houston, Department of Earth and Atmospheric Sciences, Science & Research Building 1, 3507 Cullen Blvd., Room 314, Houston, Texas 77204-5008, USA, copeland@uh.edu.

Managing Editor: Kristen "Kea" Giles, kgiles@geosociety.org, gsatoday@geosociety.org

Graphics Production: Emily Levine, elevine@geosociety.org

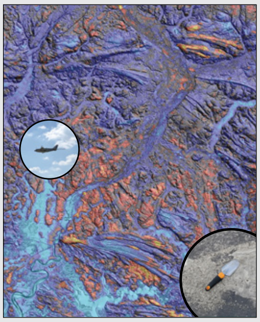
Advertising Manager: Ann Crawford, +1-800-472-1988 ext. 1053; +1-303-357-1053; Fax: +1-303-357-1070; advertising@geosociety.org

GSA Online: www.geosociety.org
GSA TODAY: www.geosociety.org/gsatoday

Printed in the USA using pure soy inks.

THE GEOLOGICAL SOCIETY OF AMERICA®

SCIENCE



Cover: Perspective view of airborne radiometric thorium draped over shaded relief lidar elevation (hillshade). Areas where Ti-Zr–rare earth element (REE)- heavy mineral sands are concentrated appear as thorium highs (yellows). Top: The airplane that collected the data. Inset: Example of Holocene Ti-Zr-REE sand concentrations. Airplane photo: James W. Bursey, Terraquest, Inc. Sands photo: Anjana K. Shah, USGS. For the related article, see pages 4–10.

GSA NEWS

Erratum: Due to editorial error, last month's cover caption was incorrect. The caption was in conjunction with the science article, "The origin and tectonic significance of the Basin and Range–Rio Grande rift boundary in southern New Mexico, USA," by Jason W. Ricketts and colleagues. The correct caption for the cover is "Photo of the basin and range topography that is typical across the Basin and Range–Rio Grande rift boundary in southern New Mexico, USA. View is from the Chiricahua Mountains, Arizona, looking east toward the Peloncillo Mountains, New Mexico, in the background. Photo by Jason W. Ricketts."

THE GEOLOGICAL SOCIETY OF AMERICA®

Mapping Critical Minerals from the Sky

***Anjana K. Shah**,** U.S. Geological Survey, DFC MS 973, P.O. Box 25046, Denver, Colorado 80225, USA, ashah@usgs.gov, ORCID: https://orcid.org/0000-0002-3198-081X; **Robert H. Morrow IV,** South Carolina Dept. of Natural Resources Geological Survey, 5 Geology Road, Columbia, South Carolina 29212, USA, morrowr@dnr.sc.gov, ORCID: https://orcid.org/0000-0001-5282-2389; **Michael D. Pace,** U.S. Geological Survey, DFC MS 973, P.O. Box 25046, Denver, Colorado 80225, USA, mpace@usgs.gov, ORCID: https://orcid.org/0000-0003-2770-5724; **M. Scott Harris,** 202 Calhoun Street, College of Charleston, Charleston, South Carolina 29412, USA, harriss@cofc.edu, ORCID: https://orcid.org/0000-0002-9220-788X; and **William R. Doar III,** South Carolina Dept. of Natural Resources Geological Survey, 217 Ft. Johnson Road, Columbia, South Carolina 29412, USA, doarw@dnr.sc.gov, ORCID: https://orcid.org/0000-0002-9895-8422*

ABSTRACT

Critical mineral resources titanium, zirconium, and rare earth elements occur in placer deposits over vast parts of the U.S. Atlantic Coastal Plain. Key questions regarding provenance, pathways of minerals to deposit sites, and relations to geologic features remain unexplained. As part of a national effort to collect data over regions prospective for critical minerals, the first public high-resolution aeroradiometric survey over the U.S. Atlantic Coastal Plain was conducted over Quaternary sediments in South Carolina. The new data provide an unprecedented view of potential deposits by imaging Th-bearing minerals in the heavy mineral assemblage. Sand ridges show the highest radiometric Th values with localized, linear anomalies, especially along the shoreface and in areas reworked by multiple processes and/or during multiple episodes. Estuarine areas with finer-grained sediments show lower, distributed Th anomalies. Th values averaged over geologic unit areas are similar for both environments, suggesting that heavy minerals are present but have not been locally concentrated in the lower-energy estuarine environments. Radiometric K highlights immature minerals such as mica and potassium feldspar. K is elevated within shallow sediments younger than ca. 130 ka, an attribute that persists in regional data from northern South Carolina to northern Florida. Both K and Th are elevated over the floodplains of the Santee River and other rivers with headwaters in the igneous and metamorphic Piedmont Terrane. The persistence of K anomalies for distances of more than 100 km from the Santee River floodplain suggests that heavy minerals are delivered from the Piedmont to offshore areas by major rivers, transported along the coast by the longshore current, and redeposited onshore by marine processes.

INTRODUCTION

Technologies ranging from advanced electronics to renewable energy and medical devices depend increasingly on minerals considered “critical”; i.e., materials that are essential for the economy and its functions, but for which there is a risk of supply disruption (National Research Council, 2008; McCullough and Nassar, 2017; Schulz et al., 2017). The need for better knowledge of domestic critical mineral resources has resulted in funding for data collection over areas prospective for critical mineral deposits, including 19 new airborne magnetic-radiometric surveys contracted through the U.S. Geological Survey since 2019 (Day et al., 2019; Earth MRI Acquisitions Viewer: https://ngmdb.usgs.gov/emri/#3/, accessed Feb. 2021). These new data are helping researchers address basic questions about critical mineral deposits such as ore genesis processes and exploration approaches; they can also have applications to other fields. As part of a multidisciplinary effort addressing mineral resource and earthquake hazard studies, an airborne radiometric and magnetic survey was flown over Lower Coastal Plain sediments near Charleston, South Carolina, USA, in 2019. The targets were potential critical mineral placer deposits and subsurface faults of the Charleston seismic zone (Shah, 2020).

Placer deposits containing critical minerals titanium (Ti; used for aircraft, medical devices, and pigments), zirconium (Zr; used in ceramics, fiber-optic components, and geothermal energy systems), and rare earth elements (REEs; used in batteries, supermagnets, solar and wind energy systems, and other advanced technology) are documented in every continent except Antarctica. They currently supply 68% and 100% of global Ti and Zr, respectively (Jones et al., 2017; Woodruff et al., 2017). Prior to the 1960s they were also a primary source of REEs, but today carbonatite and ion-adsorption clays are generally favored, probably because they involve reduced handling of thorium (Long et al., 2010; Mudd and Jowitt, 2016). Placer deposits have been mined for decades in the U.S. Atlantic Coastal Plain, where the potential resource area is vast, extending from southern New Jersey to northern Florida and Alabama; mining is currently active in Georgia and Florida (Force, 1991; Grosz and Schruben, 1994; Van Gosen et al., 2014; Berquist et al., 2015; Woodruff et al., 2017).

Also referred to as heavy-mineral sand deposits, placer deposits form when water and wind concentrate unconsolidated sediments according to density, size, and shape. Minerals such as ilmenite and rutile (containing Ti), monazite and xenotime (containing REEs), and zircon (containing Zr) are relatively dense and typically become co-located when sediments are sorted through the reworking and winnowing of

GSA Today, v. 31, https://doi.org/10.1130/GSATG512A.1.

*Corresponding author.

less dense grains (Force, 1991). This dependence on physical processes makes mining and remediation relatively simple: mineral separation is conducted using density, magnetic, or electrical methods, allowing waste, which consists primarily of lighter sands such as quartz, to be safely returned to mine pits (Van Gosen et al., 2014).

Several studies have shown that radiometric methods can directly image shallow Ti-Zr-REE–heavy mineral sand concentrations due to the natural radioactivity of monazite, an REE-phosphate mineral containing small amounts of Th and U (Mahdavi, 1964; Robson and Sampath, 1977). Early airborne surveys used scintillation to measure the total gamma ray count (Force et al., 1982; Grosz, 1983; Mudge and Teakle, 2003). In subsequent years, airborne gamma spectrometry methods were developed, allowing the distinction of signals due to K, Th, and U (International Atomic Energy Agency, 2003; Duval et al., 2005). In most of the United States, gamma spectrometry surveys are currently limited by coarse line spacing (1.6–10 km) but do show broad regions in the southeastern U.S. where Ti-Zr-REE deposits are prospective (Grosz et al., 1989; Shah et al., 2017).

The 2019 South Carolina survey, flown with modern equipment and 400-m flight line spacing, represents the first high-resolution public aeroradiometric survey over U.S. Atlantic Coastal Plain sediments. Coverage over 12,000 km^2 with a footprint of 100–200 m provides data[1] at a scale not feasible through drilling campaigns. The survey allows new, basic questions regarding the following to be addressed: (1) the geologic and geomorphologic features associated with placer deposits; (2) the corresponding geologic controls on formation; and (3) the provenance, dominant delivery pathways, and impacts on composition of the heavy mineral assemblage.

GEOLOGIC BACKGROUND

The Lower Coastal Plain of South Carolina (Fig. 1) comprises gentle, elongate sand ridges alternating with low-lying clay and mud-filled areas that formed in response to a series of Quaternary transgressions and regressions; these are punctuated by various river systems (Cooke, 1936; Colquhoun,

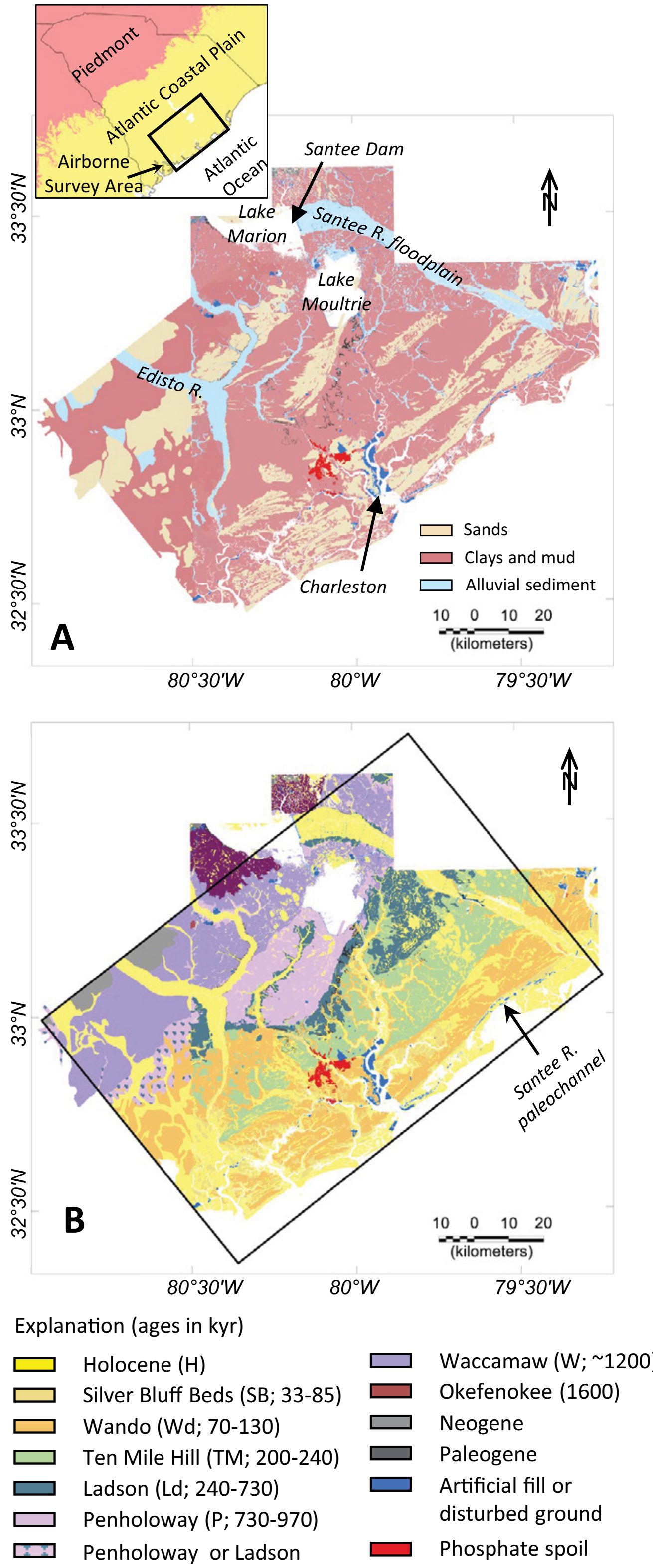


Figure 1. Generalized geology of the survey area (see text footnote 1, item S1) distinguished by facies (A) and alloformation (B).

[1]Supplemental Material. Item S1: Listing and index of geologic maps used in images and statistical analyses with age correlations for different map unit definitions. Item S2: Visual heavy mineral sand and phosphate content for over 1000 auger samples collected during previous mapping efforts. Item S3: Heavy mineral sand weight percent and economic mineral grade and tonnage estimates by Force et al. (1982) with overlays of sample positions on the new data. Item S4: Radiometric eTh, eU, and K draped over lidar (three PDF files). Go to https://doi.org/10.1130/GSAT.S.15152298 to access the supplemental material; contact editing@geosociety.org with any questions.

1969; Doar and Kendall, 2014). Within the survey area, detailed geologic mapping and geochronological studies (see footnote 1, item S1) defined a series of Quaternary alloformations that lie unconformably upon Neogene and Paleogene sediments. Most rivers in the study area drain from upland areas within the Atlantic Coastal Plain. The primary exception is the Santee River, with headwaters originating in the Piedmont and traversing metamorphic and igneous terranes for more than 100 km. The wide floodplain of the Santee River is now exposed downriver of the 1941 Santee dam.

Heavy mineral sands, eroded from the neighboring metamorphic and igneous Piedmont Province, have been observed throughout the study area via auger samples collected by R. Weems, E. Force, and others (see footnote 1, items S2 and S3). These studies found heavy mineral concentrations from 0% to more than 25% in layers up to several meters thick within Quaternary sediments. They contain ilmenite, epidote, and sillimanite with smaller amounts of rutile, monazite, leucoxene, and other minerals.

Aeroradioactivity total count surveys were flown in the study area with 1.6-km line spacing during the 1960s and early 1970s. Using these data to guide ground gamma spectrometry measurements and sample mineralogical analyses, Force et al. (1982) found direct correlations between radiometric Th and heavy mineral concentrations, attributable to Th in monazite. Radiometric K correlated well with potassium feldspars and micas, which are considered immature because leaching of potassium typically leads to alteration. They estimated grades of economic Ti-Zr-REE minerals as high as 2% and tonnage up to 70,000 metric tons at some locales (see footnote 1, item S3). They also found the mineralogy varies locally, and some heavy mineral concentrations contained large amounts of immature minerals with little economic value.

METHODS

The 2019 airborne magnetic and radiometric data were collected over a 134 km × 90 km area surrounding the city of Charleston, South Carolina, by contract for the U.S. Geological Survey (Figs. 2–4). This method provides statistical estimates of K, Th, and U concentrations within the upper 1 m of the surface and several hundred meters in each horizontal direction (International Atomic Energy Agency, 2003). Th and U involve multiple decay series, so measurements are typically referred to as equivalent uranium (eU) and thorium (eTh). The surveys were flown along NW-SE traverses at a nominal height of 100 m above ground, although areas above the city of Charleston were flown at >300 m above ground as per safety regulations. Data and details regarding contractor processing are provided by Shah (2020).

Previous geologic maps (see footnote 1, item S1) (Fig. 1) were used to calculate basic statistical measures (mean, median, standard deviation, and skewness) for K and eTh over the total area of various geologic alloformations and sediment facies. For consistency between map units, we restricted the statistical calculations to the subset of the survey area mapped by Weems et al. (2014). Lidar elevation shaded relief maps (South Carolina lidar data: https://www.dnr.sc.gov/GIS/lidar.html, accessed Feb. 2020) were used to examine the geomorphologic context of the airborne data. For ground truth, we used previously published visual estimates of heavy mineral content from more than 1000 auger samples (see footnote 1, item S2) and detailed mineralogical analyses on several dozen samples collected over high total count anomalies, including weight percent heavy minerals and mineralogy (see footnote 1, item S3).

RESULTS

Thorium

Radiometric eTh shows a reasonable correspondence with previous observations of heavy minerals in shallow samples up to variability within the resolution of the airborne survey footprint (Fig. 2A). Comparisons to sample data (see footnote 1, items S2 and S3) support heavy mineral sand concentrations near the surface as the primary source of radiometric Th anomalies. The anomalies are highest over 3–12-km-long and 400–1200-m-wide portions of sand ridges (Fig. 2B), similar to some of the shoreline deposits located near the actively mined Trail Ridge/Folkston system in Georgia and Florida (Pirkle et al., 2013). These anomalies contrast broader, rounded, and lower anomalies over clay/mud estuarine areas (Fig. 2C). Statistical measures (Figs. 2D–2E) mostly show higher eTh skewness values for sands even though the mean values for sands and clays/muds are similar. Holocene clays, which are subject to tidal flooding, show lower values because gamma rays are attenuated by the fluid medium.

Drapes over lidar elevation data (Fig. 3) show the eTh values are generally higher along the shoreface and lower along the backbarrier, similar to deposits mapped via sampling in Georgia, Florida, and eastern Australia (Roy, 1999; Pirkle et al., 2013). The highest eTh values occur mainly near the tips of the barrier islands at inlets where tidal activity is increased and near cross-cutting features visible in lidar data that suggest multiple episodes of sand reworking (marked in Fig. 3).

High eTh values are also observed over the width of the upper Santee River floodplain and immediately to the north, where a mix of terrace, eolian, and marine sediments has been observed. In the lower Santee River floodplain, eTh anomalies are focused along eolian sand ridges. The transition between these different anomaly styles occurs near the head of an Illinoian (>130 ka) paleochannel (Colquhoun et al., 1972), along which a broad eTh low is present (Fig. 2A).

Potassium

The radiometric K map (Fig. 4A) is dominated by highs over the Charleston metropolitan area, smaller towns, and along major roads, attributed to K-rich materials in concrete. High K values are also observed over the Santee River floodplain and along Holocene distributary channels up to 15 km from the floodplain (Fig. 4C). Elevated K over the Santee floodplain are consistent with previous observations of potassium feldspar or mica (Force et al., 1982).

Radiometric K is also elevated for surficial/shallow sediments that are younger than ca. 130 ka, and mean values of K within the study area (Fig. 4B) steadily decrease with age (except for Holocene clays). This is not a local phenomenon: Regional radiometric data (Duval et al., 2005) show elevated K for most sediments within 20–50 km of the coast from northern South Carolina near the Pee Dee River mouth to northern Florida (Fig. 4D) and for other rivers with headwaters in the Piedmont. In the survey area, K highs over younger sediments are discontinuous with those over the Santee River floodplain and are not focused near the Santee River.

DISCUSSION

The Distribution of Heavy Minerals

The new airborne radiometric data provide an unprecedented view of geochemical variations within the Quaternary Atlantic

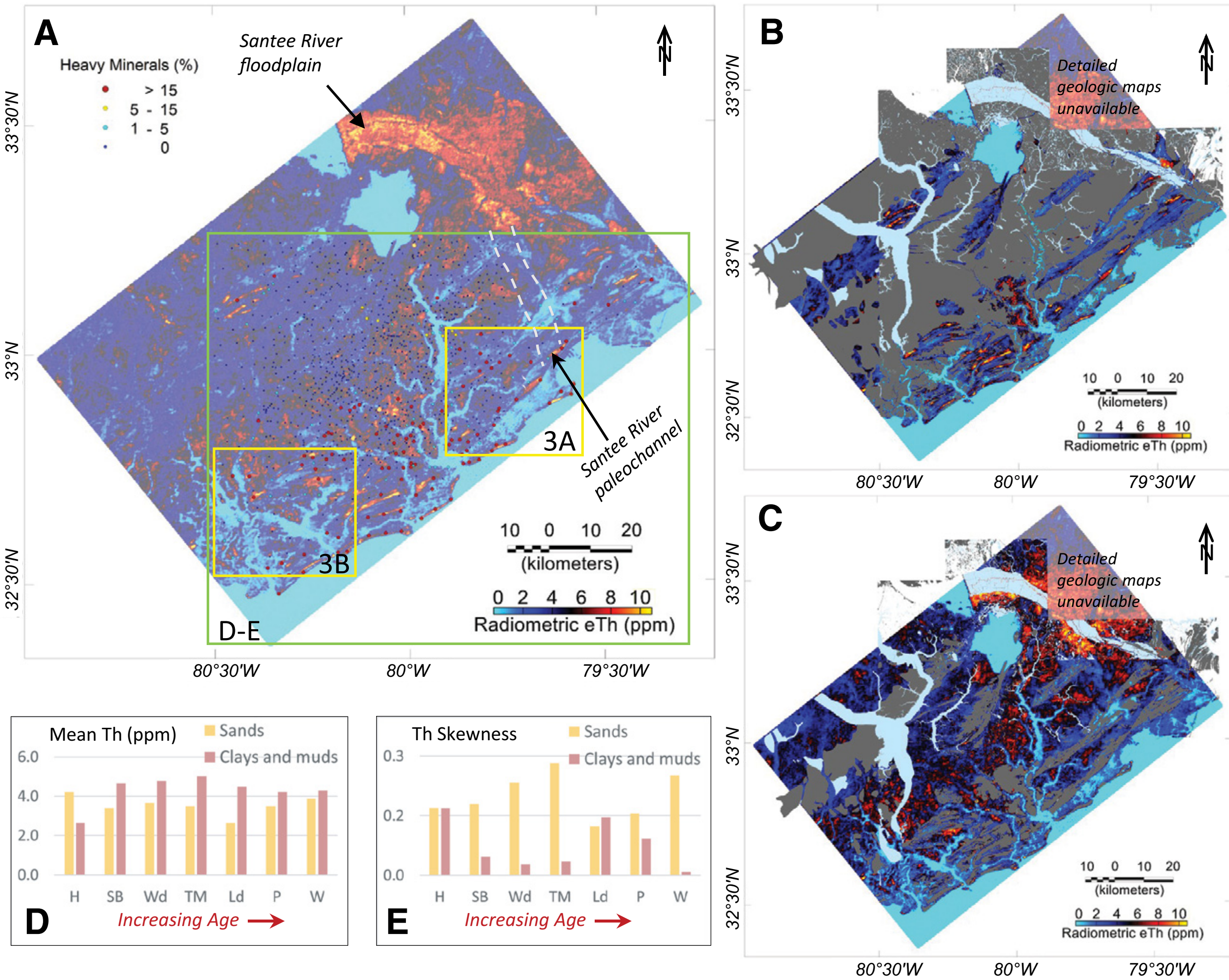


Figure 2. (A) Airborne eTh over the 2019 survey area and approximate heavy mineral percentages (circles) from visual observations of auger samples (see text footnote 1, item S2); green box shows area used for statistical calculations (D and E); yellow boxes show locations of close-ups in Figure 3. Gray dashed lines show the location of a buried paleochannel. (B–C) Airborne eTh for sands only (B) and clays/muds only (C). (D) Mean and (E) skewness values of eTh (parts per million [ppm]) for the various geologic units. H—Holocene; SB—Silver Bluff Beds; Wd—Wando; TM—Ten Mile Hill; Ld—Ladson; P—Penholoway; W—Waccamaw.

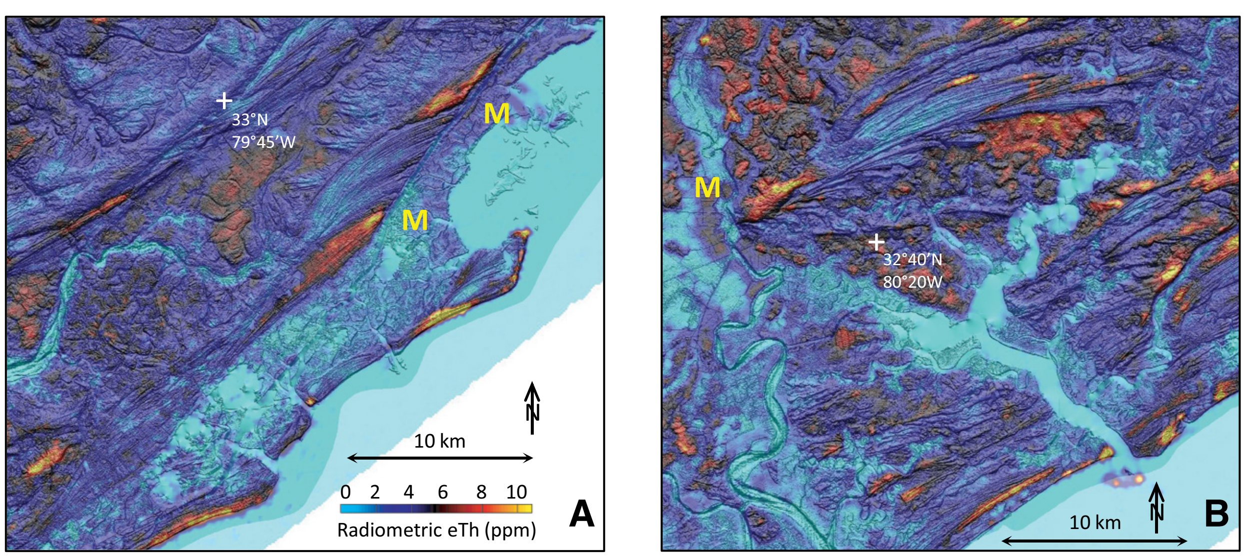


Figure 3. Close-ups of eTh draped over a lidar elevation shaded relief map (see text footnote 1, item S4) north (A) and south (B) of Charleston. eTh highs are often located along the shoreface and near streams or inlets. Highest values occur near areas marked "M" that experienced multiple episodes of reworking by marine processes.

Coastal Plain, with elevated eTh highlighting concentrations of heavy mineral sands. An interpretation of highest-grade heavy minerals residing primarily in sands along the shoreface, especially in areas that have been reworked during multiple episodes or by multiple processes, matches observations based on extensive sampling within the Quaternary coastal plain settings of Australia and the U.S. (Roy, 1999; Pirkle et al., 2013). For most finer-grained estuarine sediments, similar average eTh values combined with lower skewness values suggest that heavy minerals are present but dispersed over broad areas with lower local concentrations. These differences are attributed to greater reworking by waves and fluvial, tidal, or marine currents in the higher-energy, sand-dominated environments.

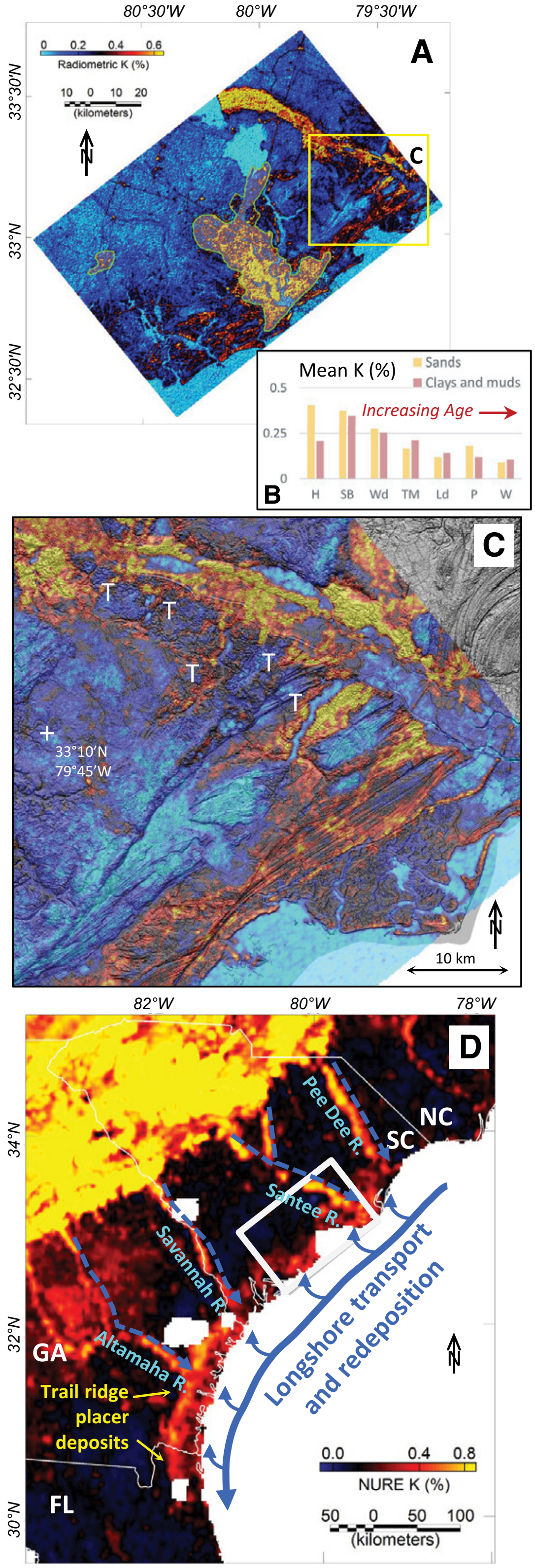


Figure 4. (A) Airborne K over the 2019 survey area. Shaded area with green outline delineates urban areas; yellow box shows location of close-up draped over lidar near the Santee River floodplain (C), where highs along tributaries are observed only up to ~15 km from the floodplain ("T"). (B) Mean value of K (%) for the various units. (D) Regional radiometric K over the Lower Coastal Plain of the southeastern U.S. (Duval et al., 2005). White box shows the location of the 2019 survey area. Potassium is elevated for younger sediments. Arrows show the suggested path of heavy minerals along major rivers to offshore areas, transported parallel to the coast, and then redeposited onshore. H—Holocene; SB—Silver Bluff Beds; Wd—Wando; TM—Ten Mile Hill; Ld—Ladson; P—Penholoway; W—Waccamaw; NC—North Carolina; SC—South Carolina; GA—Georgia; FL—Florida.

Mineral Pathways and Provenance

The mineralogy of the heavy mineral assemblage can provide key insights into sedimentary provenance. The importance of erosion and transport by fluvial processes to coastal locales was recognized by Colquhoun et al. (1972) and Neiheisel (1976), who observed immature minerals in the lower Santee River and other floodplains that must have been recently eroded from the Piedmont. However, away from major rivers, heavy mineral concentrations less than ~50 km from the Piedmont Province show mineralogy similar to the adjacent Piedmont rock, attributed to marine processes eroding a rocky coast following opening of the Atlantic Ocean (Shah et al., 2017). This study also showed that heavy mineral concentrations closer to the modern coast have more varied compositions and thus more complex delivery pathways, with specific source regions poorly known.

The presence of elevated K, representing immature minerals (Force et al., 1982), requires sediments that were recently eroded from igneous and/or metamorphic rocks in the Piedmont. The most likely transport mechanism from the Piedmont to the coast is via major rivers such as the Santee, consistent with high K anomalies observed over its floodplain. However, prominent K anomalies are also observed more than 100 km from the floodplain, requiring additional transport. The few distributary channels from the Santee River showing elevated K are less than 15 km long, making them an unlikely transport route. Additionally, the high K values over marine sediments are discontinuous with those in the Santee River floodplain.

The persistence of K-rich sediments more than 100 km from major rivers requires a mode of transport that only exists offshore. Heavy minerals were most likely delivered from the Piedmont to offshore areas by the Santee and other major rivers, transported by longshore currents during transgressions or regressions, and then redeposited onshore by currents and waves. This appears to be a regional phenomenon, because similar anomalies are present over younger sediments from northern South Carolina to northern Florida and the Pee Dee, Savannah, and Altamaha Rivers (Fig. 4D).

The transport of heavy minerals a long distance from a river source contrasts the simpler scenario suggested for sediments adjacent to the Piedmont, where heavy minerals are mostly deposited adjacent to the rocks from which they were eroded. This contrast poses an interesting question for future research: Where in the Atlantic Coastal Plain is the transition between these different modes of emplacement? Further studies using mineralogical and geochronological approaches could help to elucidate this question.

Implications for Exploration

High-resolution airborne radiometric data can provide excellent targets for exploration via drilling, with Th highlighting areas with heavy mineral sand concentrations and K highlighting areas with immature sediments. Targeted approaches based on high-resolution data can in turn facilitate more accurate assessments, with fewer samples collected in areas peripheral to the deposit (potentially leading to underestimates [see footnote 1, item S3]).

Perhaps the most interesting implications, however, involve an improved understanding of associated geologic processes at scales of hundreds of meters to hundreds of kilometers. Using relations to geomorphologic features can help to focus exploration efforts. Sediment pathways and provenance provide key information about the heavy mineral assemblage and whether economic minerals may be present. For example, the strong impact of fluvial processes proposed here suggests that Quaternary deposits, including the heavily mined Trail Ridge and Folkston deposits in Georgia and Florida, can involve a greater diversity of dense minerals.

CONCLUSIONS

High-resolution airborne radiometric data provide a powerful way to image areas prospective for critical mineral placer deposits over large regions. They can provide insights into relations to specific geomorphologic features, transport pathways, and provenance. In the survey area, they highlight the importance of not only marine and tidal processes in concentrating sediments, but also transport for hundreds of kilometers by rivers and longshore currents. These results have implications not only for exploration but also for further developing our understanding of the broader geologic processes associated with these important deposits.

ACKNOWLEDGMENTS

The airborne surveys were funded as a collaborative effort by the U.S. Geological Survey Earthquake Hazards Program, National Cooperative Geologic Mapping Program, Mineral Resources Program, and Earth Mapping Resources Initiative. The data were collected and processed by Terraquest Ltd. We thank Bradley Van Gosen and two anonymous reviewers for helpful reviews. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. government.

REFERENCES CITED

Berquist, C.R., Shah, A.K., and Karst, A., 2015, Placer deposits of the Atlantic Coastal Plain: Stratigraphy, sedimentology, mineral resources, mining and reclamation, Cove Point, Maryland, Williamsburg and Stony Creek, Virginia: Society of Economic Geologists Guidebook 50, 48 p.

Colquhoun, D.J., 1969, Geomorphology of the lower coastal plain of South Carolina: South Carolina State Development Board, Publication MS-5, 36 p.

Colquhoun, D.J., Bond, T.A., and Chappel, D., 1972, Santee submergence, example of cyclic submerged and emerged sequences, *in* Nelson, B.W., ed., Environmental Framework of Coastal Plain Estuaries: Geological Society of America Memoir 133, p. 475–496, https://doi.org/10.1130/MEM133-p475.

Cooke, C.W., 1936, Geology of the coastal plain of South Carolina: U.S. Geological Survey Bulletin 867, 196 p.

Day, W.C., Drenth, B.J., McCafferty, A.E., Shah, A.K., Ponce, D.A., Jones, J.V., III, and Grauch, V.J.S., 2019, The U.S. Geological Survey's Earth Mapping Resources Initiative (Earth MRI)—Providing framework geologic, geophysical, and elevation data for the Nation's critical mineral-bearing regions: Fasttimes, v. 24, p. 55–61.

Doar, W.R., III, and Kendall, C.G., 2014, An analysis and comparison of observed Pleistocene South Carolina (USA) shoreline elevations with predicted elevations derived from marine oxygen isotope stages: Quaternary Research, v. 82, no. 1, p. 164–174, https://doi.org/10.1016/j.yqres.2014.04.005.

Duval, J.S., Carson, J.M., Holman, P.B., and Darnley, A.G., 2005, Terrestrial radioactivity and gamma-ray exposure in the United States and Canada: U.S. Geological Survey Open-File Report 2005-1413, https://pubs.usgs.gov/of/2005/1413/ (accessed 11 Aug. 2021).

Force, E.R., 1991, Geology of titanium-mineral deposits: Geological Society of America Special Paper 259, 112 p., https://doi.org/10.1130/SPE259-p1.

Force, E.R., Grosz, A.E., Loferski, P.J., and Maybin, A.H., 1982, Aeroradioactivity Maps in Heavy-Mineral Exploration—Charleston, South Carolina, Area: U.S. Geological Survey Professional Paper 1218, 19 p., 2 plates.

Grosz, A.E., 1983, Application of total-count aeroradiometric maps to the exploration for heavy-mineral deposits in the coastal plain of Virginia: U.S. Geological Survey Professional Paper 1263, 20 p., 5 plates.

Grosz, A.E., and Schruben, P.G., 1994, NURE geochemical and geophysical surveys—Defining prospective terranes for United States placer exploration: U.S. Geological Survey Bulletin 2097, 9 p., 2 plates.

Grosz, A.E., Cathcart, J.B., Macke, D.L., Knapp, M.S., Schmidt, W., and Scott, T.M., 1989, Geologic interpretation of the gamma-ray aeroradiometric maps of central and northern Florida: U.S. Geological Survey Professional Paper 1461, 48 p., 5 plates.

International Atomic Energy Agency (IAEA), 2003, Guidelines for radioelement mapping using gamma ray spectrometry data: IAEA-TEC-DOC-1363, International Atomic Energy Agency (IAEA), Vienna.

Jones, J.V., III, Piatak, N.M., and Bedinger, G.M., 2017, Zirconium and hafnium, *in* Schulz, K.J., DeYoung, J.H., Jr., Seal, R.R., II, and Bradley, D.C., eds., Critical mineral resources of the United States—Economic and environmental geology and prospects for future supply: U.S. Geological Survey Professional Paper 1802, p. V1–V26, https://doi.org/10.3133/pp1802V.

Long, K.R., Van Gosen, B.S., Foley, N.K., and Cordier, D., 2010, The principal rare earth elements deposits of the United States—A summary of domestic deposits and a global perspective: U.S. Geological Survey Scientific Investigations Report 2010-5220, 96 p., http://pubs.usgs.gov/sir/2010/5220/, https://doi.org/10.3133/sir20105220.

Mahdavi, A., 1964, The thorium, uranium, and potassium contents of Atlantic and Gulf Coast beach sands, *in* Adams, J.A.S., and Lowder, W.M., eds., The natural radiation environment: Chicago, University of Chicago Press (for William Marsh Rice University), p. 87–114.

McCullough, E., and Nassar, N.T., 2017, Assessment of critical minerals: Updated application of an early-warning screening methodology: Mineral Economics, v. 30, p. 257–272, https://doi.org/10.1007/s13563-017-0119-6.

Mudd, G.M., and Jowitt, S.M., 2016, Rare earth elements from heavy mineral sands: Assessing the potential of a forgotten resource: Transactions of the Institution of Mining and Metallurgy Section B, Applied Earth Science, v. 125, no. 3, p. 107–113, https://doi.org/10.1080/03717453.2016.1194955.

Mudge, S., and Teakle, M., 2003, Geophysical exploration for heavy-mineral sands near Mindarie, South Australia: Australian Society of Exploration Geophysicists (ASEG) Extended Abstracts 2003, no. 3, p. 249–255.

National Research Council, 2008, Minerals, critical minerals, and the U.S. economy: Washington, D.C., The National Academies Press, 246 p., https://doi.org/10.17226/12034.

Neiheisel, J., 1976, Heavy minerals in aeroradioactive high areas of the Savannah River flood plain and deltaic plain: South Carolina Division of Geology, Geologic Notes, v. 20, no. 2, p. 45–51.

Pirkle, F.L., Pirkle, W.A., and Rich, F.J., 2013, Heavy-mineral mining in the Atlantic Coastal Plain and what deposit locations tell us about ancient shorelines: Journal of Coastal Research, v. 69, p. 154–175, https://doi.org/10.2112/SI_69_11.

Robson, D.F., and Sampath, N., 1977, Geophysical response of heavy-mineral sand deposits at Jerusalem Creek, New South Wales: Bureau of Mineral Resources Journal of Australian Geology and Geophysics, v. 2, p. 149–154.

Roy, P.S., 1999, Heavy mineral beach placers in southeastern Australia: Their nature and genesis: Economic Geology and the Bulletin of the Society of Economic Geologists, v. 94, p. 567–588, https://doi.org/10.2113/gsecongeo.94.4.567.

Schulz, K.J., DeYoung, J.H., Jr., Seal, R.R., II, and Bradley, D.C., eds., 2017, Critical mineral resources of the United States—Economic and environmental geology and prospects for future supply: U.S. Geological Survey Professional Paper 1802, 797 p., https://doi.org/10.3133/pp1802.

Shah, A.K., 2020, Airborne magnetic and radiometric survey, Charleston, South Carolina and surrounds, 2019: U.S. Geological Survey data release, https://doi.org/10.5066/P9EWQ08L.

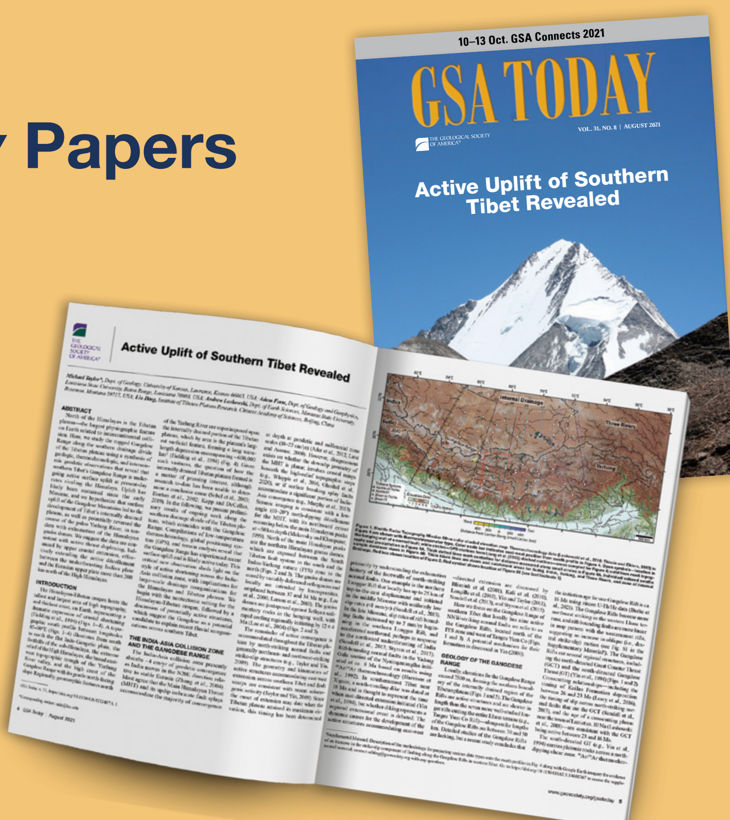
Shah, A., Bern, C.R., Van Gosen, B.S., Daniels, D.L., Benzel, W.M., Budahn, J.R., Ellefsen, K.J., Karst, A., and Davis, R., 2017, Rare earth mineral potential in the southeastern U.S. Coastal Plain from integrated geophysical, geochemical, and geological approaches: Geological Society of America Bulletin, v. 129, p. 1140–1157, https://doi.org/10.1130/B31481.1.

Van Gosen, B.S., Fey, D.L., Shah, A.K., Verplanck, P.L., and Hoefen, T.M., 2014, Deposit model for heavy-mineral sands in coastal environments: U.S. Geological Survey Scientific Investigations Report 2010-5070-L, 51 p., http://dx.doi.org/10.3133/sir20105070L.

Weems, R.E., Lewis, W.C., and Lennon, E.M., Jr., 2014, Surficial geologic map of the Charleston region, Berkeley, Charleston, Colleton, Dorchester, and Georgetown Counties, South Carolina: U.S. Geological Survey Open-File Report 2013-1030, 1 plate, https://doi.org/10.3133/ofr20131030.

Woodruff, L.G., Bedinger, G.M., and Piatak, N.M., 2017, Titanium, *in* Schulz, K.J., DeYoung, J.H., Jr., Seal, R.R., II, and Bradley, D.C., eds., Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply: U.S. Geological Survey Professional Paper 1802, p. T1–T23, https://doi.org/10.3133/pp1802T.

Manuscript received 26 Apr. 2021
Revised manuscript received 26 July 2021
Manuscript accepted 1 Aug. 2021



THE GEOLOGICAL SOCIETY OF AMERICA®

CONNECTS 2022

9–12 October
Denver, Colorado, USA

Call for Field Trip, Short Course, and Technical Session Proposals

GSA Connects 2022, being held on 9–12 October in Denver, Colorado, USA, will bring the geological community together to share ideas, best practices, and state-of-the-art knowledge. Share your scientific findings with colleagues, network with leaders in the field, and keep your skills relevant in a rapidly changing world. Plan now to be part of this gathering and amplify your research with your community by submitting a proposal for a short course, field trip, and/or a technical session.

Connect with colleagues who share your research interests and passions by leading a field trip.

Deadline: 1 Dec. 2021

Trips can be a half day to five days long, and proposals may be submitted by anyone. We are encouraging proposals for online field trips.

https://gsa.confex.com/gsa/2022AM/fieldtrip/cfs.cgi

Present your evidence-based knowledge to a large international audience by chairing a technical session.

Deadline: 1 Feb. 2022

Proposals are being taken for Pardee Symposia and Topical Sessions.

https://gsa.confex.com/gsa/2022AM/cfs.cgi

Gain recognition as an expert in your topic of research as an instructor of a short course.

Deadline: 1 Feb. 2022

Courses run the Friday and Saturday before the meeting and are a half day to two full days. Both online and in-person proposals are sought.

https://gsa.confex.com/gsa/2022AM/shortcourse/cfs.cgi

Dear Colleagues,

As you know, GSA is committed to the ideal of scientific discovery, rigor, diversity, and integrity.

I invite you to prepare a proposal for a technical session for GSA Connects 2022 that reflects your expertise and research but also pushes the boundaries of the discipline. Without expanding our horizons we will not move the geosciences forward and maintain our relevance. I challenge you to also broaden your reach with whom you collaborate by including diversity in all ways: discipline, career progression, and individuals.

Thank you for considering sharing your science and work at GSA Connects 2022.

Vicki S. McConnell, GSA Executive Director

https://www.geosociety.org

Upcoming Award Deadlines

Details: **https://www.geosociety.org/about-awards**
Nominations: **https://www.geosociety.org/awardnoms**
You can also email GSA Grants & Awards at **awards@geosociety.org**

2022 GSA Medals and Awards

Nomination deadline: 1 Feb. 2022

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

2022 Post-Doctoral Research Awards

Application deadline: 1 Feb. 2022

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

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

John C. Frye Environmental Geology Award

Nomination deadline: 31 Mar. 2022

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

OTHER AWARDS

Nomination deadline: 1 Feb. 2022

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

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

For a list of other national awards and links to information and nomination forms, go to **https://www.geosociety.org/awards/national.htm.**

GSA Scientific Division Awards

Congratulations to All 2021 GSA Division Award Recipients

GSA's primary Division awards and the other Division awards presented at GSA Connects 2021 are listed below. Learn more about GSA's scientific Divisions at **https://www.geosociety.org/divisions.**

ENERGY GEOLOGY DIVISION

Gilbert H. Cady Award
Xavier Querol, Institute of Environmental Assessment and Water Research, Barcelona

Antoinette Lierman Medlin Research Award
TBD

Curtis-Hedberg Award
Art Green

ENGINEERING AND ENVIRONMENTAL GEOLOGY DIVISION

E.B. Burwell, Jr., Award
A.W. Hatheway and T.B. Speight, 2018, Manufactured Gas Plant Remediation: A Case Study: Boca Raton, Florida, CRC Press, 1084 p.

Roy J. Shlemon Scholarship Awards
Adrienne Stephens, Portland State University

GEOARCHAEOLOGY DIVISION

Rip Rapp Archaeological Geology Award
Joseph Schuldenrein, Geoarcheology Research Associates

Claude C. Albritton, Jr., Memorial Student Research Award
Benjamin Deans, Central Washington University

GEOBIOLOGY AND GEOMICROBIOLOGY DIVISION

Outstanding Contributions in Geobiosciences Award—Pre-Tenure
Kimberly Lau, Penn State University

Outstanding Contributions in Geobiosciences Award—Post-Tenure
Phoebe Cohen, Williams College

Outstanding Contributions in Geobiosciences Award—Distinguished Career
Frank Corsetti, University of Southern California

GEOINFORMATICS DIVISION

M. Lee Alison Award for Geoinformatics
Peter Fox, RPI Tetherless World Constellation

GEOLOGY AND SOCIETY DIVISION

E-an Zen Fund Geoscience Outreach Grant
Sarah L. Sheffield and **Kristina Barclay:** Time Scavengers Undergraduate Science Communication Summer Virtual Internship Program
Sarah N. Lamm: Planetary Geology Day in Colby, Kansas, USA

GEOPHYSICS DIVISION

George P. Woollard Award
Cindy Ebinger, Tulane University

GEOSCIENCE EDUCATION DIVISION

Biggs Award for Excellence in Earth Science Teaching
Katherine Ryker, University of South Carolina

Iris Moreno Totten Geoscience Education Research Award
Leilani A. Arthurs, University of Colorado

HISTORY AND PHILOSOPHY OF GEOLOGY DIVISION

Mary C. Rabbitt History of Geology Award
Stephen Rowland, University of Nevada, Las Vegas

Gerry and Sue Friedman Award for Distinguished Service
Joanne (Jody) Bourgeois, University of Washington

HYDROGEOLOGY DIVISION

O.E. Meinzer Award
Mark Person, New Mexico Tech

Birdsall-Dreiss Distinguished Lecturer (2021)
Abraham Springer

George Burke Maxey Distinguished Service Award
Prosun Bhattacharya

Kohout Early Career Award
No award in 2021

LIMNOGEOLOGY DIVISION

Israel C. Russell Award
David T. Long, Michigan State University

Kerry Kelts Student Research Award
Natalie Packard, University of Michigan

MINERALOGY, GEOCHEMISTRY, PETROLOGY, AND VOLCANOLOGY DIVISION

Distinguished Geologic Career Award
Michael Brown, University of Maryland

Early Career Award
Xiao-Min Liu, University of North Carolina, Chapel Hill

PLANETARY GEOLOGY DIVISION

G.K. Gilbert Award
Janice Bishop, SETI Institute

Ronald Greeley Award for Distinguished Service
Jeffrey B. Plescia, Johns Hopkins University
Christian Koeberl, University of Vienna

Pellas-Ryder Award
Jan Hellmann, Institut für Planetologie, University of Münster, Germany

QUATERNARY GEOLOGY AND GEOMORPHOLOGY DIVISION

Kirk Bryan Award for Research Excellence
Maureen H. Walczak, Oregon State University, for Walczak, M.H., and 13 others, 2020, Phasing of millennial-scale climate variability in the Pacific and Atlantic Oceans: Science, v. 370, p. 716–720, https://doi.org/10.1126/science.aba7096.

Distinguished Career Award
Alan Gillespie, University of Washington

Farouk El-Baz Award for Desert Research
Claudio Latorre Hidalgo, Institute of Ecology and Biodiversity, Pontificia Universidad Católica de Chile

Gladys W. Cole Research Award
Ellen Wohl, Colorado State University

SEDIMENTARY GEOLOGY DIVISION

Laurence L. Sloss Award
Sidney Hemming, Columbia University

STRUCTURAL GEOLOGY AND TECTONICS DIVISION

Career Contribution Award
Bradley R. Hacker, University of California Santa Barbara

Outstanding Publication Award
Philippe Yamato and **Jean-Pierre Brun,** 2016, Metamorphic record of catastrophic pressure drops in subduction zones: Nature Geoscience, v. 10, p. 46–50, https://doi.org/10.1038/ngeo2852.

Other awards presented at the annual meeting include:

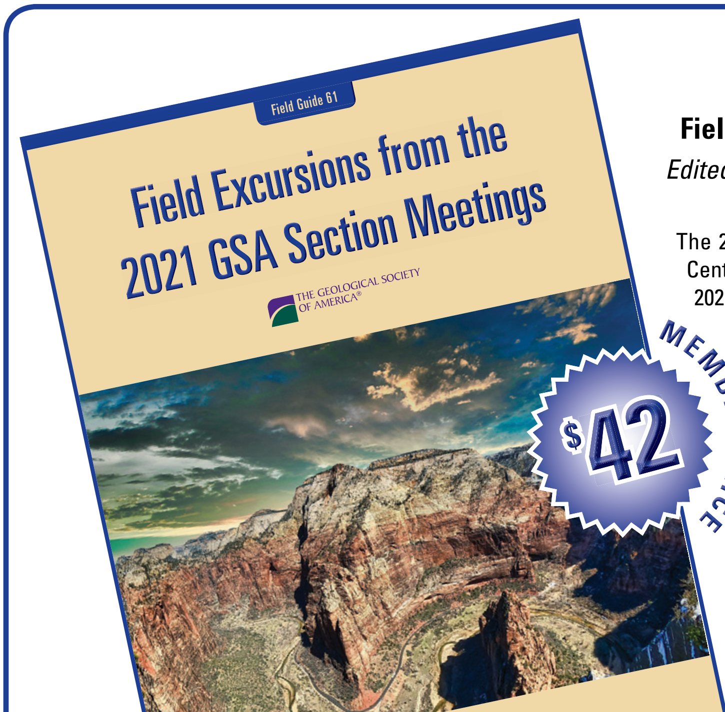
CUSHMAN FOUNDATION

W. Storrs Cole Memorial Research Award
Qing Tang, Virginia Tech

AMERICAN GEOSCIENCES INSTITUTE

AGI Medal in Memory of Ian Campbell
Marcia McNutt, National Academy of Sciences

FIELD GUIDE 61



Field Excursions from the 2021 GSA Section Meetings

Edited by Joan Florsheim, Christian Koeberl, Matthew P. McKay, and Nancy Riggs

The 2021 GSA Northeastern, Southeastern, joint North-Central/South-Central, and Cordilleran Section Meetings were held virtually in spring 2021 during continued restrictions on travel and large gatherings due to COVID-19. Eleven groups put together field guides, taking participants on treks to states from Connecticut to Nevada in the United States, to Mexico, and to Italy, and covering topics as varied as bedrock geologic mapping, geochemistry, paleodrainage, barrier islands, karst, spring systems, a southern Appalachian transect, Ordovician and Mississippian stratigraphy, high-energy events, Cretaceous arc granites and dextral shear zones, and Mesoproterozoic igneous rocks. This volume serves as a valuable resource for those wishing to discover, learn more about, and travel through these geologically fascinating areas.

FLD061, 289 p., ISBN 9780813700618

list price $60.00 | **member price $42.00**

THE GEOLOGICAL SOCIETY OF AMERICA®

BUY ONLINE ▸ rock.geosociety.org/store/

toll-free +1.800.472.1988 | +1.303.357.1000, option 3 | gsaservice@geosociety.org

Research Grants

2022 GRADUATE STUDENT RESEARCH GRANTS PROGRAM GOALS

- Support graduate student research in the geosciences and ultimately enhance the geoscience workforce.
- Provide career development opportunity for students by gaining experience with grants writing, project development and research.
- Increase the diversity of the geosciences through opportunities for students of underrepresented communities to achieve success in research.

SOME PROPOSALS FUNDED IN 2021

- Microplastic debris partitioning in urban stream waters and sediments across space and time.
- Exploration and evaluation of dimension stone in the state of Puebla.
- Inclusivity and Accessibility in Geoscience Education and Culture as Perceived by Students with Disabilities.
- Cosmogenic nuclide dating of Mars-analog paleosols.

MORE INFORMATION

- ~300 recipients annually
- Average grant amount: US$1,500–US$2,000 per student
- Apply by 2 Feb. 2022
- Contact: researchgrants@geosociety.org, +1-303-357-1025 **https://www.geosociety.org/gradgrants**

GSA invites the full participation of individuals currently being underserved in geoscience career fields. This includes, but is not limited to, individuals from racially and/or ethnically diverse communities, individuals with disabilities, individuals from LGBTIQ+ communities, and individuals who experience intersectionality with one or more of these identities. This program is supported by the National Science Foundation under Grant No. 1949901.

OTHER RESEARCH GRANTS

GSA provides members with additional opportunities to apply for research funding. Applications for these programs will be accepted beginning 1 Dec. 2021 through 1 Feb. 2022 at 5 p.m. MST.

- Farouk El-Baz Student Research Grant—Desert Studies
- Awards for Geochronology Student Research (AGeS) Program (supported by the National Science Foundation under Grant No. 1759201.)

Contact: researchgrants@geosociety.org, +1-303-357-1025
https://www.geosociety.org/grants

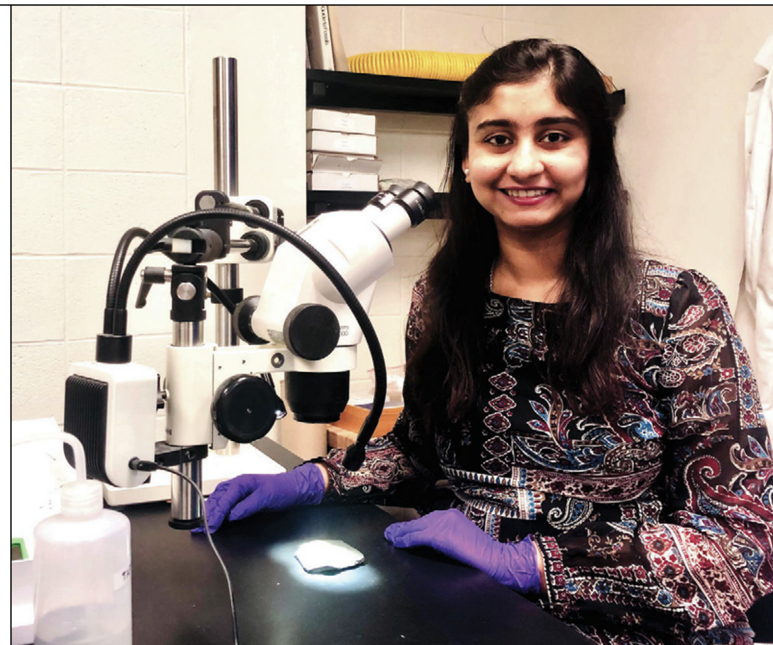
THE GEOLOGICAL SOCIETY OF AMERICA®

GSA FOUNDATION

THE GEOLOGICAL SOCIETY OF AMERICA®

Stay Connected to the Community that is Advancing Geoscience Discovery

- **Expand Your Knowledge**
  Peer-reviewed publications, free online *Geology*, Geofacets, and *GSA Today*
- **Enrich Your Skillset**
  Career guidance & lifelong learning opportunities—tech sessions, short courses, career workshops
- **Advance Scientific Discovery**
  Publish & present research, travel & research grants, and field experiences
- **Be Recognized**
  Honors & awards for outstanding contributions to science and the community
- **Support the Next Generation**
  Mentoring, advocacy, volunteer & leadership opportunities
- **Connect with the Geoscience Community**
  20,000 worldwide member community, scientific Divisions, geographic Sections



"GSA is full of opportunities for everyone; it does not matter if you are a student, early career researcher, academic, or industry professional. Never underestimate the scope of networking, and GSA is a great place for that."
—Sinjini Sinha, member since 2017

"Those early experiences—the financial support, the mentorship by established members of the earth-science community, and the shared love of geology—were fundamental to my development as a geologist. And for that, I am forever grateful to the GSA."
—Stephen Johnston, member since 1986

Join or Renew at:

Thank You 2021 GeoCorps™ America Supporters

GeoCorps provides paid, short-term geoscience opportunities that encourage participants to develop professionally by engaging in the science and stewardship of public lands. We sincerely thank the program's participants, mentors, partners, and donors for their outstanding contributions in 2021. The GeoCorps program is a partnership between the USDA Forest Service, Bureau of Land Management, Aerotek Inc., and GSA. Prospective participants can review and apply for summer 2022 GeoCorps intern projects beginning in early December 2021.

www.geosociety.org/geocorps

Clockwise from left: Bailey Nordin taking a soil core for long-term soil productivity monitoring in the Umpqua National Forest. Jake Slawson removes organic material down to bare mineral soil to assist with a long term soil productivity study in the Umpqua National Forest. Miranda Seixas, White River National Forest. Alex Barnes at the outlet of a ditch relief culvert in Steelhead Creek, Umpqua National Foresrt, Oregon.

Government partners include:

Bureau of Land Management (BLM)

USDA Forest Service

Staffing partners include:

Aerotek

Donors include:

GSA FOUNDATION

2021 PARTICIPANTS

BUREAU OF LAND MANAGEMENT (BLM)

Royal Gorge Field Office

Joshua Broussard
Apostolos (Paul) Landahl
Julie Spawn
Roberta Thompson

San Luis Valley Field Office

Hayden Yates

BLM DIRECT HIRE AUTHORITY FOR RESOURCE ASSISTANT INTERNSHIP PROGRAM

Little Snake Field Office

Aaron Evans

USDA FOREST SERVICE

Bridger-Teton National Forest

Brad Ellis

Chippewa National Forest

Jon King
Emily Lugthart

Cleveland National Forest

Claire Bartlett

Custer Gallatin National Forest

Kayla Maher
Marcella Svetz

Huron-Manistee National Forests

Noah Leslie

Nebraska National Forest—National Grasslands Visitor Center

Mattison Shreero

Prescott National Forest

Maya Bradford

Southern Region (R8) Regional Office

Mason Fredericks
Amy Kennedy

Superior National Forest

Wystan Duhn
Sara O'Hop

Tongass National Forest

Bruno Abersold
Christian DeCelle

Umpqua National Forest

Alexander Barnes
Kayla Fitzpatrick
Bailey Nordin
Jacob Slawson

White River National Forest

Anna Ledeczi
Alexander Lyles
Miranda Seixas

2021 Mentors

Frances Alvarado
James Baichtal
Joe Blanchard
Stephanie Carter
Rebecca Fincham
Emily Fudge
Sharon Fuller-Barnes
Natasha Goedert
Anna Harris
Renee Jacokes-Mancini
Marjorie Jerez
Julie Johndreau
Jeff Kroll
Travis Mason-Bushman
Jonathan Meeks
Karen Middleton
Kristina (Daisy) Morgan
David Morley
Lauren Oswald
Dan Pike
Anna Plumb
Kim Potter
Jennifer Prusse
Meghan Reedy
Dan Seifert
Zakiya Shivji
Melissa Smeins
Justin Snyder
Mark Sommer
Lima Soto
Victoria (Tori) Stempniewicz
Robin Thomas

Thank You NPS Scientists in Parks Supporters

The National Park Service (NPS) Scientists in Parks (SIP) program provides immersive, paid work experiences in natural resource fields so the next generation of park stewards—especially those underrepresented in science—have a unique opportunity to work on important real-world projects while building professional experience and a life-long connection to America's national parks. Prospective participants can review and apply for summer 2022 SIP intern projects beginning in early December 2021.

www.geosociety.org/sip

Clockwise from left: J. Gonzales looking at a formation in a cave tunnel while collecting cavern climate data. Esmeralda Elsrouji taking notes on a fossil site at Tule Springs Fossil Beds National Monument. Rachel Wright performing chemistry in the water lab at the Buffalo National River Headquarters. Kirby Heck with microphone and equipment check for a sound monitoring station on the Kahiltna Glacier in Denali National Park and Preserve.

2021 partners include:

National Park Service

Stewards Individual Placement Program

2021 donors include:

GSA FOUNDATION

Bob and Sally Newcomb

Additional funding sources include:

Devils Tower Natural History Association; DOI Regions 3, 4, and 5; DOI Regions 6, 7, and 8; Grand Canyon Conservancy; Grand Portage Band of Lake Superior Chippewa; Protectors of Tule Springs; Shenandoah National Park Trust; Zion Forever Project

SUMMER–WINTER 2021 SIP INTERN PARTICIPANTS

Acadia National Park
Anna Lee
Alaska Regional Office
Hayley Beitel
Monika Fleming
Dana Hansen
Taylor Stinchcomb
Assateague Island National Seashore
Katie Gipson
Aztec Ruins National Monument
Nicoletta Browne
Shea Nolan
Badlands National Park
Charles Bruce
Blake Chapman
Grace DeVault
Serina Griffin
Lydia Jones
Bryce McElvogue
Bandelier National Monument
Marissa Ardovino
Kathryn Brooks
Henry Davie
Kara Fox
Michelle Hill
Ella Kasten
Big Bend National Park
Isabella Fucigna
Kale'a Pawlak-Kjolhaug
Big South Fork National River and Recreation Area
Amanda Wright
Big Thicket National Preserve
Kira Ware
Biscayne National Park
Zoe Dellaert
Bryce Canyon National Park
Hannah Marshall
Buffalo National River
Mariana Perez
Courtney Werner
Rachel Wright
Cape Cod National Seashore
Eliza Fitzgerald
Cape Hatteras National Seashore
Kegan Kleeschulte
Cape Lookout National Seashore
Rachel Hilt
Capitol Reef National Park
Sara Drake
Carlsbad Caverns National Park
Riannon Colton
Henry Newell
Chaco Culture National Historical Park
Anna Sivils
Chattahoochee River National Recreation Area
Therese Kelly
Chesapeake Bay Office
Colleen Norton
Chiricahua National Monument
Anna Kurtin
Colonial National Historical Park
Mackenzie Chriscoe
Lenzie Ward
Colorado National Monument
Benjamin Landolt
Congaree National Park
Kathryn Ayers
Coronado National Memorial
Hailey Galit
Evan Laughlin
Amelia Lewis
Curecanti National Recreation Area
Autumn Moya
Death Valley National Park
Alison Frame
Maeve Holland
Carmen Kraus
Kimberly Nichter
Denali National Park and Preserve
Johanne Albrigtsen
Baylee Bessingpas
Izabella Block
Rebecca Conner
Amelia Evavold
Kirby Heck
Autumn Helfrich
Lauren Hurst
Loring Schaible
Margaret Stoneham
Denver Service Center Planning Division
Everly Jazi
Eva Tsow
Dinosaur National Monument
Colton Snyder
Emma Trost
Kaylee Velasquez
Kathryn Whelton
Dry Tortugas National Park
Kaliegh Schlender
El Malpais National Monument
Olivia Beaudette
Fire Island National Seashore
Ria Kobernuss
Taylor Solorzano
Florissant Fossil Beds National Monument
Astrid Garcia
Fort Laramie National Historic Site
Abigayle Hansen
Fort Matanzas National Monument
Katherine Sweezey
Fossil Butte National Monument
Sophia Cajune
Glacier National Park
Katherine Barrs
Holli Holmes
Golden Gate National Recreation Area
Jordan Gorostiza
Grand Canyon National Park
Carmen Kraus
Brittne MacCleary
Erikka Olson
Deron Clark
Grand Teton National Park
Elizabeth Case
Jamie Mcbryde
Great Basin National Park
Jeremy Osowski
Callum Russell
Serena Wurmser
Gulf Islands National Seashore
Philip Iversen
Grady Jakobsberg
Darby McGhee
Leah Vickery
Jordan Wingate
Hagerman Fossil Beds National Monument
Scott Kottkamp
Elizabeth Nist
Harpers Ferry National Historical Park
Marcella Svetz
Isle Royale National Park
Madelyn Barrie
Jewel Cave National Monument
Riannon Colton
Jimmy Carter National Historical Park
Josephine Duffy
John Day Fossil Beds National Monument
Rudolph Hummel
Kelly Lubbers
Jasmine Reitze
Kaili Schroeder
Joshua Tree National Park
Caroline Abramowitz
Kaloko-Honokōhau National Historical Park
Danielle Wilde
Katmai National Park and Preserve and the Alaska Regional Office
Matthew Harrington
Lake Clark National Park and Preserve
Samuel Graf
Lake Mead National Recreation Area
Benjamin Banet
Lassen Volcanic National Park
Taylor Thomas
Lava Beds National Monument
Jordan Kemp

Lewis and Clark National Historical Park
Emily Scott
Little Bighorn Battlefield National Monument
Remi Masse
Manassas National Battlefield Park
Kelly Ewing
Mesa Verde National Park
Erin Markey
Claire Stellick
Midwest Regional Office
Joseph DeVito
Mojave National Preserve
Emily Claire Johnson
Monocacy National Battlefield
Olivia Boraiko
Colleen Lewis
Mount Rainier National Park
Oriana Bosque
Andrea Minot
Heather Silvola
Mount Rushmore National Memorial
Max Maddox
National Park of American Samoa
Robert Smith
Region 1 Office, Duty Station University of Rhode Island
Kendra Devereux
Obed Wild and Scenic River
Katie Spivey
Olympic National Park
Jillian Brigham
Megan Coyle
Mallory Mintz
Oregon Caves National Monument and Preserve
Javaria Aziz
Park Facility Management Division
Miriam Ritchie
Perry's Victory and International Peace Memorial
Sophie Rabinowicz
Point Reyes National Seashore
Ellen Murphy
Redwood National Park
Kathryn McGee
Sylvia van Royen
Rocky Mountain National Park
Diego Alvarado
Raymond Flores
Benjamin Holt
Saguaro National Park
Mattea Pulido
San Juan Island National Historical Park
Jeramy Ott
Santa Monica National Recreation Area
Evan Fitzmaurice
Shared Beringian Heritage Program
Megan Withers
Shenandoah National Park
Rebekah Everett
Hannah Prokop
Marcus Tierrablanca
Sleeping Bear Dunes National Lakeshore
Lauren Charles
Holly Francart
Theodore Roosevelt National Park
Charles Salcido
Waco Mammoth National Monument
Margaret Rubin
War in the Pacific National Historical Park
Marisa Agarwal
Michelle Diminuco
Western Pennsylvania Parks
Sam Govan
Corrina Yobp
Whiskeytown National Recreation Area
Olivia Barnes
Laina Rose
Alice Stitzer
Wilderness Stewardship Division
Emily L. Brent
Hannah Stelley
Wrangell–St. Elias National Park and Preserve
Anna Carrie Thompson
Wupatki National Monument
Chad Kwiatkowski
Yellowstone National Park
Hannah Bortel
Anthony Himmelberger
Morgan Nasholds
Yosemite National Park
Sara Donatich
Autumn Helfrich
Lauren Hurst
Dorothy Shreve
John Stapke
Zion National Park
Madison Anderson

INVENTORY & MONITORING NETWORKS

Appalachian Highlands
Ross Shipley
Central Alaska
Robert Smith
Chihuahuan Desert
Kevin Gross
Cumberland Piedmont
Megan Garvey
Greater Yellowstone
Elizabeth-Ann Jamison
Gulf Coast
Claudia Silver
Klamath
Addis Gonzalez
Kira Ware
Mediterranean Coast
Hunter Klein
Nicoletta Stork
Mojave Desert
Emma Kaufman
Evan Kolb
National Capital Region
Edward Cascella
Northeast Coastal and Barrier
Colleen Keenan
Bridget Ye
Northern Colorado Plateau
Brian Schlaff
Pacific Island (within Hawai'i Volcanoes National Park)
John Benner
Esaac Mazengia
Jasmine-Marie Moku
Brayden Pollvogt
Rocky Mountain
Matthew Robinson
San Francisco Bay Area
Arista Regalia
Sierra Nevada
Ana Tobio
Sonoran Desert
Mariam Moazed
South Florida/Caribbean
John Sabin
Southeast Coast (within Congaree National Park)
Julieanne Montaquila
Southern Plains
Jonathan Sigwing
Southwest Alaska
Journey Berry
Kaitlyn Furey
Upper Columbia Basin
Jamela Thompson

NATURAL RESOURCE STEWARDSHIP AND SCIENCE DIRECTORATE

Geologic Resources Division
Noah Angell
Brian Mulroy
Karina Zyatitsky
Inventory & Monitoring Division
Myles Cramer
Water Resources Division
Brooke Bauman
Brennan Kessenich
Nina Elisaveta Loutchko
Matthew Rigdon
Autumn Sands
Alyssa Winchell

190th Anniversary of the Birth of Eduard Suess, the Father of Modern Global Geology

***A.M. Celâl Şengör,** ITU Faculty of Mines and the Eurasia Institute of Earth Sciences, Ayazağa 34469 Istanbul, Turkey, sengor@itu.edu.tr*

INTRODUCTION

When rational speculation began more than two-and-a-half millennia ago on the eastern shores of the Aegean with a view to explaining observations made on natural objects and events, geology was born. For nearly two millennia, mankind had to make do with what could be seen on the surface of the earth. Despite this severe limitation, some very ingenious theories were put forward about the behavior of our planet: It was realized that mountains rose from the sea and volcanoes and earthquakes were somehow related to the heat within our globe and they seemed associated with mountain-building. This state of affairs changed dramatically when Descartes introduced the concept of a bed (i.e., a layer) in 1644. Descartes' concept was purely imaginary, but it triggered a revolution in the hands of Nicolaus Steno in 1667 and 1669, when the origin of beds were recognized to be sedimentation, fossils former inhabitants of sedimentary basins, and the haphazard orientations of bedded sequences a result of subsequent deformation. This gave a great impetus to attempts to explain the history of the earth in terms of sedimentary sequences until it was realized that not all rocks were products of sedimentation. The next great step in the history of geology was taken by James Hutton in Scotland. Hutton argued that rocks rising as melts from the interior caused deformation of the sedimentary layers and that this process had been going on since as long ago as our observations could decipher. He further pointed out that no miracles are needed to explain the course of the geological history of the earth: The present-day phenomena we observe daily provided sufficient explanation of everything one could discover in the geological record.

Hutton's theory coincided in time with the rise of biostratigraphy that enabled geologists to erect a calendar of events in the earth's past, albeit without being able to put numbers of years onto it. These two developments gave geology an immense stimulus, and stratigraphic geology was able to erect a timetable for earth history by the middle of the nineteenth century, which we still use. All kinds of theories were advanced to explain the planet's past, and their inventors picked and chose those observations agreeable to their particular hypothesis. With Lyell's insistence that there never had been any global events in the past, geology became detailed but parochial. The spectacular failure of a few attempts at global geology encouraged this tendency to be local. It seemed that geology, while able to explain local observations, lacked a method with which earth as a whole could be understood.

SUESS, THE GEOLOGIST

This all changed when a man, born in London on 20 August 1831 to Austrian parents who had been residing there temporarily for business reasons, stepped into the picture (Fig 1). Multilingual from childhood, Suess developed an interest in geology while visiting the "Fatherland Museum" in Prague as a 19-year-old, where there was a collection of fossils. His family wished him to become an engineer to continue the family business, but the political affairs of 1848 made continuing in the technical university undesirable. Suess applied to the *Hofmineralienkabinett*, the predecessor of the present magnificent Natural History Museum in Vienna, as a volunteer paleontologist and showed such remarkable ability that he became permanently employed with full salary (by that time he had already discovered three new fossil species: one graptolite and two brachiopods). In 1857, he switched to the University of Vienna because he thought the way geology was being taught in Austria was unsatisfactory. He wanted to show that geology was more than just minerals and rocks and fossils with some mining applications.

Figure 1. Eduard Suess (1831–1914). Public domain.

As a professor, Suess was very keen on field observation, both with his students and by himself. At the beginning of his teaching career two things surprised him: the Tertiary stratigraphy observed in the Vienna basin could be extended, in the same sequence and at similar elevations above sea-level, all the way east to the region of the Aral Sea and west almost as far as Switzerland. This inspired him to question the theory of independent vertical motions of continents to explain regional unconformities, at the time advocated by Sir Charles Lyell and his followers. The persistence of the undeformed stratigraphy for such immense distances, Suess thought, could not be explained by differential vertical motions. He thought it must have been the global sea level that was changing (he called them eustatic movements in 1888), and to accomplish that the ocean basins had to have changed their capacity throughout geological time. But how did they do it?

Another surprising field observation helped him to think of a mechanism. He found that an anticlinal structure beginning in western Switzerland and continuing all the way to the western Carpathians accompanied the Alpine front. He had earlier seen, during a mapping exercise in the Alps, that the Alpine "central massifs" consisting of granites and gneisses and at the time held responsible for raising the Alpine edifice as intrusive masses, could not have done that, because their erosional debris was contained in the early Mesozoic sequences. It was clear that they had been deformed together with the younger sedimentary cover. Suess realized that not vertical, magma-driven, uplift, but lateral shortening was responsible for the origin of the Alps. His excursions in Italy further showed him that while shortening was going on in the external parts of the Apennines, stretching and subsidence, accompanied by active volcanism, dominated the internal parts, there creating the Tyrrhenian Sea. He compared this with the Carpathians and the Pannonian basin behind them and concluded that it was the motion of upper lithospheric slabs that was responsible both for the extension and the coeval shortening. This was contrary to all that was claimed about the behavior of the planet in the early seventies of the nineteenth century. Suess found a convenient explanation in the contraction theory as promulgated by the French iconoclastic geologist Constant Prévost. Prévost argued that the contraction of the globe manifested itself by vast subsidences along steep faults creating the ocean basins, and mountain-building was a reaction (he wrote *contrecoup*) to subsidence along the margins of such subsident areas. This explained in one unified theory both the changing capacity of ocean basins and the shortening-driven mountain building with subsidence in the back. James Dwight Dana, following also Prévost's theory, but mixing it with the contraction theory of Élie de Beaumont, which was incompatible with Prévost's hypothesis, had thought the same already in 1847, but Dana's theory was internally inconsistent. Subsidence alone could not give rise to asymmetric mountain structure; by contrast, it would have caused extension. Suess solved the problem by introducing the concept of detachment of large lithospheric slabs from the contracting interior, attached to it in only limited places, located excentrically with respect to the basin geometry, thus generating shortening in one margin while stretching at the opposite one. This would also explain the volcanism associated with the internal parts of mountain belts.

Suess thought that the time had come to test his ideas on a global scale. Unlike his predecessors, he did not pick convenient cases to support his theory, but reviewed, in as much detail as was then possible, the entire geology of the globe. Such a thing had never been attempted before. His initial results were published in 1875 in a small book of only 168 pages with no figures, titled *Die Entstehung der Alpen* (The Origin of the Alps). The book actually offered a quick tour of the world's mountains and an analysis of the great Cenomanian transgression (the term biosphere was also introduced in that book).

Suess' final major product was the massive, four-volume "long argument" explaining the entire global geology in terms of the ideas he had developed. *Das Antlitz der Erde* (The Face of the Earth), published between 1883 and 1909, announced the birth of modern global geology. It took Suess 26 years to complete it, and it was translated immediately into French, English, Spanish, and partially into Italian. Its introductory chapter was even published in Esperanto. Which geologist has not heard the terms horst, graben, batholith, listric fault, virgation, syntaxis, Zwischengebirge (translated into English as betwixt mountains or median masses), foreland, hinterland, foredeep (Fig. 2), hinterland basin, back-folding (and thrusting), table-land (which was later dubbed by others as craton), eustasy, Atlantic- and Pacific-type continental margins, Russian Platform, Laurentia, Gondwana-Land, Angara-Land, Tethys, Alpides, Altaids, Variscan mountains, Caledonian mountains, East African Rift Valleys, Sarmatian Stage, asylum (or refugia as is now commonly used)... ? Yet, how many of us know that they were all introduced in Suess' *magnum opus* or in his independent papers and later incorporated into the *Antlitz*. We use his concepts so commonly that we no longer feel the need to refer to his book. They have become the common property of geology (Fig. 3). But this should not lead to a professional amnesia about his

Figure 2. Suess' cross section across Asia that he sent to William Sollas, the editor of the authorized English translation of *Das Antlitz der Erde* (The Face of the Earth). This section was published in two pieces in the first foldout of the fifth volume of the English translation, the publication of which was delayed because of World War I (1924). I have only enlarged the lettering for easier reading. Notice the underthrusting of the ocean to form the foredeep.

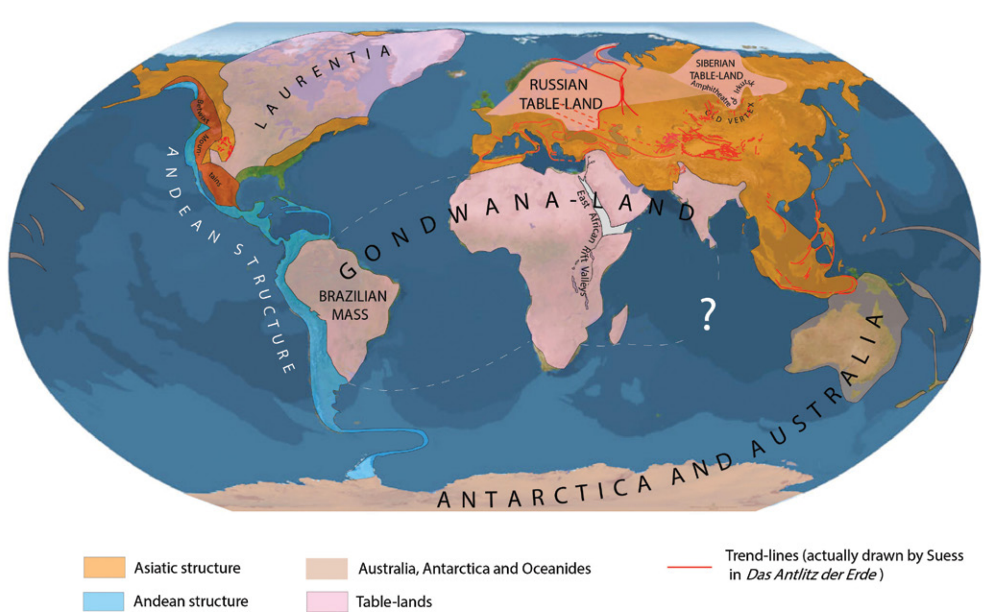


Figure 3. Tectonics of the earth according to Suess. The red lines are the trend-lines of mountain belts published in the *Antlitz*. Suess took Australia and Antarctica out of Gondwana-Land during the Mesozoic.

memory, not only because this would be terribly ungrateful, but especially because we have yet to learn so much from his work. Whether we realize it or not, we are all still his students, even, and especially, after plate tectonics.

SUESS, THE MAN AND THE PUBLIC SERVANT

I conclude this short piece about Suess by reminding my readers that he was responsible for providing fresh and healthy drinking water to Vienna and changing the course of the Danube to stop the repeated floods in Vienna. These two great engineering projects reduced the death rate from such diseases as typhoid fever and cholera in Vienna to only a few percent of their previous values. Suess was a member of the Austrian Imperial Parliament for 30 years, and in that capacity, he fought to wrench the schools from the control of the church.

Everybody who had contact with him personally acknowledged his modesty, kindness, and generosity toward his fellow humans at every level. That also made him a very successful father of six children and an exemplary spouse. Let me end with a judgment by one of the giants of Alpine geology, Rudolf Trümpy (1921–2009): "Suess was the only genious in the history of geology who had no vices."

FURTHER READING

Şengör, A.M.C., 2014, Eduard Suess and global tectonics: An illustrated 'short guide': Austrian Journal of Earth Sciences (Suess special issue), v. 107, p. 6–82

Şengör, A.M.C., 2015, The founder of modern geology died 100 years ago: The scientific work and legacy of Eduard Suess: Geoscience Canada, v. 42, p. 181–246, https://doi.org/10.12789/geocanj.2015.42.070.

Şengör, A.M.C., 2019, Eduard Suess and the essence of geology, *in* Rossetti, F., Crespo Blanc, A., Riguzzi, F., Leroux, E., Pavlopoulos, K., Bellier, O., and Kapsimalis, V., eds., The Structural Geology Contribution to the Africa-Eurasia Geology: Basement and Reservoir Structure, Ore Mineralisation and Tectonic Modelling: Cham, Denmark, Springer, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-030-01455-1_5.

THE GEOLOGICAL SOCIETY OF AMERICA®
Penrose CONFERENCE

The Geological Fingerprints of Slow Earthquakes

1–5 April 2022 | Santa Catalina Island, California, USA
https://www.geosociety.org/penrose

CONVENERS

James Kirkpatrick, McGill University, Dept. of Earth and Planetary Sciences, Montréal, Québec, Canada, james.kirkpatrick@mcgill.ca
Melodie French, Rice University, Dept. of Earth, Environmental and Planetary Sciences, Houston, Texas, USA, mefrench@rice.edu
John Platt, University of Southern California, Dept. of Earth Sciences, Los Angeles, California, USA, jplatt@usc.edu
Christie Rowe, McGill University, Dept. of Earth and Planetary Sciences, Montréal, Québec, Canada, christie.rowe@mcgill.ca
David Schmidt, University of Washington, Dept. of Earth and Space Sciences, Seattle, Washington, USA, dasc@uw.edu

SPONSORS

The Geological Society of America
NSF-GeoPRISMS
Southern California Earthquake Center

DESCRIPTION AND OBJECTIVES

The discovery of slow earthquakes twenty years ago revolutionized understanding of how plate motions are accommodated at major tectonic boundaries. Slow earthquakes are a family of events that include slow slip events, tectonic tremor, and low-frequency earthquakes. Compared to regular earthquakes, the slip across a fault during a slow earthquake occurs slowly, but significantly faster than plate-rate creep. They are often associated with "transitional" regions at the edges of seismogenic zones but occur both updip and downdip, so encompass a wide range of pressure and temperature conditions.

Understanding slow earthquakes is critical to developing better constraints on regional seismic hazards and may also provide information on the physical conditions and fault loading rates at depth. However, there are numerous outstanding issues regarding the basic processes, deformation mechanisms, and conditions that control slow-earthquake characteristics. It is increasingly clear that only field geological observations of exhumed structures can resolve these issues and differentiate between models for slow earthquake occurrence, because geodesy and seismology cannot resolve the relevant length scales.

For this conference, we solicit contributions that use geological observations, lab measurements, or numerical models to aid in understanding the physics of slow earthquakes. We encourage researchers studying analog systems from any tectonic setting or metamorphic grade relevant to modern tremor and slow earthquakes to build a wide range of geological perspectives. Contributions that address outstanding questions regarding deformation mechanisms, limits on rates of deformation, and environmental conditions are encouraged. New multidisciplinary approaches are needed to define the physical controls on slow earthquakes and to develop new insights into disparate datasets. For this conference, we aim to stimulate contributions from geological-focused, particularly field-based, investigators and to engage geophysicists with a range of backgrounds to define key unknowns and debate possible models.

The meeting conveners and organizers are closely monitoring the ongoing pandemic, but we anticipate that this meeting will be fully in-person. Additional requirements or changes may be imposed to help mitigate the risks.

PRELIMINARY AGENDA

This five-day meeting will be held at the University of California Wrigley Institute for Environmental Studies, Santa Catalina Island, California, USA. Ferry rides to and from Santa Catalina Island will be provided for attendees. The meeting format will be a balance of invited talks, breakout discussions, pop-up talks, and poster presentations. All nights will be spent at the Wrigley Institute. Participants will be expected to observe the GSA Code of Ethics & Professional Conduct (**https://www.geosociety.org/ethics**) throughout the meeting. For a detailed description of the agenda, please see the meeting website at **https://sites.google.com/view/penrose2022/attend.**

All participants will be invited to attend a day-long field trip in the middle of the meeting, taking in several exposures within an ~30–40-minute drive from the Wrigley Institute. These exposures display a variety of structural features that have been suggested as possibly associated with slow slip, including blocks of effectively rigid rock in a viscous matrix, sheeted vein complexes, and shear zones showing evidence for solution-redeposition creep associated with microfolding and dilational cracking.

ATTENDEES AND ESTIMATED COSTS

GSA and the meeting conveners are committed to fostering diversity, equity, inclusive excellence, and belonging in the geoscience community. For this meeting, we welcome and encourage applications from all gender identities, Black, Indigenous, Latinx, and People of Color, people with disabilities, LGBTQIA+ individuals, and other groups which are currently underrepresented within the earth-science community.

Thanks to the generous support of the sponsoring agencies, the anticipated registration fee will be US$100, which will cover four nights of lodging, meals, transportation to/from Santa Catalina Island, transportation for field trips, and facility usage. Participants will be expected to pay for travel expenses from their home to southern California. However, we have funds to support the travel of participants, which will be prioritized toward underrepresented groups as well as early-career and student participants. All participants will be expected to make their own travel arrangements to arrive at Long Beach, California, USA, in time for a scheduled ferry to the Wrigley Institute on Santa Catalina Island.

The conference will be limited to 64 participants, and each participant will have to commit to attending for the full duration of the conference because transport to/from Catalina Island is provided at the beginning and end of the meeting, but otherwise is limited. For more information and registration, please see the meeting website at **https://sites.google.com/view/penrose2022/attend.**

2021–2022 GSA-USGS Congressional Science Fellow Announced

Amanda Labrado

GSA and the U.S. Geological Survey are pleased to announce that Amanda Labrado will serve as the 2021–2022 GSA-USGS Congressional Science Fellow. She will spend a year working in the office of Representative Alexandria Ocasio-Cortez (D-NY).

Labrado is a biogeochemist with a broad background in earth and environmental sciences. She recently received her Ph.D. from The University of Texas at El Paso (UTEP), where she studied how microbes facilitate the formation of minerals on the top of salt domes, large geological features located beneath Earth's surface. Her graduate research was supported by a NASA Earth and Space Science Fellowship for planetary studies because her project, although centered around Earth-based observations and experiments, has implications for the search for life elsewhere. Through the course of her studies, Labrado broadened both her scientific and cultural horizons by conducting geophysical surveys of the subsurface in South Africa, geomicrobiology in Spain, and cave research in Sicily and Cambodia, along with participating in international conferences. Labrado benefited from financial support from both academia and industry, receiving numerous scholarships from various organizations, including GSA, the Society of Independent Professional Earth Scientists (SIPES) Foundation, and the American Institute of Professional Geologists (AIPG), as well as from a petroleum research consortium. She completed an internship with Chevron and was also awarded the Bruce Davidson Memorial Award in Geosciences, which commends both scholastic excellence and community involvement within the geosciences department.

Labrado was born and raised by her single mother in El Paso, Texas, which is a predominately Hispanic border community situated in the semiarid landscape between the Franklin Mountains and Rio Grande. Because this border region is greatly affected by air pollution and drought, Labrado learned how inseparable socioeconomics, policy, and science are and the challenge of successfully and effectively communicating science with various audiences. Because of this, she served as the president for the local chapter of the Association for Women Geoscientists (AWG), which promotes women and other underrepresented groups in the geosciences, and president of the El Paso Geological Society, which aids in exposing the community of El Paso to local geological attractions. These organizations helped her engage with local teachers and students and non-scientists, helping her gain a unique perspective on the intersection between environmental, social, and political issues.

In her free time, Labrado is a 500-hour yoga teacher as well as a practitioner, an outdoor enthusiast, and she loves to travel. She tutors at-risk K–12 students online with School on Wheels and enjoys volunteering with initiatives to get people outdoors. When she is not exploring, she can be found eating lots of delicious vegan Mexican food with her family and friends.

Why GSA Membership is Important to Me

1. When did you first become a member? Did anything or anyone influence you to become a member?

I became a GSA member in 1996 as a graduate student.

2. Did or do you participate in any programs, committees, apply for research grants, etc.?

I received the GSA-ExxonMobil Bighorn Basin Field Award in 2011.

3. How has GSA membership been particularly impactful on your career?

Being a GSA member is perhaps the best career decision I made. I started my academic career at a two-year campus before moving on to a four-year regional comprehensive university. I could always count on the GSA Geoscience Education Division and the National Association of Geology Teachers (NAGT) for finding opportunities for professional development and a support system. Most importantly, being part of GSA made me aware of the barriers and challenges faced by people from marginalized communities in the geosciences and gave me a space where I can find like-minded people who are as passionate as I am in making the geosciences more equitable, accessible, diverse, and inclusive at all levels. GSA helps me be a change agent in my discipline.

4. What is the greatest benefit to being a member of GSA?

Being a GSA member exposed me to the range of career opportunities for geoscientists both within and outside of academia. GSA maintains a nice balance between pure research, applied research, pedagogical research, and research on effective teaching practices. There is something beneficial for everyone, no matter whether someone is a beginning student or a seasoned geoscientist. However, as a field geologist, the greatest benefit of being a GSA member for me is

the various field trips organized as part of every GSA regional and annual meetings. Being able to visit various field locations in the company of a group of other geologists is, perhaps, the most impactful opportunity for my continued professional development.

5. What would you say to a peer who is considering joining GSA/starting their geoscience journey?

Just do it. You will not regret this decision.

Juk Bhattacharyya
GSA member since 1996

Submit Your GSA Experience Essay Today!

Let us know how GSA has made an impact on your life. Answer the questions above or write an essay of about 500 words and send us your high-resolution photo. We'd love to hear from you, and so would your colleagues!

Email gsatoday@geosociety.org with your submission.

Your Dollars Will Be Doubled to Help Students Attend Field Camp

"With the J. David Lowell Field Scholarship and aid from the department, I could attend the entire six-week session without considering costs. The level of financial support I received in pursuit of my academic and career goals is truly incredible. While passion and curiosity provided the initial fuel for my studies, I could never realize my ambitions and graduate without the help of people like you." —Cissy Ming, 2021 J. David Lowell Field Camp Scholarship recipient using their new Brunton.

BRUNTON

Your contribution can make all the difference for a student who isn't sure they have the means to complete their degree.

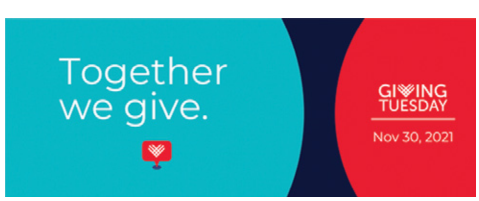
This might sound extreme, but we receive letters of thanks from students who tell us their degree completion was uncertain or even in jeopardy and that funding from GSA made what seemed impossible possible; our members who contribute to GSA programs helped them move forward with their education.

Thanks to GSAF donors, every year students receive support to attend field camp through the J. David Lowell Field Camp Scholarship Program. This year, Brunton added an extra benefit for scholarship recipients—a Compro Transit, personalized with names engraved on their leather cases. The financial award helps offset field camp costs, and this generous gift helps ease the added strain of equipment expenses for each of these students while providing them with the essential geologist's instrument.

Many students say that their field experiences bring to life the geology they studied in the classroom. However, the cost of field camp is often prohibitive and added expenses, such as equipment, leave many feeling that field camp is out of reach for them.

That's where GSA members can make a meaningful difference. **On Giving Tuesday, a global day of giving back, we kick off our efforts to provide field camp support for students with a US$10,000 match.** Challenging fellow GSA members, a generous donor will match one-to-one, up to US$10,000, every gift made to the J. David Lowell Field Camp Scholarship Program (**https://gsa-foundation.org/fund/field-camp-opportunities/**) between Giving Tuesday, 30 November, and New Year's Eve.

Help a student by making a gift on Giving Tuesday, and keep an eye on your email, GSA's social media, and the Foundation blog (**https://gsa-foundation.org/news-events/**) for stories of impact as well as other ways you can be involved. You can also contact Debbie Marcinkowski at dmarcinkowski@geosociety.org or +1-303-357-1047 to discuss ways you can help.



"Because of your generosity, I am able to finish my degrees in geology and civil engineering. I will be able to go to field camp with more financial peace of mind, and I am also able to go to a field camp that specializes in my desired career field instead of having to settle for the less expensive option. This scholarship has also motivated and inspired me to continue my education into graduate school. One year ago, this would not even have been within consideration in light of my experiences, but thanks to your support, I am on the path towards becoming the first in my family to continue my education into graduate school. After graduate school, I plan on becoming a licensed geotechnical engineer and engineering geologist. Your generosity is directly responsible for carving a path towards my future academic and personal success, and for that, I cannot overstate my gratitude. You have inspired me to be an advocate for students like me in my professional career and give back to the community as you have so graciously given to me. Again, thank you for giving me this wonderful opportunity and helping me expand my future." —Emma Fuentes, 2020 J. David Lowell Field Camp Scholarship recipient.

Get First Access to the Latest Research

With GSA's online-first publishing, you have access to groundbreaking research as soon as it's ready for publication. Visit our publications page on GeoScienceWorld at **https://pubs.geoscienceworld.org/gsa** for all of GSA's books and journals.

Subscribers can count on receiving the earliest possible access to our articles by visiting the journal's online early publication page. (From the journal's homepage, click on "content" in the top menu bar and select "early publication" from the drop-down menu.) Special Paper and Memoir chapters also are posted ahead of print (with access via your library's subscription).

Be the first to know when content is available by signing up for e-mail alerts.

Follow these steps to sign up for latest issue and pre-issue publication alerts for *Geology*, *GSA Bulletin*, and *Geosphere*:

1. Visit our publications page at **https://pubs.geoscienceworld.org/gsa** and sign in using your GSA member username and password. (After you sign in, you should be automatically redirected back to GeoScienceWorld).
2. Scroll to the bottom of the GSA publications page. Under "resources," click on "manage e-mail alerts."
3. To receive notification of the latest issues and/or early publications, click on "add alert" under the heading of your choice.
4. Check the box next to each publication for which you would like to receive an alert, then click "save changes."

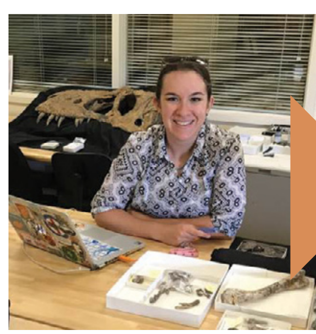
MENTORING365™

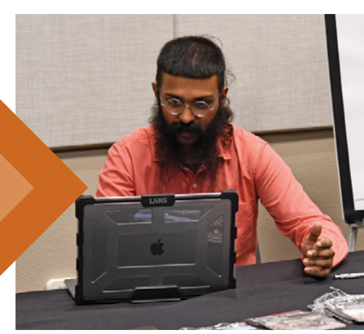
THE GEOLOGICAL SOCIETY OF AMERICA®

DEVELOP PROFESSIONAL CONNECTIONS WITH VIRTUAL MENTORING

As a GSA member, you now have access to join Mentoring365 as a mentor or mentee.

Through a three month mentorship, mentees will develop a professional relationship to help grow their network and navigate career opportunities. Mentors benefit by giving back to the geoscience community and helping to advance their communication and leadership skills.





In partnership with

AGU ADVANCING EARTH AND SPACE SCIENCE · AMS American Meteorological Society · AWG Association for Women Geoscientists · IRIS · SEG SOCIETY OF EXPLORATION GEOPHYSICISTS

Sign up now at **https://mentoring365.chronus.com/p/p1/**

BOOKMARK THE GEOSCIENCE JOB BOARD

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

POSITIONS OPEN

Tenure-Track Assistant Professor in Earth and Planetary Data Analytics, Virginia Tech

The Department of Geosciences at Virginia Tech (http://geos.vt.edu) invites applications for a tenure-track faculty position in the broad area of Earth and Planetary Data Analytics. We anticipate hiring an Assistant Professor; however, candidates at a higher rank may be considered. The successful candidate will have a research and teaching portfolio centered in data science with a focus on problems in the Earth, planetary, environmental, or climate sciences. This may include the development and/or application of data analytics, machine learning, artificial intelligence, information theory or similar cutting-edge methods for making novel advances in Earth and planetary sciences.

Candidates must hold a Ph.D. in earth science, planetary science, data science, applied math, computational science, or a closely related field at the time of appointment and have demonstrated experience in the application of data analytics, analysis or machine learning, or artificial intelligence to earth or planetary science problems. Preference will be given to candidates who demonstrate: (1) a strong commitment to principles of diversity, equity, inclusion, and accessibility in research, teaching, and university service; (2) the potential to establish a strong research program and attract external funding; (3) how their teaching and mentoring will benefit our student community.

Candidates should apply online in response at http://careers.pageuppeople.com/968/cw/en-us/job/517630/assistant-associate-or-full

Application materials include: (1) cover letter, (2) curriculum vitae, (3) statement of research interests, (4) statement of teaching philosophy, (5) statement articulating the candidate's vision to enhance diversity in geo- and planetary sciences, (6) one research product that illustrates the quality and potential of the applicant's work (e.g., peer-reviewed journal article that is published or in-press), and (7) names and contact information for three references. Each statement should not exceed two pages, and the teaching statement should address both undergraduate and graduate teaching.

Review of applications will begin on December 6, 2021, with an anticipated start of employment in August 2022. The successful candidate will be required to have a criminal conviction check as well as documentation of COVID-19 vaccination [https://policies.vt.edu/assets/ppm%20317.pdf] or receive approval from the university for a vaccination exemption due to a medical condition or sincerely held religious belief. For further information, please contact the Chair of the Search Committee, Scott King, at sdk@vt.edu

Virginia Tech does not discriminate against employees, students, or applicants on the basis of age, color, disability, sex (including pregnancy), gender, gender identity, gender expression, genetic information, national origin, political affiliation, race, religion, sexual orientation, or veteran status, or otherwise discriminate against employees or applicants who inquire about, discuss, or disclose their compensation or the compensation of other employees or applicants, or on any other basis protected by law.

If you are an individual with a disability and desire an accommodation, please contact Sharon Collins at sharon72@vt.edu during regular business hours at least 10 business days prior to the event.

Tenure-Track Assistant Professor in Earth Data Science, Temple University

The Department of Earth and Environmental Science at Temple University (https://ees.cst.temple.edu) invites applications for a tenure-track Assistant Professor position in Earth Data Science, to begin July 1, 2022. We welcome applications from individuals who take a data-intensive approach to answer earth and environmental science questions. We particularly seek candidates who implement rigorous statistical analysis or leverage cutting-edge developments in data science which inform models of modern or ancient systems.

The successful candidate will develop a highly creative, externally funded research program, mentor graduate and undergraduate students, and teach undergraduate and graduate courses in geology/environmental science. Collaboration among faculty is strongly encouraged to leverage established expertise in hydrogeology, human-environment interactions, surface processes and sedimentary systems, energy, environmental and polar geophysics, geochemistry, and planetary geology. Making use of the existing high-performance and scientific computer cluster (https://www.hpc.temple.edu) is also encouraged.

Temple University is a state-related R1 university located in the vibrant, urban center of Philadelphia with a total undergraduate and graduate enrollment of approximately 40,000 students. The Department of Earth and Environmental Science, which is affiliated with the College of Science and Technology, provides rigorous training in geological and environmental science to undergraduate (BS and BA Geology, BS Environmental Science), Masters (Geology), and Ph.D. (Geoscience) students.

To apply, email following materials as one PDF file to eessearch@temple.edu 1) cover letter; (2) CV; (3) statement of research plan; (4) statement of teaching philosophy; (5) names and contact information of at least three references; and (6) reprints of up to three peer-reviewed publications. Review of applications will begin December 3, 2021. The position will remain open until filled but application materials should be submitted by this date for full consideration. Temple University is an equal opportunity, equal access, affirmative action employer committed to achieving a diverse community (AA, EOE, M/F/D/V). The department specifically encourages applications from women and minorities.

Inquiries about this position should be directed to the search committee chair, Dr. Atsuhiro Muto amuto@temple.edu

Assistant Professor, Geochemistry, Yale University

The Department of Earth and Planetary Sciences at Yale University invites applications for a tenure track faculty appointment in the broad area of geochemistry at the Assistant Professor level. Relevant fields include (but are not limited to) global biogeochemical cycling, paleoclimatology, atmospheric chemistry, biogeochemistry, geomicrobiology, planetary evolution, and Earth surface processes.

We seek candidates who will develop outstanding research programs, have strong prospects for exceptional scholarly impact and teaching excellence, and who will enhance the existing strengths of the Department and University. The successful applicant will develop and implement externally funded research programs, teach and advise students, and facilitate interdisciplinary research.

The Yale EPS department is committed to fairness, equity, and inclusion of all people from all backgrounds. We value diversity among our students, staff, and faculty and strongly welcome applications from women, persons with disabilities, protected veterans, and underrepresented minorities. Yale University is an Affirmative Action/Equal Opportunity employer.

Applicants should submit a letter of application, a curriculum vitae including a full list of publications, a statement of research and a statement of teaching interests via apply.interfolio.com/94167. Applicants are also required to request three letters of recommendation via Interfolio. Review of applications will begin on October 20, 2021, and will continue until the position is filled. For information regarding the Department of Earth and Planetary Science, visit our web site at https://earth.yale.edu. For questions regarding this position, please email Noah Planavsky, search committee chair, at noah.planavsky@yale.edu.

Structural and Neotectonics Tenure Track Position, Geological Sciences Department, California State University San Bernardino

The Department of Geological Sciences at California State University, San Bernardino (CSUSB) invites applications for a tenure-track position in structural geology and/or neotectonics at the Assistant Professor level to begin August 2022. Applicants must have a strong commitment to teaching and a willingness to direct undergraduate and graduate students in research. Preference will be given to candidates with experience in structural geology and field mapping. Teaching responsibilities will include introductory courses, structural geology, neotectonics, introduction to geological mapping, advanced field geology, and upper-level undergraduate and graduate courses in the applicant's specialty. This faculty member reports to the Chair of Geological Sciences and is a full-time faculty member appointment.

Minimum Qualifications: a Ph.D in Geological Sciences or a related field is required by time of appointment on August 1, 2022.

If interested, apply at: https://careers.csusb.edu/en-us/job/504568/structural-and-neotectonics-tenure-track-position-geological-sciences-department. Salary is commensurate with experience. Application review begins November 1, 2021 until the position is filled.

The Department has five full-time faculty members and offers B.A., B.S., and M.S. degrees; see details at: https://www.csusb.edu/geology. CSUSB exists in a geologically rich and diverse region of North America; specifically, our Department is located 0.5 km from the San Andreas Fault - the Pacific Plate Boundary.

CSUSB is in San Bernardino, 60 miles east of Los Angeles. CSUSB serves approximately 20,000 students, of which 81% are first-generation college students, and graduates about 5,000 students annually. CSUSB has one of the most diverse student populations of any university in the Inland Empire, and the second highest Hispanic enrollment of all public universities in California.

Assistant Professor (Tenure-Track), Earth and Ocean Sciences: Tectonics, Tufts University

Tufts University invites applications for a tenure-track position as an Assistant Professor of Earth and Ocean Sciences in Tectonics, beginning September 1, 2022. The candidate will: 1) teach three courses annually including Introductory Physical Geology, Structural Geology, and a new course in Tectonics; 2) perform high-quality research in their area of specialism; 3) engage undergraduate students in their research through research projects and senior honors theses. We encourage the successful candidate to take advantage of opportunities for collaborative teaching and research with other faculty at the university.

Qualifications include: a Ph.D., post-doctoral experience, and demonstrated potential for research supported by external funding. Candidates will be expected to be inspiring undergraduate teachers and to initiate impactful research in the Earth sciences taking advantage of undergraduate involvement.

All application materials must be submitted via Interfolio at apply.interfolio.com/92685. Please submit the following: (1) a cover letter, (2) a statement of teaching philosophy and experience, (3) a statement of research expertise and experience, (4) a curriculum vitae, (5) the names (with contact addresses) of three references, and (6) a diversity statement or statements regarding commitment to diversity. Questions about the position can be directed to Professor Jack Ridge, Chair of the Search Committee at jack.ridge@tufts.edu. Review of applications will begin November 1, 2021, and will continue until the position is filled.

The Earth and Ocean Sciences Department (EOS) at Tufts has an undergraduate-only major and minor program and our faculty comprises 5 tenure-track professors and a full-time lecturer. We strongly encourage our students to perform independent research mentored by EOS faculty. The department prides itself in offering students an array of field and laboratory experiences from introductory to upper course levels. Tufts University is in the Boston area and is near a diverse array of igneous and metamorphic rock terranes as well as regions that are remnants of tectonic events from over 250 million years ago, conducive to field trips across New England and the northeastern U.S. The department takes advantage of our location to offer field trips in many of our courses. We also offer extended trips over winter and spring breaks to the western U.S. as well as travel for field study as a part of research projects. For the department's statement on its commitment creating a diverse and inclusive environment see: Department of Earth and Ocean Sciences: Directions (tufts.edu)

Tufts University is dedicated to creating a diverse and inclusive environment for teaching and research. For more information on the university's efforts see: https://www.tufts.edu/strategic-themes/diversity-and-inclusion, https://diversity.tufts.edu/,)

Tufts University, founded in 1852, prioritizes quality teaching, highly competitive basic and applied research, and a commitment to active citizenship locally, regionally, and globally. Tufts University also prides itself on creating a diverse, equitable, and inclusive community. Current and prospective employees of the university are expected to have and continuously develop skill in, and disposition for, positively engaging with a diverse population of faculty, staff, and students.

Tufts University is an Equal Opportunity/Affirmative Action Employer. We are committed to increasing the diversity of our faculty and staff and fostering their success when hired. Members of underrepresented groups are welcome and strongly encouraged to apply. Read the University's Non-Discrimination statement and policy. If you are an applicant with a disability who is unable to use our online tools to search and apply for jobs, please contact us by calling Johny Laine in the Office of Equal Opportunity (OEO) at 617-627-3298 or at johny.laine@tufts.edu. Applicants can learn more about requesting reasonable accommodations at http://oeo.tufts.edu.

Assistant Professor, Earth Materials, The University of Texas at El Paso

The Department of Earth, Environmental and Resource Sciences is hiring a faculty member in the broadly-defined area of Earth Materials who is capable of teaching at the undergraduate and graduate levels, conducting fundamental research, building an active research portfolio, publishing in peer-reviewed journals, and mentoring students at all levels. We are most interested in applicants with expertise in state-of-the-art higher temperature mineralogical and petrological techniques and concepts that complement our existing programs in natural resources and economic geology, geophysics, geothermal energy, structural geology, and geochronology, among others. Candidates with the ability and desire to build a vigorous, externally funded research program are encouraged to apply. We are especially interested in applicants who have a demonstrated commitment to teaching, mentoring and advising students from diverse backgrounds.

The complete announcement and online application can be found at https://utep.interviewexchange.com/jobofferdetails.jsp?JOBID=136180. Review of applications will begin on November 15, 2021 and continue until the position is filled. Interested candidates are encouraged to contact us as early as possible. Direct inquiries to Dr. Antonio Arribas, aarribas@utep.edu.

OPPORTUNITIES FOR STUDENTS

PhD Research Assistantship in Experimental Geochemistry, Mississippi State University. The Department of Geosciences at Mississippi State University (MSU) is looking for a highly motivated candidate for graduate assistantship (PhD) to conduct research in experimental geochemistry at MSU and Los Alamos National Laboratory (LANL). The assistantship is fully funded for 3 years by DOE NEUP Program (starting in January 2022). The student is expected to perform research both at MSU and LANL spending comparable time at those institutions. The student is expected to develop close collaboration with scientific teams at LANL and MSU.

The project aims at the development of general understanding of the properties of phosphate minerals, their structures, and their stability in aqueous and hydrothermal systems. The main focus of the project is evaluating the ability of phosphate minerals to incorporate iodine and uranium in their structures. The successful candidate is expected to conduct experiments on apatite crystallization from uranium and iodine bearing fluids; conduct geochemical and microscopy analyses on experimental products; perform thermodynamic calculations; prepare publications.

The candidate needs to have a MS (or international analog of MS) degree in broad discipline of geology, chemistry, or physics. Preference will be given to a person who has experience in the fields of crystal growth and/or aqueous chemistry as well as in electron microscopy, mass spectrometry, and/or spectroscopy techniques.

Interested applicants should contact Prof. Rinat Gabitov at rinat.gabitov@gmail.com

MSU is an equal opportunity employer, and all qualified applicants will receive consideration for employment without regard to race, color, ethnicity, sex, religion, national origin, disability, age, sexual orientation, genetic information, pregnancy, gender identity, status as a U.S. veteran, and/or any other status protected by applicable law. We always welcome nominations and applications from women, members of any minority group, and others who share our passion for building a diverse community that reflects the diversity in our student population.

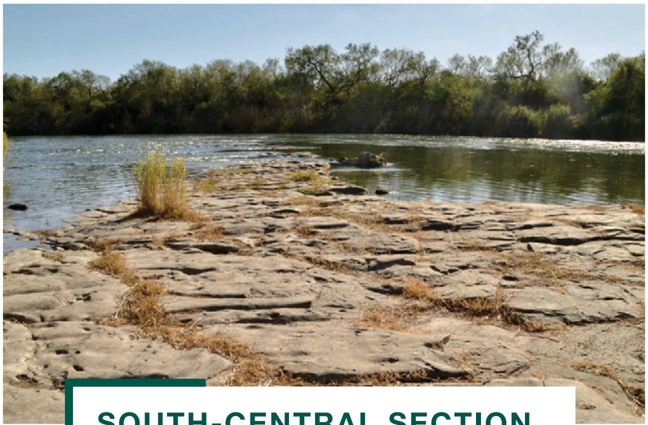
Apply for PhD and MS, Department of Geosciences, Baylor University. The Department of Geosciences at Baylor University invites applications for PhD and MS students starting in August 2022. Admission to the program includes 5 years of financial support for PhD students and 2 years of financial support for MS students through graduate assistantships. Admitted students also receive a tuition waiver, 80% health insurance subsidy, annual conference travel funding, and research funding for graduate students on a competitive basis. Candidates should have at least an undergraduate degree in geology, geophysics, or in a related area and excellent analytical and writing skills. Students holding a BS degree may apply directly to the PhD program.

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

Applications are due by January 5, 2022 for Fall 2022 program entry. Details about the application process and priority deadline can be found here: https://www.baylor.edu/geosciences/index.php?id=952059. Applications can be submitted online here: https://grad.baylor.edu/apply/. Please contact us at geosciences@baylor.edu for more information or with questions.

THE GEOLOGICAL SOCIETY OF AMERICA®

2022 GSA SECTION MEETINGS



SOUTH-CENTRAL SECTION

14–15 March
McAllen, Texas, USA
Meeting chairs: Juan González, juan.l.gonzalez@utrgv.edu; Chu-Lin Cheng, chulin.cheng@utrgv.edu
https://www.geosociety.org/sc-mtg

A resistant layer of the Roma sandstone is exposed crossing the Rio Grande. Photo by Juan González.

JOINT CORDILLERAN–ROCKY MOUNTAIN SECTION

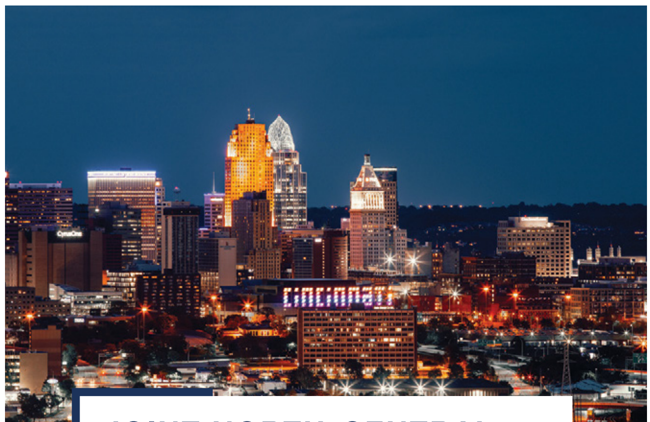
15–17 March
Las Vegas, Nevada, USA
Meeting chairs: Michael Wells, michael.wells@unlv.edu; Alexis Ault, alexis.ault@usu.edu
https://www.geosociety.org/cd-mtg

Red Rock Canyon, Nevada.
Photo by Daniel Halseth on Unsplash.

NORTHEASTERN SECTION

20–22 March
Lancaster, Pennsylvania, USA
Meeting chairs: Andy deWet, adewet@fandm.edu; Chris Williams, cwillia2@fandm.edu
https://www.geosociety.org/ne-mtg

Susquehanna River, southern Lancaster County.
Photo by Emily Wilson.



JOINT NORTH-CENTRAL–SOUTHEASTERN SECTION

7–8 April
Cincinnati, Ohio, USA
Meeting chairs: Craig Dietsch, dietscc@ucmail.uc.edu; Rebecca Freeman, rebecca.freeman@uky.edu
https://www.geosociety.org/nc-mtg

Cincinnati skyline at night.
Photo by Jake Blucker on Unsplash.

Field Guide 62

From Terranes to Terrains

GEOLOGIC FIELD GUIDES ON THE CONSTRUCTION AND DESTRUCTION OF THE PACIFIC NORTHWEST

Edited by Adam M. Booth and Anita L. Grunder

The eight field trips in this volume, associated with GSA Connects 2021 held in Portland, Oregon, USA, reflect the rich and varied geological legacy of the Pacific Northwest. The western margin of North America has had a complex subduction and transform history throughout the Phanerozoic, building a collage of terranes. The terrain has been modified by Cenozoic sedimentation, magmatism, and faulting related to Cascadia subduction, passage of the Yellowstone hot spot, and north and westward propagation of the Basin and Range province. The youngest flood basalt province on Earth also inundated the landscape, while the mighty Columbia watershed kept pace with arc construction and funneled epic ice-age floods from the craton to the coast. Additional erosive processes such as landslides continue to shape this dynamic geological wonderland.

FLD062, 352 p., ISBN 9780813700625 | list price $60.00 | **member price $42.00**

GSA BOOKS ▸ rock.geosociety.org/store/

toll-free 1.800.472.1988 | +1.303.357.1000, option 3 | gsaservice@geosociety.org

THE GEOLOGICAL SOCIETY OF AMERICA®