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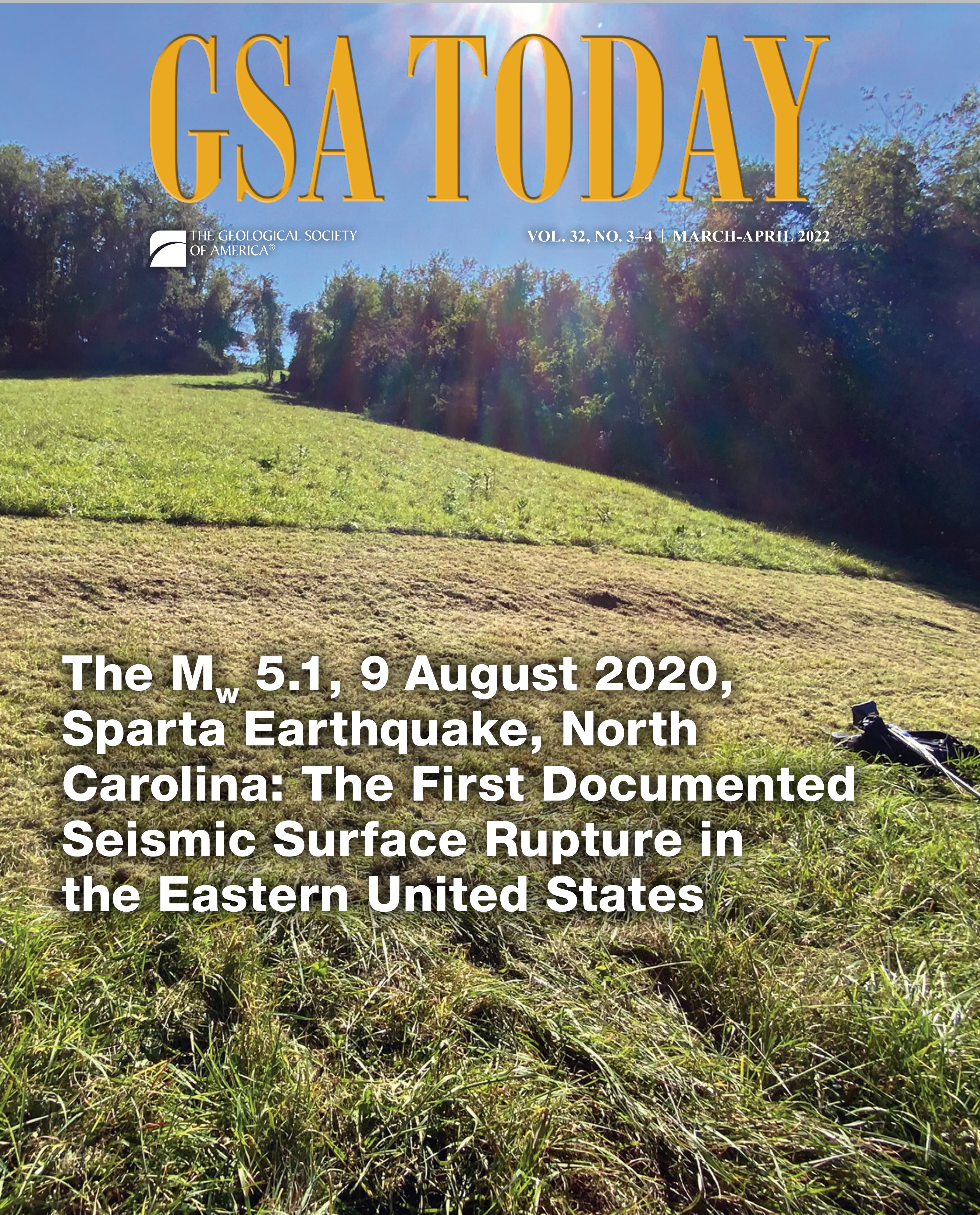

GSA TODAY

THE GEOLOGICAL SOCIETY OF AMERICA®

VOL. 32, NO. 3–4 | MARCH-APRIL 2022

The M_w 5.1, 9 August 2020, Sparta Earthquake, North Carolina: The First Documented Seismic Surface Rupture in the Eastern United States

MARCH-APRIL 2022 | VOLUME 32, NUMBER 3–4

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.

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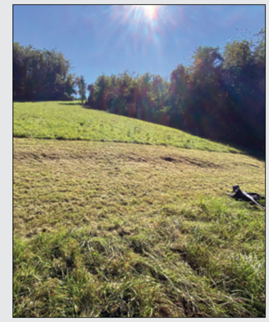

Cover: Perspective of a section of the surface rupture of the 9 Aug. 2020 M_w 5.1 Sparta, North Carolina, USA, earthquake, looking south. Here, about 3 km eastward from downtown Sparta, along a north-facing slope, the rupture is expressed by reverse faulting, generating a linear scarp up to ~25 cm height. The southern block (hanging wall) is consistently uplifted. The vegetation was removed to study the scarp and to help with topographic and geophysical surveys. In the footwall, a backpack and a topography survey pole provide a scale for the morphological feature. Photo by Paula Figueiredo, Sept. 2020. See related article, p. 4–11.

GSA NEWS

The M_w 5.1, 9 August 2020, Sparta Earthquake, North Carolina: The First Documented Seismic Surface Rupture in the Eastern United States

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ABSTRACT

At 8:07 a.m. EDT on 9 Aug. 2020 a M_w 5.1 earthquake located ~3 km south of Sparta, North Carolina, USA, shook much of the eastern United States, producing the first documented surface rupture due to faulting east of the New Madrid seismic zone. The co-seismic surface rupture was identified along a 2-km-long traceable zone of predominantly reverse displacement, with folding and flexure generating a scarp averaging 8–10-cm-high with a maximum observed height of ~25 cm. Widespread deformation south of the main surface rupture includes cm-dm–long and mm-cm–wide fissures. Two trenches excavated across the surface rupture reveal that this earthquake propagated to the surface along a preexisting structure in the shallow bedrock, which had not been previously identified as an active fault.

Surface ruptures by faulting are rarely reported for M <6 earthquakes, and hence the Sparta earthquake provides an opportunity to improve seismic hazard knowledge associated with these moderate events. Furthermore, this earthquake occurred in a very low strain rate intraplate setting, where earthquake surface deformation, regardless of magnitude, is sparse in time and rare to observe and characterize.

INTRODUCTION AND BACKGROUND

The M_w 5.1 Sparta earthquake was the largest in North Carolina in nearly 100 years (Stover and Coffman, 1993) and the strongest in the eastern United States since the 2011 M_w 5.8 Mineral, Virginia, earthquake. The maximum intensity was VI–VII (MMI) at Sparta and was widely felt across the eastern and central United States (USGS, 2020a). Most notably, the earthquake generated the first documentated co-seismic surface rupture by faulting in the eastern United States (Fig. 1).

Moderate (5 < M <6) to large (M ≥7) earthquakes in intraplate settings, such as the North American–Atlantic passive margin, are rare (Wolin et al., 2012). Notable earthquakes in the eastern and central U.S. include the 1755 Cape Ann (M 5.9; Ebel, 2006), the 1811–1812 New Madrid sequence (three ≥M7; Hough and Page, 2011), the 1886 Charleston, South Carolina (M 6.8–7.2; Chapman et al., 2016), and the 2011 Mineral, Virginia (M_w 5.8; Horton et al., 2015). Earthquakes occurring within the East Tennessee, central Virginia, Giles County, and coastal Charleston seismic zones contribute to North Carolina seismic hazard.

In the Blue Ridge physiographic province of North Carolina, historical earthquakes such as the 1861 Wilkesboro MMI V–VII, the 1916 M 5.2 Skyland, and the 1926 MMI V–VI Mitchell County had intensities comparable to the Sparta earthquake. However, there is insufficient information to infer which fault(s) generated them (Reinbold and Johnston, 1987; Stover and Coffman, 1993). The seismic catalog of Reinbold and Johnston (1987) documents 166 earthquakes since 1776, strong enough to be felt and interpreted to have their epicenters in or near North Carolina. However, instrumental seismicity records low magnitude (M ≤ 4) earthquakes, and in the Blue Ridge province, the mean hypocenter depth is 12 km (Bollinger et al., 1985).

The tectonic framework in the southern Appalachians preserves multiple Paleozoic orogenic events recorded by NE-trending regional structures (Hatcher et al., 2007). Crossing these structures are several poorly understood WNW to E-W topographic lineaments. Their genesis is speculated to result from early-to-mid-Mesozoic extension (e.g., Garihan and Ranson, 1992), Cenozoic mantle reorganization, which may account for Cenozoic regional uplift (Weems and Edwards, 2007; Gallen et al., 2013; Hill, 2018), or tectonic inheritance from Iapetian rifts (Thomas, 2011). In addition, some WNW lineaments have brittle deformation of unknown age and are roughly normal to

GSA Today, v. 32, https://doi.org/10.1130/GSATG517A.1.

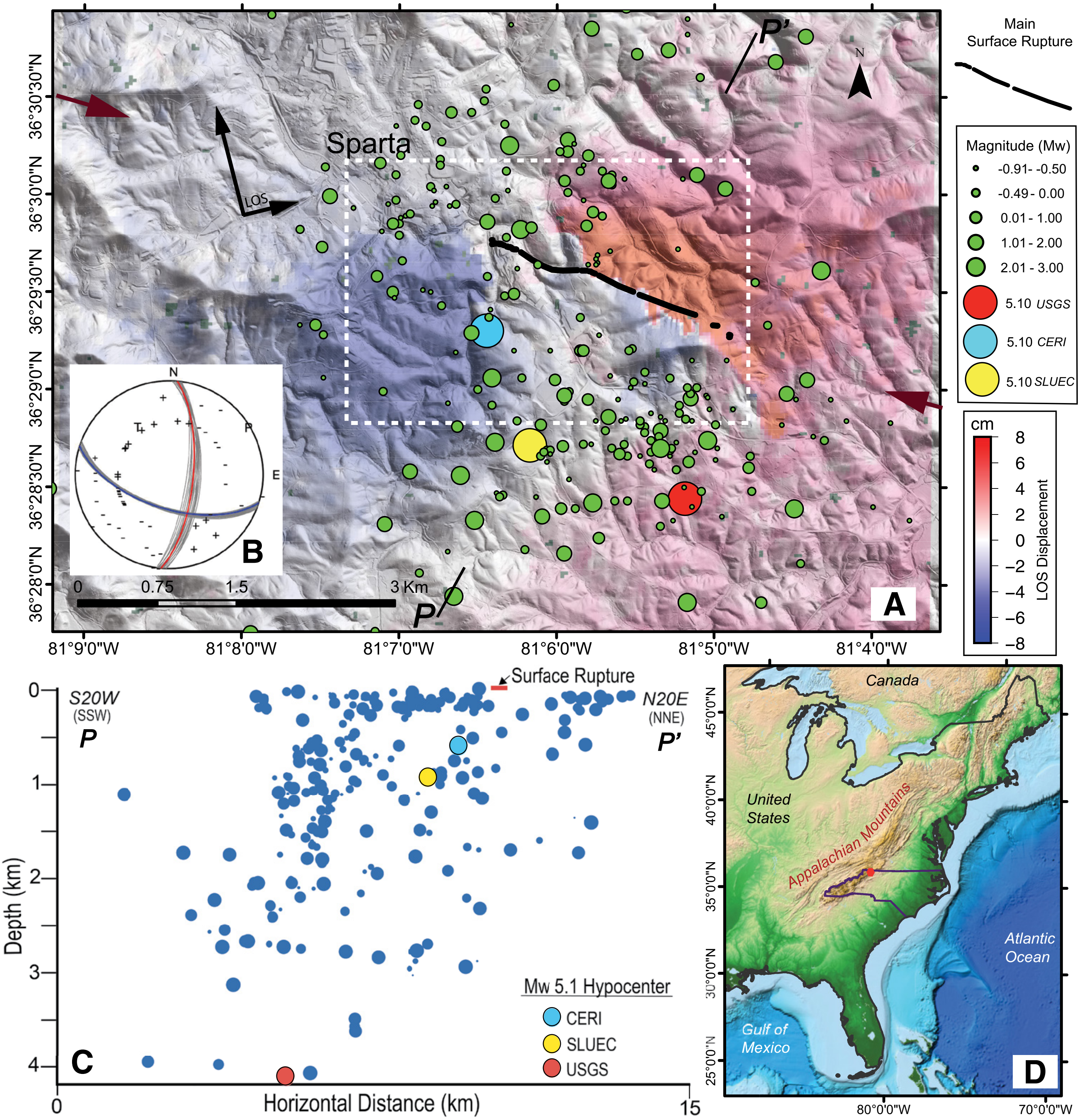

Figure 1. Location, earthquake sequence, and interferometric synthetic aperture radar interferogram for the Sparta earthquake. (A) Unwrapped phase interferogram overlaying a lidar-derived hillshade model with the main surface rupture (black line) and August 2020–February 2021 instrumental seismicity (circles; USGS catalog). Topographic lineament marked by brown arrows. Figure 2 location denoted by the dashed white rectangle. Line P–P' indicates the projection plane for seismicity. (B) Focal mechanism solution (Horton et al., 2021). (C) Projection of seismic sequence (USGS catalog) into a plane with azimuth N20°. (D) Location of the earthquake (red) in eastern North America, with North Carolina outlined. LOS—line of sight; CERI—Center for Earthquake Research and Information, University of Memphis; SLEUC—Saint Louis University Earthquake Center.

the NE-SW to ENE-WSW regional S_{Hmax} (Snee and Zoback, 2020), favoring them as potentially seismogenic. However, these WNW-trending structures are not included in the USGS Quaternary Faults or U.S. Seismic Source Characterization for Nuclear Facilities databases (Crone and Wheeler, 2000; Machette et al., 2004; U.S. Nuclear Energy Regulatory Commission, 2012).

THE SPARTA EARTHQUAKE

The surface rupturing M_w 5.1 Sparta earthquake occurred on a WNW-striking previously unknown structure, now named the Little River fault (Hill et al., 2020). The main event generated peak ground accelerations of at least 0.2 g with an MMI of VI–VII in Sparta (USGS, 2020a). Roads, utility lines, and masonry structures were damaged, including the collapse of walls and chimneys and the cracking and shifting of foundations, causing North Carolina's governor to declare a local state of emergency and the North Carolina General Assembly to provide U.S.$24M for earthquake recovery (Office of State Budget and Management, 2020, pers. comm.). Fortunately, there were no casualties or significant damage to major infrastructures.

The mainshock hypocenter and focal mechanism have been estimated independently by several groups. Horton et al. (2021) at the Center for Earthquake Research and Information, University of Memphis (CERI), calculated a first-motion focal mechanism consistent with a N108°-striking 60° SW-dipping nodal plane, with a 24° rake (Fig. 1B) and a best-fitting centroid depth of 0.6 km based on modeling regional waveforms and an epicenter location (36.488° N, 81.106° W) using a grid search procedure. The Saint Louis University Earthquake Center calculated a centroid depth of 1 km with a N115°, 50° SW nodal plane and rake of 40° based on best-fit modeling of regional waveforms (SLUEC, 2020). Analysis by SLUEC (2020) and Horton et al. (2021) yield similar results consistent with a shallow (<1 km) left-lateral reverse rupture on a SW-dipping plane. These results, however, differ from the preferred USGS solution, which places the event deeper (4.1 ± 1.8 km), with a nodal plane striking N176°, 48° W and a rake of 136° (USGS, 2020b). The earthquake sequence started with eight foreshocks with M_w 1.8–2.6 during the 24 h before the mainshock, followed by at least 300 aftershocks over the next six months, the largest being an M_w 2.9 on 11 August. The aftershock sequence was mainly recorded with a real-time broadband seismic array installed by CERI 48 h after the main shock. Most aftershocks were M_w <1.5, shallower than 3 km, and distributed across a 40-km^2 elliptical area with its major axis trending NW to WNW (USGS Catalog August–February 2021; Fig. 1A). The plotted aftershock hypocenters projected onto a cross section normal to the rupture suggest that the earthquake sequence is associated with a SW-dipping structure (Fig. 1C).

RECOGNITION OF THE SURFACE DEFORMATION

The recognition and mapping of a surface rupture trending ~N110° began on the day of the earthquake and continued for several months. The collection of uncrewed aerial systems (UAS) imagery and processing of digital terrain models aided field mapping, highlighting minor topographic changes along the surface rupture and identifying small-scale deformation features (Figs. 2B–2F). In addition, the co-seismic scarps were surveyed with a real-time kinematic global positioning system to measure displacements.

A preliminary interferometric synthetic aperture radar (InSAR) analysis was conducted using ascending Sentinel-1A imagery acquired a day before the Sparta earthquake (8 August) and Sentinel 1B imagery acquired six days later (14 August). Despite areas of poor coherence, the unwrapped interferogram delineates an area of deformation of ~20 km^2 (Fig. 1A). An irregular contact between a positive and negative line-of-sight (LOS) trends ~N125° for ~3-km, roughly coincident with the mapped co-seismic surface rupture. The southern block has a negative LOS (movement away from the ENE-looking satellite), while the northern block has a positive LOS (movement toward the satellite). These patterns are consistent with left-lateral reverse motion occurring along the SW-dipping nodal plane identified in the focal mechanism.

In the hanging wall, located ~300 m and 600 m from the main surface rupture, the *Alleghany 13* and *Funeral* geodetic monuments surveyed by the North Carolina Geodetic Survey in September–November 2020 moved 19.7 cm to the ESE and 5.7 cm to the ENE, respectively, and *Alleghany 13* rose 15 cm (Fig. 2A). The geodetic monument *Alleghany 15*, located ~600 m north of the main surface rupture shifted 7.8 cm toward the SW. These movements are consistent with the determined focal mechanism and InSAR analysis.

Along the central portion of the surface rupture, several 250 MHz ground-penetrating radar (GPR) profiles were acquired perpendicular to the surface rupture. The GPR profiles consistently show sub-horizontal reflectors in the upper ~4 m crossed by a few 20–30° south-dipping reflectors. While this is the expected co-seismic rupture geometry, one dipping reflector projects to the surface a few meters to the north of the surface rupture (Fig. 3G).

GEOLOGICAL ANALYSIS OF SURFACE DEFORMATION

No major ground cracking was evident near the epicenter. The majority of the surface rupture is located to the south and southeast of Sparta, and north of U.S. Route 21, stretching for ~2 km and across a generally <25-m-wide zone. The most prominent features and primary evidence of surface rupture are straight ten to hundreds of meters long, ~N110°-trending occasionally en échelon ground ruptures. Along the rupture, a co-seismic topographic step, formed by reverse scarps and folding/flexure of the topography, has an average height of 8–10 cm and a maximum of ~25 cm. The southern block is consistently uplifted. The surface rupture has four sections (A to D in Fig. 2A):

1. **Greenway Drive industrial park (section A):** South of downtown Sparta several ground fissures (crossing U.S. Route 21) and small scarps align in strike for a distance of ~300 m as they cross the industrial park at Greenway Drive. The structures trend N100–110°, and some exhibit a subtle right-stepping en échelon pattern. The scarps are single or multiple minor steps, building to a ~20 cm high maximum (Figs. 2B–2D). Folding associated with the uplift caused extension at the top of the hanging wall with oblique fissures and cracks. Evidence for lateral displacement is minor, and no marker was laterally displaced across the rupture trace. Several buildings were moderately damaged in the industrial park, particularly those on the surface rupture. Many secondary ground fissures were induced by ground shaking to the south and west of the industrial park (Fig. 2A).
2. **Little River valley (section B):** The rupture crosses the Little River valley for ~500 m along a steep and densely vegetated slope that hampers features

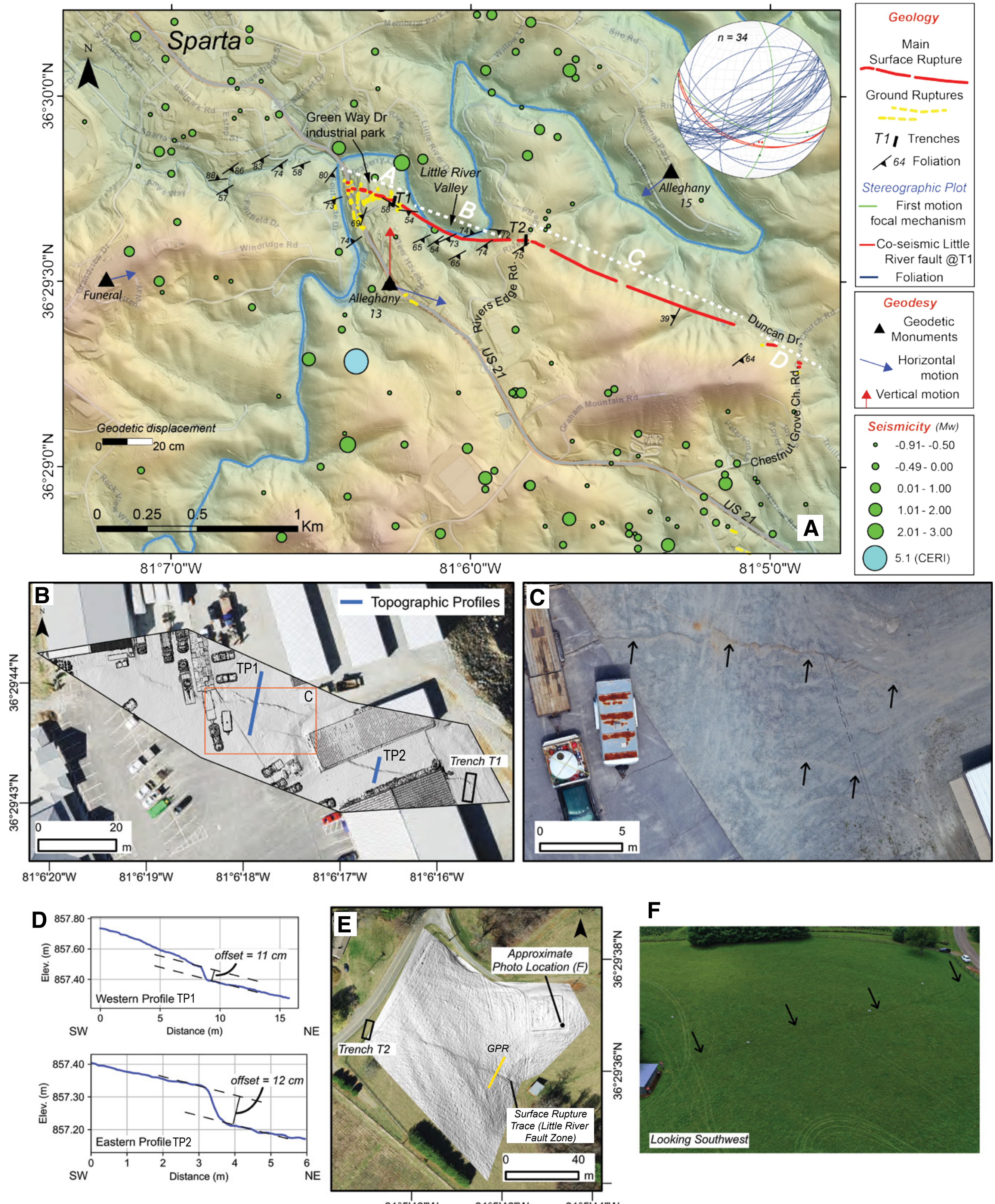

Figure 2. Co-seismic main surface rupture along the newly identified Little River fault. (A) Main surface and ground ruptures, locations of displaced geodetic monuments, and earthquake sequence. Topographic map overlaying digital elevation model (DEM) and hillshade. White dashed lines indicate the surface rupture sections (A–D) described in the text. The stereogram displays the focal mechanism (green), measured fault (red), and foliation (blue) orientations. Location of 2A provided by inset in Figure 1A. (B and C) Greenway Drive industrial park, uncrewed aerial systems (UAS) imagery in B is overlain by UAS-DEM with topographic profiles TP1 and TP2 (blue lines) along the surface rupture. The red rectangle is the inset area of (C), where arrows highlight surface rupture trace. (D) Topographic profiles TP1 and TP2 (VE = 10×) extracted from UAS-DEM. (E and F) Rivers Edge Road, UAS imagery in E is overlain by UAS-DEM and includes the location of ground penetrating radar profile line 02 presented in Figure 3G. Arrows in (F) highlight the surface rupture crossing the field.

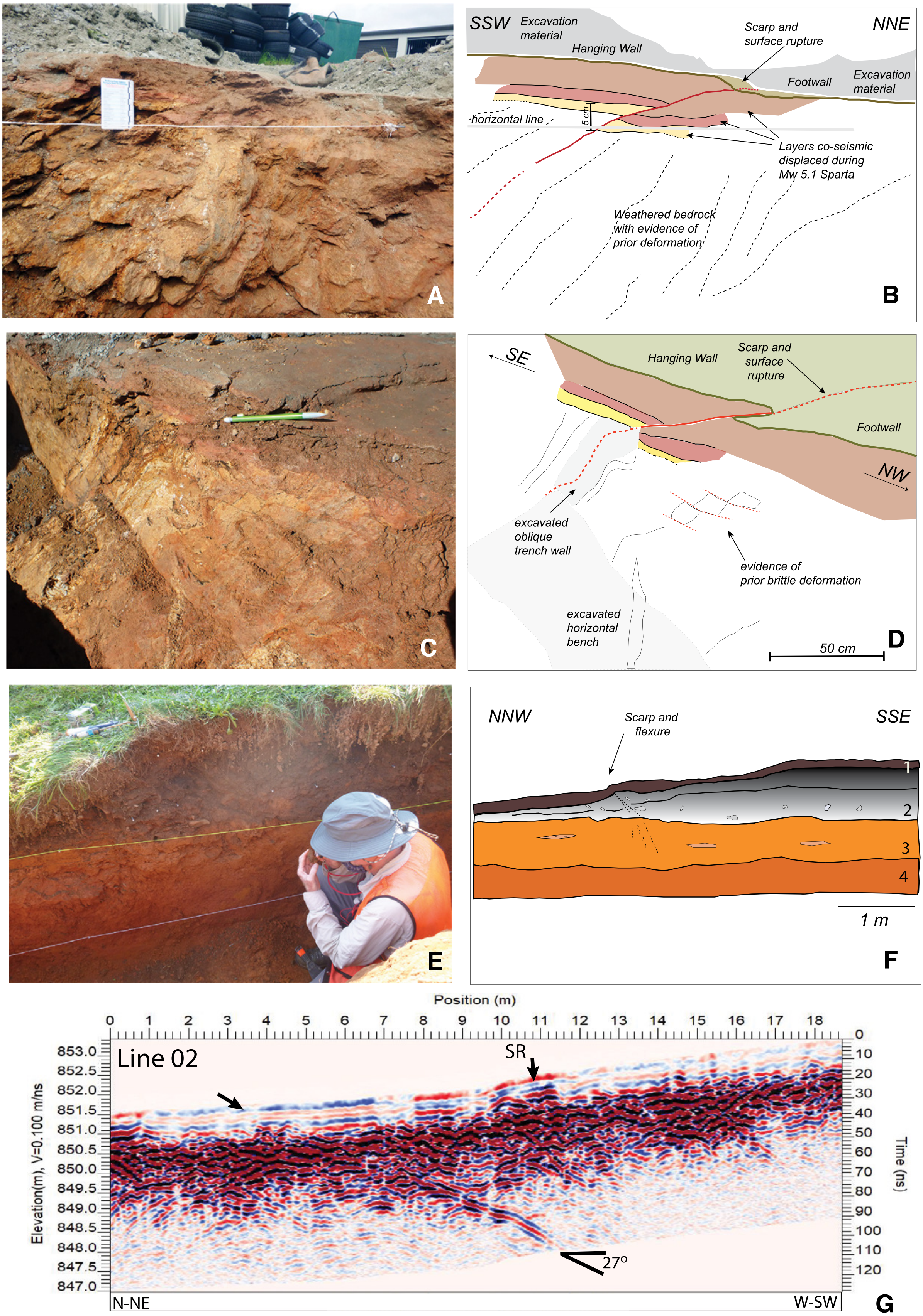

Figure 3. Views and interpretations of trenches and ground penetrating radar (GPR) results. (A and B) T1 southern wall exhibiting reverse faulting of upper layers by a low-angle plane, rooted in a preexistent fabric in metamorphic bedrock. (C and D) The T1 southern wall highlights previous ductile and brittle deformation. (E) View of the scarp and colluvium in the eastern wall of T2. (F) Fault trench log for the eastern wall of T2 showing flexure with no faulting. (G) GPR Line 02 (location in Fig. 2E), highlighting a low-angle south-dipping reflector. SR—surface rupture.

recognition. We identified two small N110°-trending fissures in the south river bank, with 2–3 cm of reverse vertical offset. Minor rockfall on the southern slope and a small liquefaction feature in a sand bar on the northern riverbank were also documented.

3. **Rivers Edge Road (section C):** An ~8-cm-high rupture scarp, trending ~N90°, crossed Rivers Edge Road, causing buckling of the road and breakage of a buried water pipe (Figs. 2E–2F). Eastward, the surface rupture crosses a north-facing slope in open fields and forest patches, striking ~N110° with a linear and continuous trace. The topographic step is single or complex, with heights varying between 5 and ~25 cm. It was trackable for ~1,100 m until the scarp and fissures stopped being detectable due to dense vegetation.
4. **Chestnut Grove Church Road (section D):** The surface rupture is subdued as it continues from Duncan Drive to Chestnut Grove Church Road. Small fissures and WNW-trending 3–4-cm-high steps occur in a cattle path close to Duncan Drive. Following the rupture strike N110° to Chestnut Grove Church Road, extensional co-seismic fissures broke the road into several decameter blocks, which have a similar geometry to older cracks in the asphalt. These co-seismic fissures suggests that preexisting mass wasting–related features were activated during the earthquake. We interpret these as minor deformation along the eastward rupture termination.

South of U.S. Route 21 and southwest of Sparta, co-seismic deformation not related to the main rupture trace, expressed by ground fissures in less consolidated material in road cuts and riverbanks, resulted from ground shaking or translational sliding (Fig. 2A). Near Little River, riverbank fissures are subparallel with cm-dm–long and mm-cm–wide openings. At an industrial parking lot (3238 U.S. Route 21, Glade Valley, North Carolina), co-seismic fissures extend for several m with mm-to-cm openings, exhibiting shortening and extensional displacement. These features are likely due to co-seismic deformation along several preexisting pavement discontinuities formed by earlier downslope processes and differential compaction in artificial fills.

FAULT TRENCHING AND SUBSURFACE ANALYSIS

We excavated two trenches to investigate the earthquake deformation (Figueiredo et al., 2020). Trench T1 was excavated three days after the mainshock at the Greenway Drive industrial park (section A) at the tip of a rupture segment (Figs. 2A and 3A–3D). A ~5-m-long and ~1.2-m-deep trench exposed weathered Neoproterozoic to Ordovician metasedimentary bedrock of the Ashe Metamorphic Suite overlain by northward-thickening horizontal layers of clay and sand construction fill. A thrust fault is recognized in the upper few dm of the trench displacing surficial fill deposits ~10 cm along a fault plane (N100°, 19° S) with 4-cm vertical displacement of the southern hanging wall, forming a small, very well-preserved scarp. The low-angle fault roots into weathered bedrock ~20 cm into a steeper preexisting plane (N115°, 45° S) interpreted to be associated with the Paleozoic fabric. Primarily dip-slip slickenlines were identified in the low-angle and steeper fault surfaces, although oblique slickenlines were observed near the surface in folded materials of the scarp (Hill et al., 2020). Small excavations within the industrial park across minor scarps corroborate reverse faulting and cumulative co-seismic vertical displacements of up to 10 cm. Moreover, markers in the pavement across the fault trace were not laterally displaced. Older fault gouge with manganese-coated surfaces and breccia in the weathered bedrock indicates brittle deformation, with dip-slip slickenlines. The age of the brittle deformation is unknown.

Trench T2 (~1.3-m deep and ~10-m long) was opened along the side of Rivers Edge Road across an ~8-cm-high scarp next to a buckled road and broken water pipe (Figs. 2A and 3E–3F). The excavation exposed two clay-rich colluvial units (2 and 3) and saprolite (4), which were not displaced by a fault despite being positioned across the scarp. The upper colluvium (1) was gently warped; however, this folding was not observed in the lower colluvium or saprolite. The absence of faulting despite the evident compression was corroborated by a 250 MHz GPR profile parallel to T2 interpreted as recording minimal-to-no stratigraphic disturbance in the upper 4 m. We argue that T2 is located in a compressional step-over.

There was no clear evidence for cumulative Quaternary deformation prior to the 2020 earthquake due to a lack of additional Quaternary markers at depth in T1. Nonetheless, both trenches unequivocally demonstrate surface deformation caused by an active fault.

RELATION TO TECTONIC FRAMEWORK AND GEOMORPHOLOGY

The focal mechanism, InSAR interferograms, field observations, and aftershock sequence provide evidence supporting a SSW-dipping seismogenic fault. The surface ruptures are ~N110°, similar to the strike of the south-dipping nodal plane for the first motion moment tensor solutions and the InSAR unwrapped interferograms. None of these matches mapped tectonic structures in the Sparta area (Rankin et al., 1972; NCGS, 1985; Merschat et al., 2020). However, the Little River fault is subparallel to the Boone and Mills Gap faults, located 50 and 150 km to the southwest, respectively (Wooten et al., 2010; Hill, 2018). Hill (2018) argued that WNW lineaments in North Carolina are likely brittle Cenozoic structures. The surface rupture is located along a subtle ~10-km-long WNW-ESE–trending topographic lineament visible in digital elevation models and centered on the fault zone (Fig. 1A).

DISCUSSION

The Sparta earthquake is unusual for eastern North America and worldwide because $4.5 < M_w < 5.5$ earthquakes rarely produce surface ruptures. It was also unexpected, occurring along an unknown structure trending oblique to the regional NE-SW structural trend and triggered at shallower depths than regional seismicity.

The fault identified in trench T1 (N115°, 45°S) was interpreted as reactivation of a foliation plane (Fig. 2A). We argue that the foliation parallel to the active fault in T1 could be locally rotated due to brittle deformation, similar to anomalous WNW rotated foliation observed in the Mills Gap fault zone (Wooten et al., 2010). Trench T2 is placed at a compressional step-over without evidence of faulting. Nonetheless, GPR profiles acquired 20 m to the east of T2 and along an ~600-m segment consistently show a low-angle south-dipping reflector (Fig. 3G). This reflector projects to the surface a few meters north of the co-seismic scarp, where ground deformation was not recognized. We suggest that this reflector may be (1) related to an older earthquake structure or (2) the result of deformation partitioning on an unidentified complex set of structures during the 2020 earthquake.

The strike of the seismogenic structure inferred from seismology and remote sensing is consistent with field observations. However, and interestingly, the kinematics are different from the observed slip. The focal mechanism derived from waveform analysis and the InSAR unwrapped interferogram indicate oblique-reverse motion. Geodetic monuments were displaced differently on the hanging wall and footwall supporting a left-lateral and reverse motion. In contrast, the geologic field evidence suggests predominantly reverse faulting and associated folding along a low-angle (~20°) fault plane that roots in a steeper preexistent fabric (~50°). This discrepancy may indicate complex strain partitioning or a change of slip during the earthquake. The initial, deep rupture may be predominantly strike-slip, possibly along a steeper structure with subsequent up-dip failures on shallower preexisting planar discontinuities in the bedrock accommodating most of the reverse component. Slip variations during an earthquake rupture are recognized from recent and historical earthquakes (Kearse and Kaneko, 2020). Further research is needed to understand slip partioning associated with the Sparta earthquake.

Eastern North American earthquakes commonly have complex ruptures. According to Horton et al. (2015), significant earthquakes such as the 1988 M_w 5.9 Saguenay and 1989 M_w 6.0 Ungava, both in Quebec, and the 2011 M_w 5.8 Mineral, Virginia, event had large local stress drops and complex ruptures that evolved spatially and temporally. The 2011 Mineral earthquake had three subevents, with most of the seismic moment release occurring at a depth of 8 km as the earthquake rupture propagated from SW to NE along strike and up-dip (Chapman, 2013; Hartzell et al., 2013; Horton et al., 2015). The Sparta earthquake had a shallow centroid depth and moment release more favorable for surface rupture.

The regional S_{Hmax} is NE-SW to ENE-WSW (Snee and Zoback, 2020), consistent with an oblique-reverse focal mechanism and overall reverse fault characteristics. Several processes can increase the stress field and trigger seismicity, including glacioisostatic adjustments, loading/unloading of sediments or water, and static stress changes; however, none of these apply to the Sparta region. Walsh et al. (2015) analyzed the Coulomb static stress transfer during the 2011 Mineral earthquake, and except for an area in the range of 10 km from the main event, stress changes are negligible (~1 mbar) and much less than the values needed to trigger earthquakes at a regional scale. Since Sparta is located ~300 km from the 2011 Mineral seismic area, relevant stress perturbations from the 2011 earthquake are unlikely to be the cause. The Sparta focal mechanism (SLUEC, 2020; Horton et al., 2021) is similar to the ones obtained for the Giles County, Virginia, seismic zone, located ~100 km to the north-northeast. Across a six-year survey, Munsey and Bollinger (1985) calculated several predominately strike-slip moment tensor solutions where the left-lateral solutions have an ESE trend dipping steeply to the south, similar to the 2020 Sparta earthquake.

In intraplate settings, recognizing active structures and quantifying their deformation rates for seismic hazard can be challenging when seismicity is diffuse and infrequent, with long periods of quiescence spanning 10^{5-6} years (e.g., Clark et al., 2012). The recognition and documentation of moderate earthquakes with surface rupture, like that of the 2020 Sparta M_w 5.1 earthquake, has increased recently (e.g., King et al., 2019; Ritz et al., 2020), likely due to the increasing knowledge and availability of remote sensing methods. These earthquakes provide direct evidence of seismicity that is generally poorly expressed or misunderstood in the paleoseismologic record. In the case of the Sparta earthquake, the application of the magnitude-surface deformation empirical relationships (e.g., Wells and Coppersmith, 1994) would support a larger magnitude event. This discrepancy indicates that paleoseismology data may be underestimating seismic hazard for certain cases. Thus, documentation of surface deformation generated from moderate seismicity is meaningful and relevant for seismic hazard assessment, not only for intraplate settings.

CONCLUSIONS

The moderate M_w 5.1 Sparta earthquake produced complex oblique reverse-faulting with surface rupture, the first recorded earthquake to do so across the eastern United States. The seismogenic source strikes WNW and dips SW, and instrumental data support a left-lateral earthquake with reverse slip. However, field investigations of the main surface rupture, document predominantly reverse slip, controlled by a preexisting planar structure, inferred to show brittle deformation of probable Cenozoic age. This structure, now recognized and named Little River fault, is possibly part of a WNW-ESE set of lineaments inferred to have Cenozoic activity that crosses the dominant NE-SW Appalachian structural grain. The shallow (~0.6–1.0 km) hypocenter promoted surface rupture. Left-lateral reverse motion on a WNW-ESE–trending fault is consistent with the regional stress field, with S_{Hmax} oriented NE-SW to ENE-WSW. The occurrence of Quaternary activity preceding the 2020 Sparta earthquake has yet to be determined.

Two moderate earthquakes (2011 M_w 5.8 Mineral and 2020 M_w 5.1 Sparta), occurred in eastern North America during the past decade, causing disruption and economic loss. These occurred along structures not included in any database as potentially active, suggesting that the regional seismic hazard may be underestimated.

ACKNOWLEDGMENTS

We thank the National Science Foundation for supporting this research (EAR-2102530, support from Tectonics, Geomorphology and Land Use Dynamics, and the Geophysics programs) and the people of Alleghany County in North Carolina for providing access to their lands, particularly Ann Downing and the business owners within the Greenway Drive industrial park. U.S. Geological Survey research supported by the National Cooperative Geologic Mapping Program and Earthquake Hazards Program. Thanks to Sarah Wells and Ashley Lynn for field assistance and Daria Khashchevskaya for help with graphics, and to Thomas Pratt and J. Wright Horton, Jr., and two anonymous reviewers for their comments, which greatly improved this manuscript. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. government.

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Manuscript received 4 June 2021
Revised manuscript received 4 Jan. 2022
Manuscript accepted 5 Jan. 2022

Three Former GSA Members Honored with Lunar Crater Names

Emily Zawacki, 2021–2022 GSA Science Communication Fellow

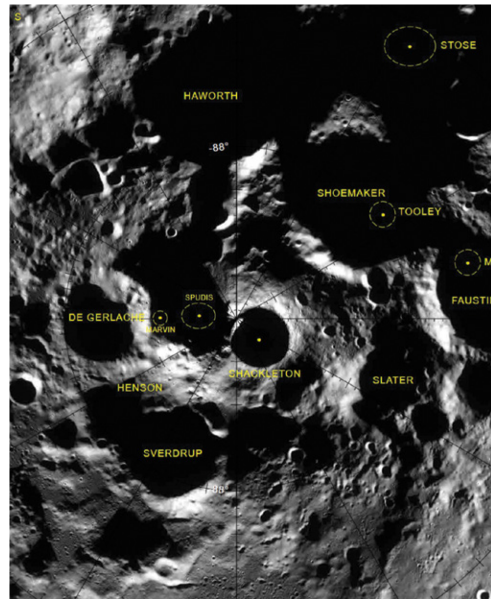
Previously unnamed impact craters on the south polar region of the moon are being named to honor three former Geological Society of America (GSA) members. These craters were discovered while studying the south pole of the moon in advance of NASA's Artemis mission, which will mark the return of humans to the moon, and the Intuitive Machines second Commercial Lunar Payload Services mission. The craters will be named to honor geologists Dr. Anna Jonas Stose, Dr. Ursula B. Marvin, and Dr. Paul B. Spudis.

David Kring, who leads the Center for Lunar Science and Exploration, proposed lunar polar crater names for Stose and Marvin because of their significant contributions to geological science. Mark Robinson, a professor at Arizona State University, additionally proposed a crater name for Spudis.

Stose was a pioneer in the field of geology, with significant contributions to the understanding of the geology of the Appalachian Mountains. She was born in 1881 and received her Ph.D. in 1912. She later held positions at the American Museum of Natural History, several state geological surveys, and the U.S. Geological Survey. Stose was elected as a GSA Fellow in 1922. She was among the first women field geologists and produced a significant number of publications over her sixty-year–long career, with many of her discoveries on Appalachian geology still recognized and accepted today.

Marvin was a geologist specializing in meteorites and an Antarctic adventurer. She was born in 1921. She began pursuing doctoral studies at Harvard in the early 1950s but departed graduate school to prospect for ore deposits in Brazil and Angola with her husband. Marvin later returned to Harvard to work on meteorites in the Harvard collection, which was then relocated to the Smithsonian Astrophysical Observatory. Marvin belatedly earned her Ph.D. in 1969 after the Harvard geology department allowed her to use her published research on meteorites in lieu of a thesis. Marvin was one of the original analysts of samples from the Apollo 11 mission, and she continued to work with samples returned from later missions. During the 1970s and 1980s, Marvin participated in Antarctic expeditions to search for meteorites, one of which recovered the first fragments of Moon materials found on Earth. She was chair of GSA's History of Geology Division in 1982, and she received the GSA History of Geology Award in 1986.

Spudis was an expert in lunar and terrestrial planetary geology. His work provided fundamental contributions to the understanding of impact basins and craters and volcanism on Earth and other planets. Spudis was born in 1952 and earned his Ph.D. in geology in 1982. He held positions at the U.S. Geological Survey serving as the principal investigator for NASA's Planetary Geology Program, the Lunar and Planetary Institute, the Johns Hopkins University Applied Physics Laboratory, and Moon Express Inc. He served on numerous science advisory committees, including the Presidential Commission on the Implementation of U.S. Space Exploration Policy in 2004. Spudis was a dedicated advocate for astronauts returning to the Moon, which is now being realized by NASA's Artemis mission program. Spudis was a GSA member from 1978 until his passing in 2018. He was posthumously named as a Michel T. Halbouty Distinguished Lecturer at the GSA annual meeting in 2018, with the presentation delivered by Ben Bussey.



Lunar craters. Credit: NASA/Goddard Space Flight Center/Arizona State University.

"Although these names were proposed because of the merits of past work, we hope that they also motivate students," said Kring. "It is important to understand: Apollo demonstrated that lunar exploration can influence the dreams of the nation's children. I am among those who were inspired. It will be wonderful if NASA's new Artemis lunar exploration program generates the same result in an increasingly diverse way."

Get into The Field with These GSA Awards


Alina Hernandez in the field.

J. DAVID LOWELL FIELD CAMP SCHOLARSHIPS

The importance of field schools to practicing geologists is unquestionable, yet the opportunities to experience field geology are dwindling. GSA and the GSA Foundation are proud to announce that the J. David Lowell Field Camp Scholarships will be available to undergraduate geology students for the summer of 2022. These scholarships provide awardees with US$2,000 to attend the field camp of their choice.

Many field camps were delayed during the pandemic, so this year GSA will help more students get into the field. For 2022, there is a special opportunity for 30 scholarships.

Applications are reviewed based on diversity, economic/financial need, and merit. Students must submit an online application form, two letters of recommendation, and a cover letter.

Who should apply? Undergraduate students

Deadline: 25 March

GSA FIELD CAMP EXCELLENCE AWARD

GSA also offers support to field camp instructors and directors for field camp improvements and/or operations. This US$10,000 award will be based on safety awareness, diversity, and technical excellence and can be used to assist with the awardee's summer field season.

Who should apply? Field camp instructors and directors. The award must be used toward field camp operations and/or improvements.

Deadline: 25 March

Learn more at **www.geosociety.org/field-experiences**.

GSA FOUNDATION

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Questions? Contact Jennifer Nocerino, jnocerino@geosociety.org.

GSA Scientific Division Awards

ENERGY GEOLOGY DIVISION

Gilbert H. Cady Award

Nominations due 1 Mar.
Submit nominations to the Cady Award chair (the past Division chair).

This award recognizes outstanding contributions in the field of coal geology that advance the science both within and outside of North America. **https://community.geosociety.org/energydivision/awards/cady**

Curtis-Hedberg Award

Nominations due 1 May.
Submit nominations to the Curtis-Hedberg Award chair (the past Division chair).

The inaugural Curtis-Hedberg Award will be made for outstanding contributions in the field of petroleum geology. **https://community.geosociety.org/energydivision/awards/curtishedberg**

GEOARCHAEOLOGY DIVISION

Richard Hay Student Paper/Poster Award

Nominations due 1 Sept.
Submit nominations to gsa.agd@gmail.com.

Richard Hay was a long-standing member of the Division and had a long and distinguished career in sedimentary geology, mineralogy, and archaeological geology. He is particularly well known for his work on the Olduvai Gorge and Laetoli Hominid-bearing sites and was awarded the Division's Rip Rapp Award in 2000. The Division is proud to have our student travel award bear his name. The award is a travel grant for a student (undergraduate or graduate) presenting a paper or poster at GSA's annual meeting. The grant is competitive and will be awarded based on the evaluation of the scientific merit of the research topic and the clarity of an expanded abstract for the paper or poster prepared by a student for presentation in the Division's technical session at the meeting. **https://community.geosociety.org/geoarchdivision/awards/student/hay**

Claude C. Albritton, Jr., Award

Nominations due 15 Mar.
Submit nominations to gsa.agd@gmail.com.

The Albritton Award Fund provides research scholarships and fellowships for graduate students in the earth sciences or archaeology. Recipients are students who have (1) an interest in achieving a master's or Ph.D. in earth science or archaeology; (2) an interest in applying earth-science methods to archaeological research; and (3) an interest in a career in teaching and academic research. Awards in the amount of US$650 are given in support of thesis or dissertation research, with emphasis on the field and/or laboratory aspects of the research. **https://community.geosociety.org/geoarchdivision/home**

GEOSCIENCE EDUCATION DIVISION

Biggs Award for Excellence in Earth Science Teaching

Nominations due 1 Mar.

This award recognizes innovative and effective teaching in college-level earth science. Earth-science instructors and faculty members from any academic institution engaged in undergraduate education who have been teaching full-time for 10 years or fewer are eligible (part-time teaching is not counted in this requirement). Both peer- and self-nominations will be accepted. This award, administered by the GSA Foundation, is made possible by support from the Donald and Carolyn Biggs Fund, the GSA Geoscience Education Division, and GSA's Education and Outreach Program. An additional travel reimbursement is also available to the recipient to enable him or her to attend the award presentation at the GSA annual meeting. **https://community.geosociety.org/gedivision/awards/biggsaward**

HISTORY AND PHILOSOPHY OF GEOLOGY DIVISION

History and Philosophy of Geology Student Award

Nominations due 15 June
Submit nominations to the Division's secretary/treasurer.

This award provides US$1000 for a paper to be given at the national GSA meeting. Awards may also be given for second place. Oral presentations are preferred. Faculty advisors may be listed as second author, but not as the lead author of the paper. The proposed paper may be (1) a paper in the history or philosophy of geology; (2) a literature review of ideas for a technical work or thesis/dissertation; or (3) some imaginative aspect of the history or philosophy of geology we have not thought of before. Students should submit an abstract of their proposed talk and a 1,500–2,000-word prospectus for consideration. Currently enrolled undergraduates and graduate students are eligible as are those who received their degrees at the end of the fall or spring terms immediately preceding the national GSA meeting. The award is made possible by a bequest from the estate of Mary C. Rabbitt. Monies for the award are administered by the GSA Foundation. **https://community.geosociety.org/histphildiv/awards/student**

LIMNOGEOLOGY DIVISION

Israel C. Russell Award

Nominations due 15 Mar.
Nominations should be forwarded electronically to the Division treasurer David Finkelstein.

This award recognizes major achievements in limnogeology through contributions in research, teaching, and service. Nominations should consist of a letter describing the nominee's accomplishments in the field of limnogeology (broadly defined and including limnogeology, limnology. and paleolimnology), service to students and teaching, and contributions to GSA, as well as a curriculum vitae. **https://community.geosociety.org/limnogeologydivision/awards/russell**

Kerry Kelts Research Award

Nominations due 30 June

Nominations should be forwarded electronically to the Division chair.

This award is for undergraduate or graduate student research related to limnogeology, limnology, or paleolimnology.**https://community.geosociety.org/limnogeologydivision/awards/kerrykelts**

MINERALOGY, GEOCHEMISTRY, PETROLOGY, AND VOLCANOLOGY DIVISION (MGPV)

MGPV Distinguished Geologic Career Award

Nominations due 31 Mar.

This award will go to an individual who, throughout his or her career, has made distinguished contributions in one or more of the following fields of research: mineralogy, geochemistry, petrology, volcanology, with emphasis on multidisciplinary, field-based contributions. Nominees need not be citizens or residents of the United States, and membership in GSA is not required. The award will not be given posthumously. **https://community.geosociety.org/mgpvdivision/awards/dgca**

MGPV Early Career Award

Nominations due 31 Mar.

This award will go to an individual near the beginning of his or her professional career who has made distinguished contributions in one or more of the following fields of research: mineralogy, geochemistry, petrology, volcanology, with emphasis on multidisciplinary, field-based contributions. Nominations are restricted to those who are within eight years past the receipt of their final degree. Extensions of up to two years will be made for nominees who have taken career breaks for family reasons or caused by serious illness. Nominees need not be citizens or residents of the United States, and membership in GSA is not a requirement. The award will not be given posthumously. **https://community.geosociety.org/mgpvdivision/awards/earlycareer**

PLANETARY GEOLOGY DIVISION (PGD)

The Eugene M. Shoemaker Impact Cratering Award

Nominations due 19 Aug.

This award is for undergraduate or graduate students, of any nationality, working in any country, in the disciplines of geology, geophysics, geochemistry, astronomy, or biology. The award, which will include US$2500, is to be applied to the study of impact craters, either on Earth or on the other solid bodies in the solar system. Areas of study may include, but are not limited to, impact cratering processes; the bodies (asteroidal or cometary) that make the impacts; or the geological, chemical, or biological results of impact cratering. **https://community.geosociety.org/pgd/awards/shoemaker**

Ronald Greeley Award for Distinguished Service

Nominations due 30 June

This award is given to members of the PGD, and those outside of the Division and GSA, who have rendered exceptional service to the PGD for a multi-year period. The award is not open to serving members of the management board but may be awarded to past members of the management board who have provided exceptional service to the PGD. Nominations, which should include a description of what the nominee has given to the PGD community, may be made by any PGD member to the management board. **https://community.geosociety.org/pgd/awards/greeley**

QUATERNARY GEOLOGY AND GEOMORPHOLOGY DIVISION

Farouk El-Baz Award for Desert Research

Nominations due 1 Apr.

Submit nominations to Anne Chin (anne.chin@ucdenver.edu).

This award recognizes excellence in desert geomorphology research worldwide. It is intended to stimulate research in desert environments by recognizing an individual whose research has significantly advanced the understanding of the Quaternary geology and geomorphology of deserts. Although the award primarily recognizes achievement in desert research, the funds that accompany it may be used for further research. The award is normally given to one person but may be shared by two people if the recognized research was the result of a coequal partnership. Any scientist from any country may be nominated. Because the award recognizes research excellence, self-nomination is not permitted. Neither nominators nor nominees need be GSA members. Nominations should include (1) a statement of the significance of the nominee's research; (2) a curriculum vitae; (3) letters of support; and (4) copies of no more than five of the nominee's most significant publications related to desert research. Please submit electronically unless hardcopy previously approved. Monies for the award are derived from the annual interest income of the Farouk El-Baz Fund, administered by the GSA Foundation. **https://community.geosociety.org/qggdivision/awards/el-baz**

Distinguished Career Award

Nominations due 1 Apr.

Submit nominations to the Division secretary.

This award is presented annually to a Quaternary geologist or geomorphologist who has demonstrated excellence in their contributions to science. Because the award recognizes research excellence, self-nomination is not permitted. Neither nominators nor nominees need be GSA members. Nominations should include (1) a brief biographical sketch; (2) a statement of no more than 200 words describing the candidate's scientific contributions to Quaternary geology and geomorphology; (3) a selected bibliography of no more than 20 titles; and (4) a minimum of four letters from colleagues supporting the nomination. Please submit electronically unless hardcopy previously approved. **https://community.geosociety.org/qggdivision/awards/distinguished-career**

SEDIMENTARY GEOLOGY DIVISION

Sedimentary Geology Division and Structural Geology and Tectonic Division Joint Award: Stephen E. Laubach Structural Diagenesis Research Award

Nominations due 1 Apr.

This award promotes research that combines structural geology and diagenesis and curriculum development in structural diagenesis. It addresses the rapidly growing recognition that fracturing, cement precipitation and dissolution, evolving rock mechanical properties, and other structural diagenetic processes can govern recovery of resources and sequestration of material in deeply buried, diagenetically altered and fractured sedimentary rocks. The award highlights the growing need to break down disciplinary boundaries between structural geology and sedimentary petrology, exemplified by the work of Dr. Stephen Laubach and colleagues. Graduate students, postgraduate, and faculty-level researchers are eligible. **https://community.geosociety.org/sedimentarygeologydiv/awards/laubach**

STRUCTURAL GEOLOGY AND TECTONIC DIVISION

Career Contribution Award

Nominations due 1 Mar.

This award is for an individual who throughout his or her career has made numerous distinguished contributions that have clearly advanced the science of structural geology or tectonics. Nominees need not be citizens or residents of the United States, and GSA membership is not required. Nominations should include the following information: (1) name of nominee, present institutional affiliation, and address; (2) summary statement of nominee's major career contributions to the science of structural geology and tectonics; (3) selected key published works of the nominee; and (4) name and address of nominator. **https://community.geosociety.org/sgt/awards/careercontribution**

Outstanding Publication Award

Nominations due 1 Mar.

This award is given annually for a published work (paper, book, or map) of exceptional distinction that clearly advances the science of structural geology or tectonics. Nominations should include (1) a full citation; (2) nomination (as short as a paragraph; letters or reviews may also be included); and (3) the name and address of the nominator. **https://community.geosociety.org/sgt/awards/outstandingpublication**

In Memoriam

The Society notes with regret the deaths of the following members (notifications received between 1 October and 22 December 2021).

Sidney R. Ash
Portland, Oregon, USA
Notified: 15 December 2021

Marcus P. Borom
Tucson, Arizona, USA
Date of death: 27 July 2021

Donald R. Bowes
Glasgow, Scotland, UK
Date of death: 3 November 2021

Kenneth W. Ciriacks
Tucson, Arizona, USA
Date of death: 25 July 2021

Dana K. Clark
Gardnerville, Nevada, USA
Notified: 3 December 2021

Lindrith Cordell
Tucson, Arizona, USA
Date of death: 3 October 2021

Frank W. Dickson
S. Kingstown, Rhode Island, USA
Date of death: 6 September 2021

Jean-Claude Dionne
Québec, QC, Canada
Date of death: 27 June 2021

Alan C. Donaldson
Morgantown, West Virginia, USA
Date of death: 9 June 2021

Marlan W. Downey
Dallas, Texas, USA
Notified: 3 November 2021

Russ Dyer
Reno, Nevada, USA
Date of death: 9 December 2021

Melville C. Erskine Jr.
Grants Pass, Oregon, USA
Date of death: 29 September 2021

Roy E. Ervin
Hilliard, Ohio, USA
Notified: 19 October 2021

Tom Freeman
Columbia, Missouri, USA
Date of death: 17 September 2021

Frederick A. Frey
Cambridge, Massachusetts, USA
Date of death: 13 September 2021

Patrick R. Getty
Plano, Texas, USA
Date of death: 15 November 2021

George Gilchrist
Sudbury, Ontario, Canada
Notified: 28 November 2021

William H. Hanson
Marinette, Wisconsin, USA
Date of death: 19 November 2021

Leonard Jacob Jr.
Kennebunk, Maine, USA
Notified: 3 November 2021

Stuart E. Jenness II
Ottawa, Ontario, Canada
Date of death: 1 October 2021

Victor F. Labson
New York, New York, USA
Notified: 24 November 2021

John Parmelee McDowell
Los Ranchos, New Mexico, USA
Date of death: 19 January 2021

Gerard V. Middleton
Lancaster, Ontario, Canada
Date of death: 2 November 2021

Charles G. Mull
Salt Lake City, Utah, USA
Date of death: 3 October 2021

Cecil B. Raleigh
Tiburon, California, USA
Date of death: 18 February 2021

Michael Sandison
Maylandsea, Essex, UK
Date of death: 19 October 2021

Robert E. Sheridan
Piscataway, New Jersey, USA
Date of death: 7 October 2021

Paul J. Umhoefer
Flagstaff, Arizona, USA
Notified: 29 November 2021

Kathryn A. West
Newark, Delaware, USA
Date of death: 1 April 2021

Robert S. Yeats
Corvallis, Oregon, USA
Date of death: 5 December 2021

Of Fortitude and Faith: My GSA Story

John Akudike

"Why not apply?" I asked myself for the umpteenth time. "You'd enjoy the experience," a part of me assured. "No, you don't even stand a chance! You're not a student yet," another part accused. At the time, the call for applications to the GSA On To the Future (OTF) program was open in May. While I was yet to make the 6,800 miles travel from Lagos, Nigeria, to Texas, USA, to commence my studies, I would be a student by the time the conference was to begin in October. But this was not enough to convince me. Hence, I stalled until the last week of May, when the application would close. I then reached out to a mentor, the phenomenal Ogochukwu Ozotta, an OTF alumnus, who encouraged me to go for it, and so I did. I went all-in with my application, sharing my story and journey through life—a story of fortitude and faith. Today, the rest is history.

John Akudike with GSA President Barbara Dutrow at the Portland International Airport.

Connecting young people to drive change and reverse ill narratives in society has always been my goal. While guiding students to win scholarships, create positive impacts globally, and live their dreams, I knew that my little efforts would indirectly create a ripple effect that would benefit other students. Furthermore, teaching others new concepts has been a strong point for me, as there is no more incredible feeling than seeing the twinkling in their eyes when they grasp such concepts. Thus, I usually seek opportunities to improve my skills and knowledge and scale my impact. It was on such a search that I saw the OTF application. Despite my fears, I applied some faith and received the good news of my selection to receive partial funding to attend the GSA Connects 2021 meeting.

I began connecting with professionals and students I knew would be instrumental to my development through the pre-conference OTF meetings. Most of those I met at the conference were receptive to sharing their stories and offering advice to budding geoscientists like me. Overall, the conference was one immersive experience I would not forget in a hurry. The short course, poster sessions, and technical sessions I joined were very insightful, and it felt good to share with others the knowledge we had garnered and our plans for the future of geoscience.

I also opted to volunteer for about 14.5 hours before and during the conference despite not being obligated, as I just couldn't wait to give back to the organization that had supported my first international conference attendance, amongst other exciting perks. I volunteered as a short-course assistant and GSA RISE (Respectful Inclusive Scientific Events) liaison before the conference and as a registration assistant during the conference. At the conference, I also joined the Diversity and Inclusion Committee meeting. I was impressed at the initiatives GSA was instituting to provide access to members of diverse abilities. I am most honored to contribute to such positive changes in geosciences.

Through several sessions with professionals and my peers at the conference, I learned about more opportunities in geoscience and how I could thrive as an international student in the U.S. I realized that I would have to be more intentional in putting in the work and following excellence in my studies, scientific research, and social development. I am better today for the lessons I learned at GSA.

I acknowledge that I am not only a product of fortitude and faith, but most importantly, a beneficiary of the support of a "village" of personalities—my family, mentors, professors, friends, and organizations such as GSA. I immensely thank all who have directly and indirectly supported my dreams by offering the scholarships, sponsorships, mentorship, and guidance that has led me to where I am now. My greatest ambition will always be to pay this support forward in service to humanity, giving others hope where there seems to be none, and doing my best to make the world better through my work. The GSA community is one that I am proud to be a part of, and I look forward to contributing more, proving that with fortitude and faith, everything is possible.

Expand Your Professional and Peer Network by Applying to the On To the Future Program

Applications are now being accepted for GSA's popular On To the Future (OTF) program. If you are a student or recent graduate from a group underrepresented in the geosciences who has never attended a GSA Connects meeting, apply by 28 May. Awardees will receive a travel grant to attend the GSA Connects 2022 meeting in Denver, Colorado, USA. Included with your award is a one-year GSA membership, full meeting registration, mentorship at the meeting, special morning sessions with leadership, a reception, and professional and peer connections that will last you a lifetime. GSA encourages low-income, Black, Indigenous, and People of Color, first-generation, non-traditional, women, veterans, LGBTQ+, and students with disabilities to apply.

www.geosociety.org/OTF

Climate in the National Spotlight

Charles Gertler

For five years before starting as the GSA-USGS Congressional Science Fellow in the U.S. Senate, I spent most of my time studying the physics and chemistry of the atmosphere as a Ph.D. student. My days could not have been more different than those during my time in the Senate—long periods of reading, struggling with code to run and analyze simulations, performing calculations, and, when the time was right, writing. Despite rich collaborations with my mentors and other scientists throughout the world, my Ph.D. was largely a solitary and gradual pursuit, in stark comparison to the fast-paced teamwork reacting to often hourly changes that characterized my time in the Senate.

And yet, the science I produced as a Ph.D. student was part of a body of work that I have been privileged to witness firsthand affect decision making at the national level. This confirmed to me that many optimistic scientists are right to believe that science can shape the largest decisions we make as a nation and society—that the slow pursuit of new knowledge and higher precision creates a baseline of evidence from which to act. I also learned that the process of making those large-scale decisions could not be more different from the process of producing the knowledge that leads to them. I now appreciate even more that an understanding and experience with both processes can lead to impactful work and outcomes.

While the fate of the Build Back Better Act remains undecided, my responsibilities as a Congressional Science Fellow were dedicated mostly to certain climate provisions in that package that were priorities of Senator Edward J. Markey (D-MA), in whose office I served. I witnessed targets that had been distilled by decades of scientific research and public engagement on acceptable risks (e.g., 1.5 °C of average surface temperature warming compared to preindustrial temperatures, a net zero economy by 2050, 100% carbon-free electricity by 2035) serve as both goalposts and litmus tests for the results of complex negotiations.

To be sure, many scientists take rightful issue with such simplified distillations of complex physics and social trade-offs. To be a climate scientist is to understand that there is no magical point of no return, that each marginal bit of warming brings more changes to the climate system, and that the farther we get from our baseline climate, the larger the unknowns about the behavior of the system and other potential dangers. To be a climate policy professional is to understand that those dangers are in large part a function of the social and economic structures that organize our society, which in turn are what lead to warming. We cannot promise with absolute precision how a 1.5 °C world would differ from a 1.6 °C world.

But still, simple tests are remarkably useful for reaching a deal in a multilateral negotiation, because they serve as markers to certify that all parties can be confident that their needs are being met. I frequently heard the question asked as to whether one party or another —be it a leader or a set of stakeholders—would be able to accept certain conditions. From my vantage point, in constructing the Build Back Better Act, climate science had as much of a seat at the table as the President; a climate bill had to be acceptable to the conditions determined by the science, just as the bill had to be acceptable to the major political entities pursuing its creation. The biggest question about the climate portion of the bill was, does this combination of incentives and new programs reach emissions reduction targets consistent with 1.5 °C warming? If those conditions, with their origins deep in the field of climate science, were not met, the bill was not going to be acceptable physically, politically, or otherwise.

It is not surprising that our field was given such a prominent seat at the table this past year. Climate science and climate change seemed to reach into the public consciousness more than at other point in recent memory. On top of the many notable and arresting climate disasters of 2021, a new Intergovernmental Panel on Climate Change assessment report warned with increased precision of the consequences of continued global warming and stated with lower uncertainty that present climate disasters were due to historic warming. The Nobel Prize in physics was awarded to a humble giant in my field not far from Washington D.C., Professor Syukoro "Suki" Manabe at Princeton. The presidential campaigns in the 2020 Democratic primary took bolder stances on climate than ever before. Perhaps due to this increased public awareness, advocates of climate policy were more optimistic than they had been in at least a decade that major climate policy could be passed.

These advocates are right to be optimistic, and despite the recent political challenges to enacting climate legislation as conceived at the end of 2021, should continue to be. One reason for optimism is that while scientists worked to identify the problem of climate change and refine our understanding of the risks to a point where policy makers could act to deal with it, another group of thinkers worked to create a menu of potential policy options to deploy, representing a broad swath of the political spectrum in their approaches. I learned through smaller-scale action on The Hill that a problem is not enough for our political system to act—there must already be potential solutions ready to deploy, and ideally a critical mass and broad coalition of support to address the issue. This is now finally the case with climate.

History took place when the Build Back Better Act passed the House on 21 Nov. 2021, regardless of whether the bill becomes law in that exact form. It was a privilege to see my own scientific field influence federal legislation at such close range, and as I continue to pursue a career that enables climate action consistent with scientific knowledge, I will take numerous lessons from this experience with me. Foremost among them is that simple thresholds that capture the essence of scientific knowledge—if not the full complexity—can be useful and even necessary to achieve results in political negotiations. In addition, a problem in search of a solution is not enough for political action; potential solutions and political coalitions of support are necessary for success. The tremendous amount of scientific work done to characterize climate change and to quantify its risks with precision was effort on the scale of the problem, an undertaking that continues to serve the greater good.

This manuscript is submitted for publication by Charles Gertler, 2020–2021 GSA-USGS Congressional Science Fellow, with the understanding that the U.S. government is authorized to reproduce and distribute reprints for governmental use. The one-year fellowship is supported by GSA and the U.S. Geological Survey, Department of the Interior, under Assistance Award No. G20AP00106. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. government. Gertler worked in the office of Sen. Edward Markey (D-MA) and can be contacted by email at charles.gertler@gmail.com.

GSA Elections Begin 8 March 2022

We congratulate our incoming president who was elected by GSA membership in 2021.

PRESIDENT
(July 2022–June 2023)

Mark Gabriel Little
Executive Director, CREATE-NCGrowth
University of North Carolina at Chapel Hill
Chapel Hill, North Carolina, USA

2022 Officer and Council Candidates

GSA's success depends on you—its members—and the work of Officers and Councilors serving on GSA's Executive Committee and Council. Notice of the election will be posted on the GSA's secure website with instructions for accessing the online ballot. You will receive an electronic voting reminder. When the ballot opens, information on the candidates will be available online for review. Paper versions of the ballot and candidate information will be available upon request. Please help continue to shape GSA's future by voting on these candidates. Ballots must be submitted electronically or postmarked by 7 April 2022.

VICE PRESIDENT/ PRESIDENT-ELECT
(July 2022–June 2024)

Christopher (Chuck) M. Bailey
Professor, Dept. of Geology
William & Mary
Williamsburg, Virginia, USA

TREASURER
(July 2022–June 2023)

Brian G. Katz
Environmental Consultant
Weaverville, North Carolina, USA

COUNCILOR POSITION 1
(July 2022–June 2026)

Gene M. Peters
Chief, Counterterrorism & Forensic Science Research
FBI Laboratory
Quantico, Virginia, USA

Richard M. Ortiz
Principal Geologist
Lettis Consultants International Inc. (CI)
West Sacramento, California, USA

COUNCILOR POSITION 2
(July 2022–June 2026)

Carol D. Frost
Professor Emerita, Dept. of Geology and Geophysics
University of Wyoming
Laramie, Wyoming, USA

Matthew J. Kohn
University Distinguished Professor, Dept. of Geosciences
Boise State University
Boise, Idaho, USA

COUNCILOR POSITION 3—Sections Liaison
(July 2022–June 2026)

Kathleen DeGraaff Surpless
Professor and Chair, Dept. of Geosciences
Trinity University
San Antonio, Texas, USA

Nancy S. Williams
GSA North-Central Section Past Secretary
Springfield, Missouri, USA

GSA Committee Vacancies Available for Nominations by 15 June 2022

Go to **https://rock.geosociety.org/Nominations/CS.aspx** to volunteer or nominate**.** Open positions and qualifications are detailed online at **https://rock.geosociety.org/forms/viewopenpositions.asp** or see the January issue of *GSA Today*. Terms begin 1 July 2023 unless stated otherwise.

COMMITTEE NAME	NO. OF VACANCIES	POSITION TITLE & SPECIAL REQUIREMENTS	TERM (YEARS)
Academic and Applied Geoscience Relations Committee	1	Member-at-Large Industry	3
Annual Program Committee	2	Members-at-Large	4
		Member-at-Large Student	2
Arthur L. Day Medal Award Committee	2	Members-at-Large	3
Bascom Mapping Award Committee	1	Member-at-Large Government	3
		Member-at-Large Industry	3
		Member-at-Large	3
Council Officers	5	President-Elect	3
		Treasurer	1
		Councilor	4
Diversity in the Geosciences Committee	4	Members-at-Large	3
		Member-at-Large Industry	3
		Member-at-Large Student	3
Education Committee	3	4-Year College Faculty Representative	4
		Members-at-Large	4
		Graduate Student Representative	2
Geology and Public Policy Committee	3	Members-at-Large	3
		Member-at-Large Student	3
GSA International	4	Chair	4
		International IIG Chair	4
		Member-at-Large	4
		Secretary	4
Membership and Fellowship Committee	3	Members-at-Large Industry	3
		Members-at-Large Student	3
Nominations Committee	2	Members-at-Large	3
North American Commission on Stratigraphic Nomenclature	1	GSA Representative	3
Penrose Conferences and Thompson Field Forums Committee	1	Member-at-Large	3
Penrose Medal Award Committee	2	Members-at-Large	3
Professional Development Committee	2	Members-at-Large	3
Public Service Award Committee	1	Member-at-Large	3
Publications Committee	1	Member-at-Large	4
Research Grants Committee	11	Members-at-Large (various specialties)	3
Young Scientist Award (Donath Medal) Committee	3	Members-at-Large	3

GeoCareers Programs at the 2022 Section Meetings

GEOCAREERS WORKSHOPS

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

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

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

MENTOR PROGRAMS

GSA student members will have the opportunity to discuss career prospects and challenges with applied geoscientists from various sectors.

South-Central Section Meeting
Shlemon Mentor Program: Monday, 14 March
Mann Mentors in Applied Hydrology Program: Tuesday, 15 March

Joint Cordilleran and Rocky Mountain Section Meeting
Shlemon Mentor Program: Wednesday, 16 March
Mann Mentors in Applied Hydrology Program: Thursday, 17 March

Northeastern Section Meeting
Shlemon Mentor Program: Sunday, 20 March
Mann Mentors in Applied Hydrology Program: Monday, 21 March

Joint North-Central and Southeastern Section Meeting
Shlemon Mentor Program: Thursday, 7 April
Mann Mentors in Applied Hydrology Program: Friday, 8 April

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

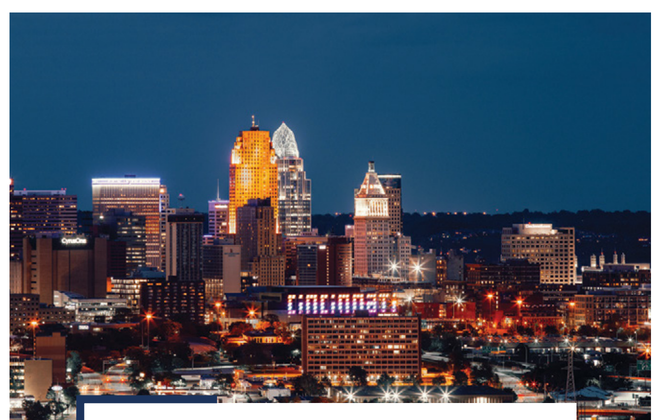
15–17 March
Las Vegas, Nevada, USA
Meeting chairs: Michael Wells, michael.wells@unlv.edu; Alexis Ault, alexis.ault@usu.edu
https://www.geosociety.org/cd-mtg

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.

Who is a Geoscientist?

Who do you picture when you hear the word “geoscientist?” For many, the image does not match who they see every day in the mirror and in their communities. It is no secret that geoscience is the least diverse of all the scientific fields. GSA is aware of this disparity and has a long history of working to address it. One of the ways GSA has endeavored to expand representation in the geosciences is through the On To the Future (OTF) program, which was started at the 2013 annual meeting as a part of GSA’s 125th celebration. Since then, more than 650 students have received OTF scholarships.

The OTF scholarship helps students who are underrepresented in the geosciences not only attend their first GSA annual meeting—through travel support and meeting registration—but also pairs students with a one-to-one mentor and provides opportunities to meet with GSA leadership. Mentors help the students navigate their first professional scientific meeting, provide career advice, and introduce students to their networks. OTF students also receive a one-year membership to GSA, which helps them remain connected to the science and continue to build relationships started at the meeting.

Many OTF students and alumni have shared that being a part of the OTF cohort introduced them to other people who are experiencing the same challenges—imposter syndrome, feelings of isolation which have been exacerbated by the pandemic, lack of a network, lack of confidence in presentation skills, and no representation among faculty. And yet they are still doing geoscience. This helps participants see themselves and others like them as geoscientists and increases confidence in their own abilities.

Yueyi Che, one of the OTF students who attended GSA Connects 2021 in Portland, Oregon, USA, shares:

> My most vivid memory from GSA 2021 was the moment I spoke to the microphone when I was on stage giving my first oral presentation. My voice sounded a bit high-pitched with occasionally a little giggle because I was shy and excited at the same time. The voice from the microphone sounded just like me, but it sounded so unfamiliar to me. At that moment, I realized that I have never associated the voice from a podium with the sound of a young woman. I realized how deep the stereotype of a scientist was embedded even within myself. That is why we need to bring more diverse people to the podium. We need to hear their voices more so we will be used to listening and sharing different perspectives. I think that is what a meeting is all about, bringing voices from around the world together to generate new ideas.

Recognizing the importance of the OTF program, one longtime, generous GSAF donor is committed to making sure other people don’t run into the same problems they did when trying to become a geologist. Challenging fellow members, they will match one-to-one, up to US$10,000, every gift made to the On To the Future scholarship (https://gsa-foundation.org/fund/on-to-the-future-fund/) between now and 30 June. Please consider making a gift today to provide students with an On To the Future scholarship (see https://gsa-foundation.org/donate/). Every gift helps students become a part of the geoscience community with others like them and broadens the image of who a geoscientist is.

Yueyi Che presenting her research at GSA Connects 2021.

www.gsa-foundation.org

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

POSITION OPEN

Director of The Mississippi Mineral Resources Institute, and (Associate or Full) Professor of Geology and Geological Engineering, University of Mississippi

The School of Engineering at the University of Mississippi is seeking an experienced researcher, administrator, and faculty member for the position of Director of the Mississippi Mineral Resources Institute and tenured/tenure-track faculty in the Department of Geology and Geological Engineering. The faculty appointment will be at a rank commensurate with qualifications and experience. Position details and instructions to apply can be found here: [https://careers.olemiss.edu/job/University-Director-of-MMRI-and-Full Associate-Professor-of-Geology-&-Geological-Engineering-MS-38677/822335400/]. Screening of applications begins February 15, 2022, and continues until the position is filled. The University of Mississippi embraces a meaningful and holistic commitment to advancing diversity, equity, and inclusion. The University of Mississippi is committed to embracing a collaborative, innovative, and inclusive community that affirms all employees.

OPPORTUNITY FOR STUDENTS

Thesis research opportunities and graduate assistantships at Sul Ross State University in West Texas. The Geology Program at Sul Ross State University has positions open for students to pursue a Master of Science degree beginning Fall 2022. The SRSU Geology Program emphasizes field research in surface and groundwater, paleontology, sedimentary petrology, igneous petrology, and structural geology.

The program is looking for students to undertake the following research projects:

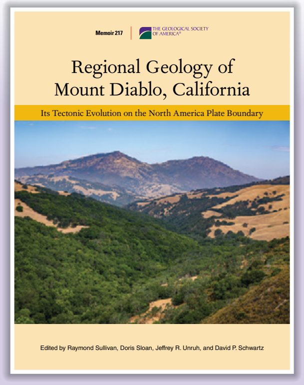
- Petrogenesis and tectonic association of Miocene mafic lavas in the Santana graben, Trans-Pecos Texas (Prof. Kevin Urbanczyk)
- A field-based kinematic analysis of Laramide structures in Trans-Pecos Texas: Was crustal shortening oblique or orthogonal? (Prof. Jesse Kelsch)
- Paleozoic stratigraphy and petrology of carbonates and clastics (Prof. Liz Measures)
- The stratigraphy and paleontology of Upper Cretaceous–Paleogene strata of the Big Bend and northern Mexico (Prof. Thomas Shiller)
- A study of the geomorphology and flood history of the Rio Grande in the Colorado Canyon area, Big Bend Ranch State Park (Prof. Kevin Urbanczyk)

Graduate students are funded as teaching assistants for undergraduate geology or chemistry labs, or by tutoring positions in mathematics. These graduate positions pay $1,000/month for the first two semesters and $1,250/month thereafter. Out-of-state tuition is also waived for non-residents.

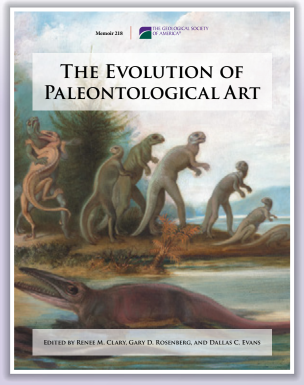
Sul Ross is a small university in the mountainous region of far west Texas, near three national parks and in proximity to the geology faculty's research areas. Our faculty are committed to providing individual attention and excellent resources to each student.

Qualified individuals are encouraged to learn more at https://www.sulross.edu/courses/m-s-geology/ and to reach out to a faculty member about the program, their thesis-research projects, and the application process. Applications are accepted through the spring semester.

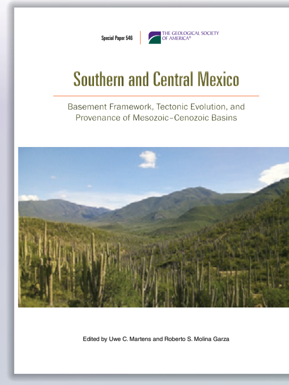
Browse the GSA STORE



Regional Geology of Mount Diablo, California: Its Tectonic Evolution on the North America Plate Boundary
Edited by Raymond Sullivan, Doris Sloan, Jeffrey R. Unruh, and David P. Schwartz
MWR217, 472 p. + insert, ISBN 9780813712178
$70.00 | **member price $49.00**



The Evolution of Paleontological Art
Edited by Renee M. Clary, Gary D. Rosenberg, and Dallas C. Evans
MWR218, 275 p., ISBN 9780813712185
$60.00 | **member price $42.00**



Southern and Central Mexico: Basement Framework, Tectonic Evolution, and Provenance of Mesozoic–Cenozoic Basins
Edited by Uwe Martens and Roberto S. Molina Garza
SPE546, 468 p., ISBN 9780813725468
$120.00 | **member price $84.00**

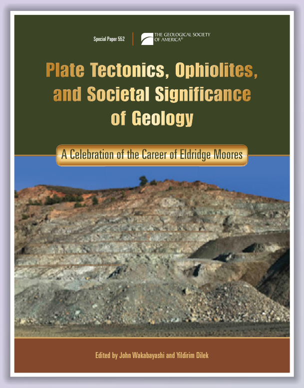
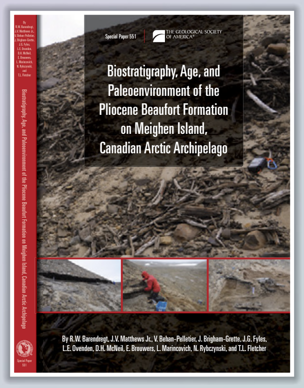
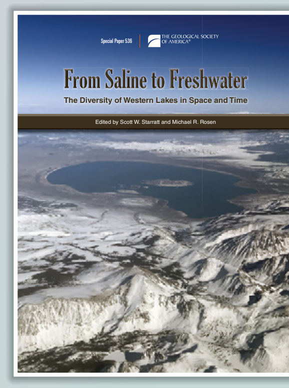


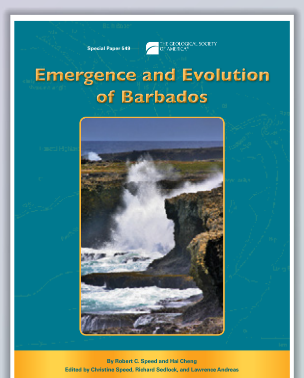
Plate Tectonics, Ophiolites, and Societal Significance of Geology: A Celebration of the Career of Eldridge Moores
Edited by John Wakabayashi and Yildirim Dilek
SPE552, 296 p., ISBN 9780813725529
$55.00 | **member price $38.00**



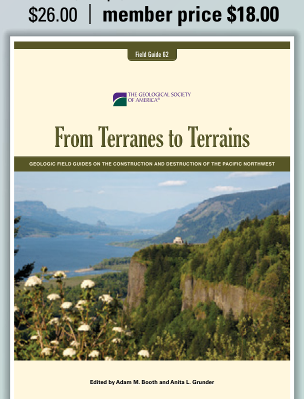
Biostratigraphy, Age, and Paleoenvironment of the Pliocene Beaufort Formation on Meighen Island, Canadian Arctic Archipelago
By R.W. Barendregt, J.V. Matthews Jr., V. Behan-Pelletier, J. Brigham-Grette, J.G. Fyles, et al.
SPE551, 39 p., ISBN 9780813725512
$26.00 | **member price $18.00**



From Saline to Freshwater: The Diversity of Western Lakes in Space and Time
Edited by Scott W. Starratt and Michael R. Rosen
SPE536, 506 p., ISBN 9780813725369
$99.00 | **member price $70.00**



Emergence and Evolution of Barbados
By Robert C. Speed and Hai Cheng; edited by Christine Speed, Richard Sedlock, and Lawrence Andreas
SPE549, 126 p., ISBN 9780813725499
$60.00 | **member price $42.00**



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

Field Excursions from the 2021 GSA Section Meetings
Edited by Joan Florsheim, Christian Koeberl, Matthew P. McKay, and Nancy Riggs
FLD061, 289 p., ISBN 9780813700618
$60.00 | **member price $42.00**

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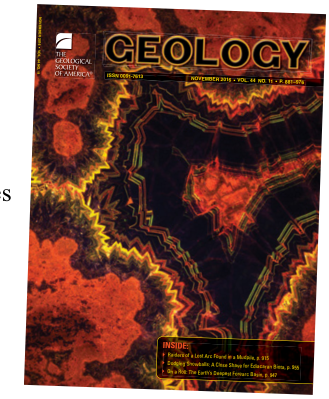
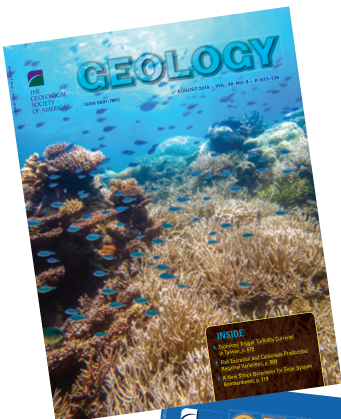
THE GEOLOGICAL SOCIETY OF AMERICA®

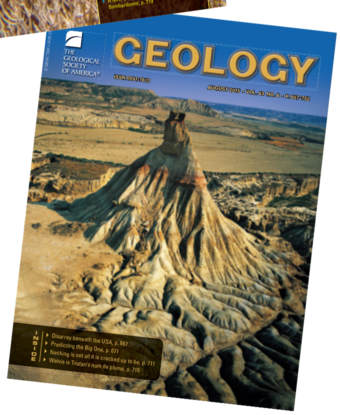
Geology: The Cover Story

Geology is celebrating 50 years of publishing in 2022, and we’re taking a look back at how the journal has evolved. Most readers now access geology articles online, and while we still create a cover for each issue, those images—and their “teasers”—used to be much more of a feature.

Appearing from January 1983 to July 2019, attention-grabbing phrases dreamed up by *Geology* science editors helped highlight a few articles in each issue. Here are some of our favorites. (Note: We are not responsible for injuries sustained from pun-induced wincing.)







Ocean magma chambers: A good Oman? (January 1993)
Quakes show their mussels (March 1994)
Mafic plutons sink to new low (May 1994)
Corals corral Wrangellers (December 1994)
The icehouse cometh (July 1996)
Sirius issues discussed (August 1996)
When in Rome, do stratigraphy (August 1996)
Synchronized spawning approved for Australian games (November 1996)
Ooze clues (August 2000)
Notorious BIG’95 (October 2002)
Roast slab with mantle melt (October 2002)
Dryas actually wettest (January 2004)
Top Raman on the barbie (January 2004)
All along the Wasatch tower (May 2004)
Riders on the Stoma (January 2005)
Long-Soufrièring Montserrat (April 2005)
Conifers gotta lotta stomata (September 2005)
Stony deserts are the ^{10}Be’s ^{21}Ne’s (December 2005)
LIPs provide the kiss of death (May 2015)
A ripple effect: Size matters (March 2017)
Fully exposed in the tropics: The feedback is negative (August 2017)
Dating in a swinging hot spot (January 2018)

Bringing Lost Worlds to Light: New Memoir Presents the Evolution of Paleontological Art

We're excited to announce the release of a new GSA memoir that samples the history of art about fossils. The 29 chapters and accompanying artwork in Memoir 218: *The Evolution of Paleontological* Art explore important developments in visualization of ancient life forms and the vanished worlds in which they lived, and how paleoart continues to inspire our fascination with the past.

The memoir begins with several chapters that trace the history of writings and art about fossils to show how paleoart encapsulates the scientific history of fossil investigation, as well as Earth's history. They also show how our understanding of fossils and ancient lives has evolved through time.

From illustrations of dinosaur tracks to three-dimensional sculptures, paleoart also helps educate students and the public by providing a standardized representation of fossil specimens, while also allowing for the preservation of fossil records for future reference.

Chapters covering postage-stamp art, murals, and microfossil art emphasize a major theme of the volume—that science can be of interest to and is for everyone.

Covering paleoart from Henry De la Beche to Charles R. Knight to Henry Augustus Ward to present-day innovators, this volume recognizes the contributions of notable women paleontological artists such as Elisabeth Rungius Fulda, Helen Ziska, Lindsey Morris Sterling, Margret Joy Flinsch Buba, Mary Morland Buckland, and Orra White Hitchcock.

Finally, this memoir presents the modern understanding that paleoart helps communicate important lessons about the interdependent relationships between humans and other organisms and the environment, and it propels us toward wise stewardship of our planet.

https://rock.geosociety.org/Store/detail.aspx?id=MWR218