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Modeling Mass Movements Across Varied Geological Terrains: Processes, Hazards, and Mitigation

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Guest Editors:

Dr. Sajinkumar K.S.
Department of Geology, University of Kerala, India
sajinks@keralauniversity.ac.in

Dr. Yunus Ali Pulpadan
Department of Earth Sciences, IISER Mohali, India
yunusp@iisermohali.ac.in

Dr. Srikrishnan Siva Subramanian
Centre of Excellence in Disaster Mitigation and Management, IIT Roorkee, India
srikrishnan@dm.iitr.ac.in

Dr. Nikhil Nedumpallile Vasu
British Geological Survey, Nottingham, UK
nikned@bgs.ac.uk

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***GSA TODAY* STAFF**

Executive Director, CEO, and Publisher: Melanie Brandt

Science Editors: 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; **Christian Koeberl**, Department of Lithospheric Research, University of Vienna, Althanstrasse 14, A-1090 Vienna, Austria, christian.koeberl@univie.ac.at.

Managing Editor: Katie Busser, kbusser@geosociety.org, gsatoday@geosociety.org

Graphics Production: Mia Rincón, mrincon@geosociety.org

For advertising inquiries, contact: advertising@geosociety.org

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The 1080 Ma Enchanted Rock Batholith is one of many late-stage, A-type intrusive rocks across the Llano Uplift that stitch together the several rock packages that were metamorphosed during the Grenville Orogeny. Credit: Jmbuytaert via Wikimedia Commons.

Long-Term Monitoring of a Campus-Scale Geothermal Heat Pump System Using Distributed Temperature Sensing

Chloé Fandel,[1,*] Daniel Maxbauer,[1] Sarah Titus,[1] Kelton Barr,[2] Jonathon Cooper,[1] Bruce Duffy,[3] Martha Larson,[4] Mary Savina,[1] and Bob Tipping[5]

ABSTRACT

Geothermal heat pumps are a fast-growing technology for decarbonizing heating and cooling systems. Monitoring existing systems over time can provide useful information for how subsurface heterogeneities will impact efficiency in new systems. Carleton College (Northfield, Minnesota) installed a district-scale, closed-loop geothermal heat pump system in 2018, with over 200 vertical boreholes that extend ~150 m through Paleozoic sedimentary rocks. Fiber-optic distributed temperature-sensing cables in five boreholes provide insight into daily, seasonal, and yearly temperature patterns. At certain intervals, downhole temperature consistently deviates toward the pre-operational temperature, creating persistent pinch points across times and in all seasons, which we attribute to higher groundwater flow. Vertical wells in two borefields are grouted differently: Wells in one field only have thermal grout, while wells in the other field have an interval of pea gravel through an interval of predicted high groundwater flow. Total energy exchange data for each borefield suggest that the field with pea gravel is more efficient than the fully grouted one. There are hints that the subsurface reservoir acts like a sink (absorbing and transmitting thermal energy so that the temperature oscillates around a constant mean), rather than like a battery (storing thermal energy in summer to be released in winter), but more data are needed to fully characterize long-term patterns. The influence of groundwater flow and the long-term responses of the subsurface have implications for borefield design and highlight the importance of monitoring new geothermal systems.

INTRODUCTION

Geothermal heat pumps are a promising technology for decarbonizing heating and cooling systems and are one of the fastest-growing renewable energy sources worldwide (Monschauer et al., 2023). Unlike geothermal systems that rely on high-temperature subsurface reservoirs, heat pumps leverage steady subsurface temperatures (Rybach, 2022). In temperate climates, the ground temperature is cooler than the surface air in summer but warmer in winter, providing both a heat sink and source.

Currently, most geothermal heat pumps are for single-family homes (Monschauer et al., 2023). However, district-scale installations that distribute heat to multiple buildings could play a key role in decarbonization (Vinther Pedersen, 2020; Liu et al., 2023). Examples of district-scale geothermal heat pump installations in the United States include Epic Systems (McDaniel et al., 2018), Ball State University (Siliski et al., 2016), and West Chester University (Helmke et al., 2016). Few systems have long-term monitoring, which makes it difficult to predict how they will interact with the local geologic and hydrogeologic context. This lack of monitoring can cause operational challenges down the road, as, for example, at Ball State University and at Stockton College, where long-term monitoring showed consistent increases in ground temperatures (Epstein and Sowers, 2006; Siliski et al., 2016).

Carleton College installed a district-scale geothermal heat pump system in 2018 with three borefields, one of which included fiber-optic distributed temperature-sensing (DTS) cables in five boreholes. The resulting high-resolution downhole temperature data, when combined with overall campus energy-use data, provide insight into daily, seasonal, and yearly temperature patterns in the subsurface. This system also provides a natural laboratory because the borefields have slightly different designs that allow us to compare the role of borehole design and construction on the behavior and efficiency of geothermal heat pumps.

* cfandel@carleton.edu
[1] Department of Geology, Carleton College, Northfield, Minnesota 55057, USA
[2] Kelton Barr Consulting LLC, St. Louis Park, Minnesota 55426, USA
[3] Department of Physics & Astronomy, Carleton College, Northfield, Minnesota 55057, USA
[4] RMF Engineering, Baltimore, Maryland 21228, USA
[5] Minnesota Department of Health, St. Paul, Minnesota 55164, USA
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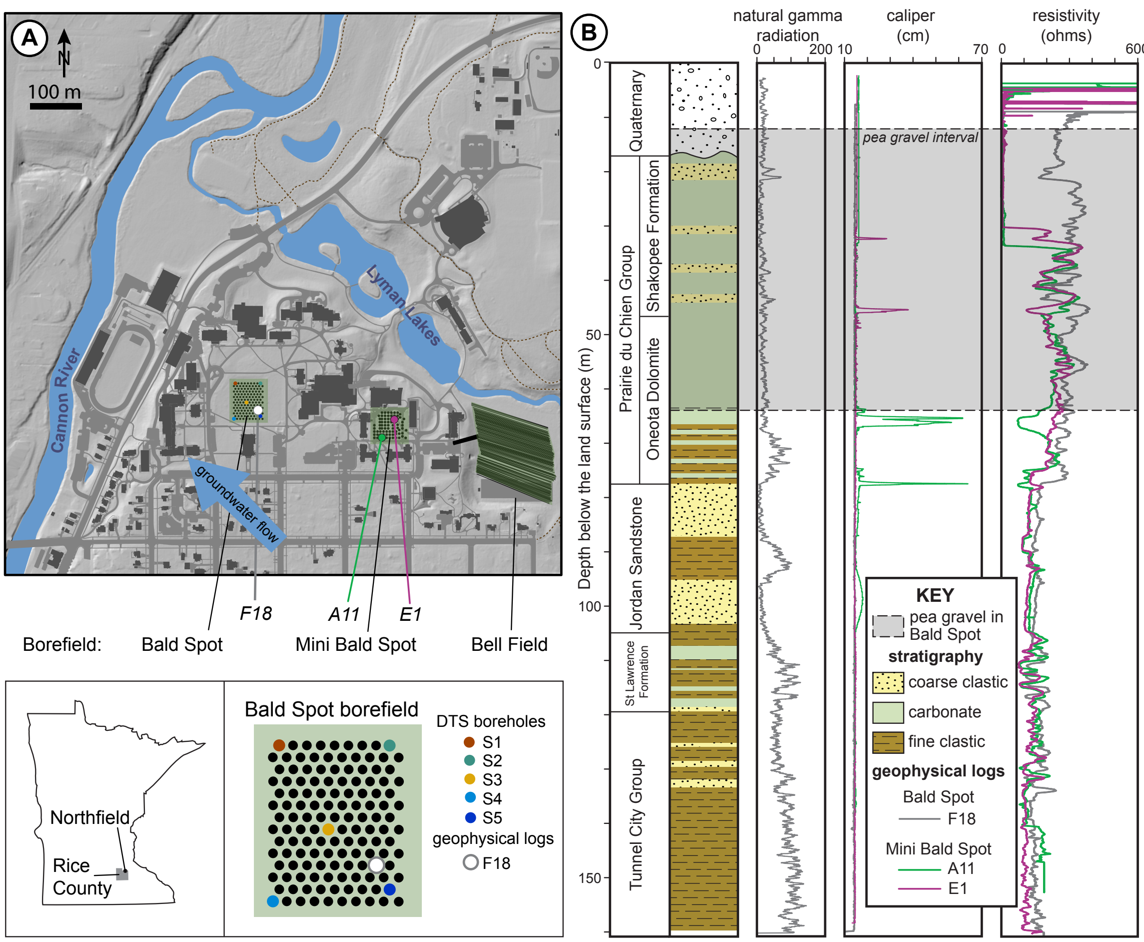

Figure 1. (A) Carleton College borefield and instrumentation map. Boreholes in the Bald Spot and Mini Bald Spot fields are vertical; boreholes in Bell field are horizontal. Inset: Location of Northfield in Minnesota. The center of the Bald Spot field is at 44.461025°N, 93.154706°W. (B) Stratigraphic column and geophysical logs.

CAMPUS GEOTHERMAL SYSTEM

The Carleton College district heating and cooling system consists of a closed-loop geothermal ground-source heat pump with three borefields (Bald Spot-133 bores, Mini Bald Spot-77 bores, Bell Field-95 bores), a central energy station, and a piped 49 °C hot-water heat-distribution system to campus buildings (Fig. 1A). The system captures, redistributes, and exchanges heat for campus needs through the heat pump. Additional energy needs (during the coldest and hottest days) are met by boilers and chillers in the central energy station, powered by a combination of natural gas and electricity.

The borefields each have a slightly different design. Two fields have vertical bores that extend to 158.5 m through the local bedrock with ~6 m spacing between bores. The third borefield (Bell field) consists of horizontal bores in shallow unconsolidated sediment. Here, we focus on the fields with vertical bores because they create a natural experiment. Each ~15 cm diameter borehole is connected to the others by a closed loop of polyvinyl chloride (PVC) geothermal piping. The piping travels down and up each individual borehole and contains recirculating fluid, so that heat, but not fluid, exchanges through the walls. The annular space inside the borehole is filled with a thermal grout, which minimizes the risk of contamination via vertical groundwater flow along the boreholes while maximizing the thermal conductivity of the area around the pipe. However, in the Bald Spot field, a special waiver was obtained from the Minnesota Department of Health to use pea gravel rather than grout in an interval of expected high groundwater flow (11.8–64.9 m below the surface). The local stratigraphy is the same in both fields; thus, the only major difference is the presence or absence of the pea-gravel fill interval.

Five bores in the Bald Spot field are instrumented with fiber-optic cables that record temperature at 0.1 °C, 0.25 m, and 30 min resolution (Fig. 1A; see detailed description in Supplemental Material[6]).

LOCAL GEOLOGY

The vertical bores pass through Cambrian–Ordovician sedimentary rocks deposited in a shallow sea. These continuous, flat-lying strata are topped by a veneer of glacial sediments.

[6] Supplemental Material. Figure S1. Depth and amplitude of borehole temperature deviations. Figure S2. Monthly downhole temperatures showing seasonal heat exchange. Please visit https://doi.org/10.1130/GSAT.S.30152638 to access the supplemental material; contact editing@geosociety.org with any questions.

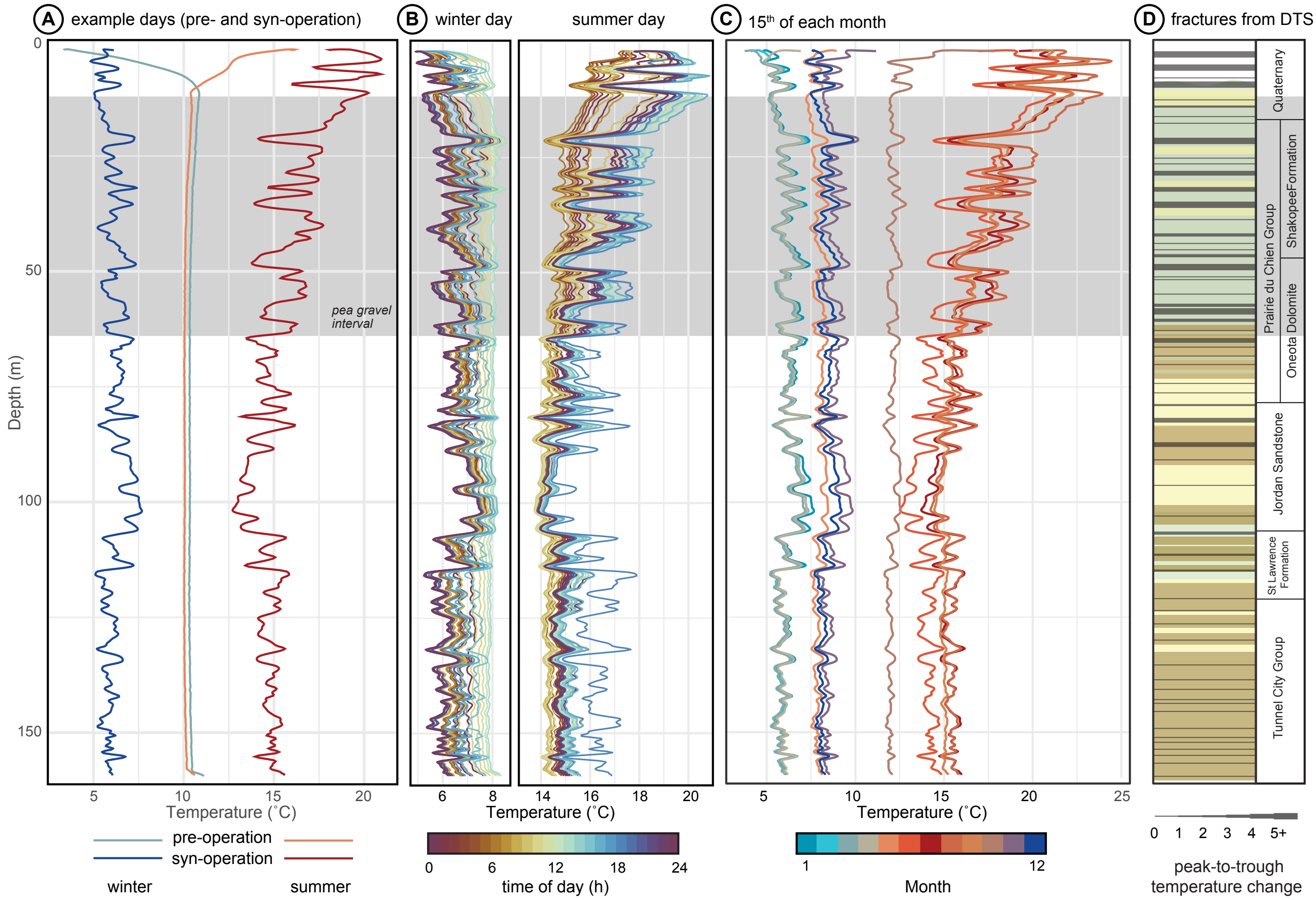

Figure 2. Data from borehole S1 over different time scales. (A) Downhole distributed temperature-sensing (DTS) temperature profiles for 1 h (11 a.m. to 12 p.m.) of a representative day, in winter and summer, before and during system operation. (B) Hourly profiles for a winter (left) and summer (right) day. (C) Monthly profiles (11 a.m. to 12 p.m. on the 15th day of each month). (D) Fracture locations interpreted from pinch points in September data in panel C.

The main aquifers are the Ordovician Prairie du Chien Group (targeted for pea-gravel fill in the Bald Spot field) and the Cambrian Jordan Sandstone (Fig. 1B). Groundwater flow through the Prairie du Chien Group (subdivided into the Shakopee and Oneota Formations) is common along extensive bedding-parallel fractures and dissolution features (Tipping et al., 2006). Several of these fractures appear in geophysical logs from the Mini Bald Spot field, where they correlate with abrupt changes in resistivity (Fig. 1B). There is also a regional-scale paleokarst horizon within the Oneota Formation (Tipping et al., 2006). Groundwater flow through the underlying Jordan Sandstone is attributed to granular characteristics of the unit as well as bedding-parallel fractures (Runkel et al., 2003).

The two deepest units beneath campus tend to have lower hydraulic conductivities than the overlying aquifers (Runkel et al., 2003). The Cambrian St. Lawrence Formation, composed of interbedded sands and carbonate rock, may have some secondary porosity due to dissolution along bedding planes (Runkel et al., 2003). Several peaks in the gamma radiation in this unit also correlate with changes in resistivity (Fig. 1B). The upper part of the Cambrian Tunnel City Group is an aquifer in the Twin Cities basin; the higher porosity and permeability in this interval are attributed to bedding-parallel fractures (Runkel et al., 2006).

DATA AND INTERPRETATIONS

The DTS data illustrate temperature patterns in space and time. We first use downhole data to illustrate the basic operation of the system in winter and summer. Then, we show hourly and monthly snapshots from a single well along with fracture interpretations based on the temperature profiles. Last, we examine trends over several years in the Bald Spot field.

DOWNHOLE TEMPERATURES

Figure 2A shows temperature profiles from a single borehole (S1) before and after the system was operational. The pre-operational data in winter and summer show seasonal fluctuations in the top 10 m. The amplitude of the fluctuations decreases as depth increases, until the extinction depth is reached, and the temperature remains constant at around 10 °C (Lapham, 1989; Briggs et al., 2014). This constant subsurface temperature generally represents an equilibrium slightly above the mean annual surface temperature (Carson, 1961), which in Northfield is 7.2 °C (Minnesota Department of Natural Resources, 2023). In regions with extensive winter snow cover, such as Minnesota, a difference of more than 3 °C between the mean annual air and ground temperatures is not uncommon.

The post-operational profiles show seasonal fluctuations along the entire length of the borehole. The winter curve shows cooler-than-average temperatures as buildings extract heat from the ground, while the summer curve shows warmer-than-average temperatures as buildings dump heat into the ground. Each curve contains seasonally mirrored wiggles at various depths. Wiggles away from the baseline temperature show the locations of the largest seasonal temperature fluctuations; wiggles toward the baseline show locations of the smallest fluctuations, creating pinch points. We attribute pinch points to intervals of high horizontal groundwater flow, where groundwater near the mean annual temperature brings the borehole temperature closer to the pre-operational baseline.

Next, we show temperature snapshots over a 24 h period in winter and summer (Fig. 2B). In both seasons, hourly curves show mirrored fluctuations of 2–3 °C over the course of 24 h, in response to changes in campus energy demand driven by diurnal temperature cycles at the surface. The subsurface temperature increases during the warmest part of the day in both seasons (a rightward shift in the afternoon, when heating demand is lowest in winter and cooling demand is highest in summer). The deviation from the baseline temperature is greatest during hours of peak heating/cooling demand (cold winter nights and hot summer afternoons).

The winter and summer hourly profiles are not, however, perfectly symmetric. Summer temperatures deviate farther from the baseline than those in winter and span a wider range over a single day (Fig. 2B). This pattern is likely due to the limiting condition created by the freezing point of water. Thermal energy is circulated through the system by heated or chilled water, which must be prevented from freezing. In the winter, the borehole temperature must therefore be kept above 0 °C (and, to allow for some margin of error, is actually kept above 3.9 °C). Thus, there is a limit to the amount of heat that can be extracted from the ground in winter, but no corresponding limit to the amount of heat that can be added to the ground in summer.

There are also temperature variations at the monthly scale (Fig. 2C). The overall profile is shifted toward warmer temperatures during the summer months and cooler temperatures during the winter months, with shoulder-season months closer to the baseline temperature. Deviation from the baseline is greatest during months of peak cooling/heating demand (deep winter and midsummer–early fall).

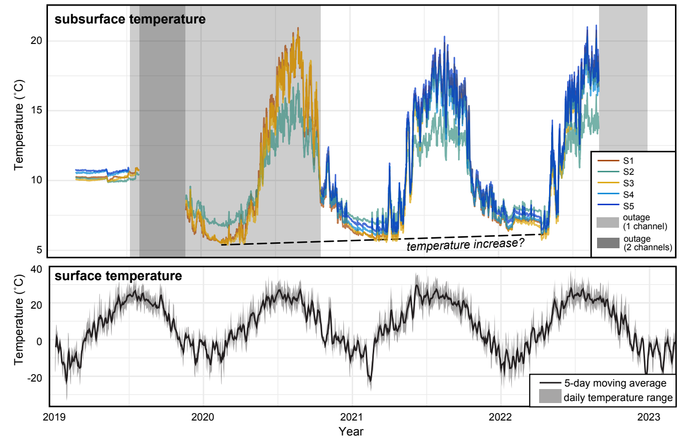

Figure 3. (A) Mean daily temperature for each distributed temperature-sensing (DTS) instrumented borehole. See Figure 1A for locations. (B) Mean air temperature (five-day moving average). Data: Minnesota Department of Natural Resources (2025).

Across any time scale, pinch-point locations and relative magnitudes remain constant, as expected if they indicate horizontal intervals of high groundwater flow. Consistent with what we know about the hydrogeology of the local stratigraphy, we interpret these pinch-point intervals to be the locations of subhorizontal fractures that facilitate groundwater flow (Fig. 2D). For a single well, we show horizontal lines at each pinch point, where the line width reflects the magnitude of the temperature deviation (maximum peak-to-trough value), based on data at noon on 15 September 2021 (the warmest month of full campus occupancy). Fractures cannot always be traced across all five wells (see Supplemental Material). This may be due to a combination of factors including discontinuous fractures across the field, slight deviations in the DTS depth calibrations, and uncertainties in determining where a fracture belongs within each pinch-point interval. Large fractures appear to be present in the Shakopee Formation, which is known to have solution-widened fractures and karst development (Tipping et al., 2006). The peak-to-trough temperature differences at these pinch points in the Shakopee Formation may also be larger because they coincide with the pea-gravel interval in the Bald Spot borefield. The Jordan Sandstone has the fewest pinch points, especially in its lower coarse-clastic interval, consistent with groundwater flow via primary porosity. All other units also appear to have fractures that enhance groundwater flow.

BOREFIELD TEMPERATURE

To examine the evolution of borehole temperature in the Bald Spot field over time, we plotted the average temperature for all five DTS wells for a 3 yr period compared to the mean annual surface temperature (Fig. 3). Though there are some data gaps due to DTS system outages, two notable patterns emerge.

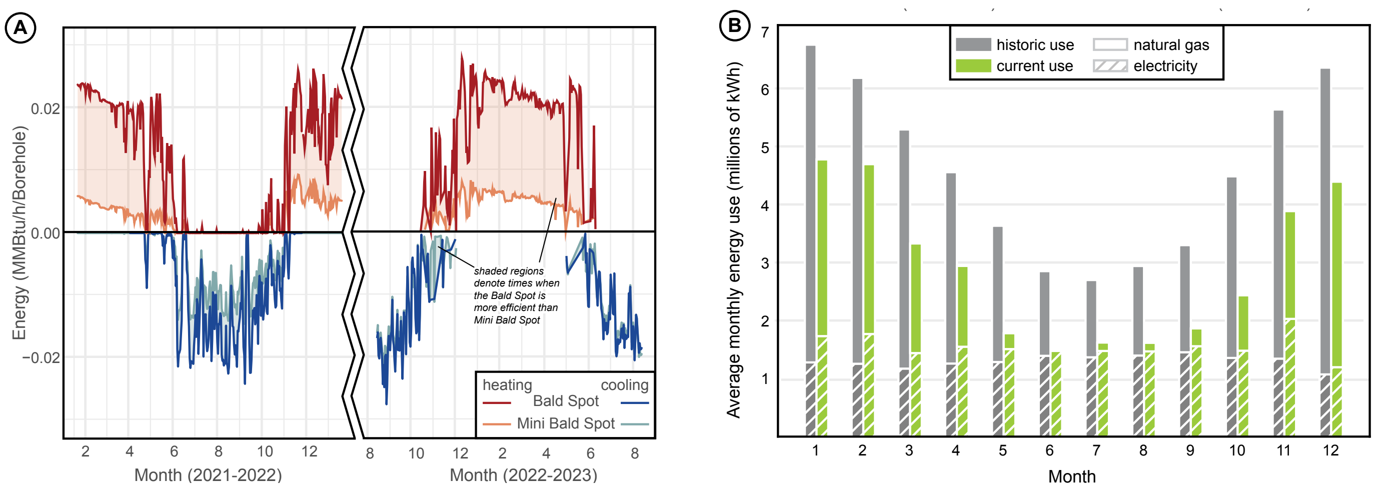

Figure 4. (A) Average energy flux per borehole in the Bald Spot and Mini Bald Spot fields. Energy flux in the Bald Spot field is higher magnitude than that in the Mini Bald Spot field, suggesting that the Bald Spot field is more efficient. (B) Campus energy use by source pre– and post–geothermal system. The geothermal system significantly reduced natural gas use as well as overall energy consumption.

First, the temperature is similar across all five wells regardless of location within the borefield. For instance, borehole S1 is not warmer than the others, even though it is downgradient in terms of local groundwater flow direction. This observation suggests that there is no significant thermal gradient across the borefield, and that the thermal influence of each borehole is localized in a small radius. The one exception to this pattern is borehole S2, which has consistently lower summer temperatures and consistently higher winter temperatures. The downhole patterns in this well (see Supplemental Material) suggest ambient upward groundwater flow from the Jordan aquifer to the lower-hydraulic-head Prairie du Chien aquifer, as also observed in an open-hole test well drilled nearby (Tipping et al., 2006). The temperature data from S2 suggest that the grout failed within the borehole, and that the pea-gravel interval in this location acts similarly to an open hole, allowing upward groundwater flow to bypass bedding-parallel fractures in the Oneota Formation.

Second, the winter temperature within the borefield appears to increase slightly over time, indicated by the dotted line in Figure 3. There is no corresponding increase in surface temperature. We return to this pattern in the discussion, but ultimately more annual data may be necessary to detect a convincing long-term trend.

DISCUSSION

Pea-Gravel Effectiveness

We determined the relative efficiency of the Bald Spot and Mini Bald Spot fields by using the borehole fluid flow rate, outflow temperature, and return flow temperature for each field to calculate the total thermal energy flux in millions of British thermal units (BTUs) per hour.

The Bald Spot field provides more heating and cooling energy throughout the year compared to the Mini Bald Spot field, even when normalized by the number of bores in each field (Fig. 4A). In heating mode, the Bald Spot field boreholes provide more energy compared to the Mini Bald Spot field, as illustrated by a larger (more positive) heat flux per borehole. In cooling mode, the system pushes more thermal energy into the Bald Spot field from buildings, illustrated by consistently larger (more negative) heat flux per borehole, although the difference between the two fields is less pronounced than in winter. Normalizing the heat flux by borefield surface area or volume produces similar patterns. These data suggest that filling boreholes with pea gravel in intervals of high groundwater flow velocity can increase borefield thermal exchange efficiency, thereby improving system performance.

OVERALL SYSTEM PERFORMANCE

The geothermal system has significantly reduced overall campus energy consumption, though the data are somewhat complicated by the coronavirus disease 2019 (COVID-19) pandemic (Fig. 4B). For the five years before the system was operational (2014–2018), the average annual campus energy consumption (natural gas and electricity) was ~54.2 million kWh/yr. In 2022, the first full calendar year in which campus occupancy returned to pre-pandemic levels, total energy consumption was ~34.8 million kWh, representing a 36% reduction. This reduction occurred entirely in natural gas usage, which decreased by ~58%. This is significant because, while natural gas consumption directly and unavoidably contributes to greenhouse gas emissions, electricity can be sourced from a variety of low-carbon sources (wind, solar, etc.).

The geothermal system was projected to reduce energy use by 45%. The 10% difference between projected and actual reduction could be related, in part, to higher heating, ventilation, and air conditioning (HVAC) requirements since the pandemic, which we estimate have caused a 5%–7% increase in electricity consumption. Circulating fluid through the heat exchange system has also increased electricity consumption, and total building square footage has increased slightly over time.

WHAT HAPPENS TO THE GROUND TEMPERATURE OVER TIME?

The system was originally modeled to act as a battery, storing thermal energy during the summer for use during the winter, rather than as a sink, where groundwater flow rapidly transmits thermal energy away from the boreholes. Our temperature data show features consistent with both possible scenarios.

Battery-like behavior is suggested by the slight increase in winter ground temperatures over time (Fig. 3) as well as the seasonal asymmetry of the downhole temperature profiles, where winter deviations from baseline temperature are smaller than those in summer (Fig. 2). We initially interpreted these data as reflecting a slowly warming borefield, acting as a battery somewhat unbalanced between winter and summer. However, conversations with the system managers revealed more complexity: The fluid temperature in the boreholes consistently approaches the freeze-protection cutoff threshold in the winter, at which point individual compressors are shut down, and boilers generate heat instead (Rob Hanson, 2023, personal commun.). This allows the subsurface temperature to recover toward the pre-operational mean, making it difficult to interpret year-to-year winter temperature trends.

Sink-like behavior is supported by the pinch points, which demonstrate the importance of groundwater flow along fractures across all time scales (Fig. 2). Groundwater flow could also explain why the system is less efficient than projected. The flow rate appears to be rapid enough, on a seasonal time scale, to remove the heat added to the ground in summer before the start of winter, making the borefield a bad battery. On a daily or hourly time scale in the winter, however, flow is too slow to bring in enough heat to keep the boreholes above the freezing shut-off temperature. The system's capacity to absorb heat is therefore much larger than its capacity to provide heat, making it only a moderately efficient sink.

Communities considering geothermal heat pump systems have been concerned about a long-term subsurface warming trend limiting the long-term efficiency of the system (Li et al., 2009; Florea et al., 2017). Because of groundwater flow and winter shutoffs, we cannot identify any evidence of this trend at Carleton.

ADVICE FOR NEW DISTRICT-SCALE SYSTEMS

If your institution is considering installing a geothermal borefield, this may be an opportunity to set up a monitoring system to study borefield efficacy and scientific questions specific to your location, such as our pea-gravel experiment. Our advice is based on what we did well and what we wish had been possible:

- Collect baseline data about groundwater flow and the subsurface prior to construction. Monitoring wells outside the planned borefield, located up and down the groundwater hydraulic gradient, are ideal. These wells can be used for later experiments, such as hot fluid injection to observe groundwater and heat flow through the borefield (if paired with multiple DTS-instrumented boreholes).
- Install a temperature measurement system in a borehole separate from those used for the geothermal system (e.g., a monitoring well) to make data interpretation simpler. Collect geophysical measurements from this borehole, which can then be compared directly to DTS observations. Collect temperature information prior to system initiation.
- Create an accurate three-dimensional map for the geothermal working fluid pipes, borehole locations, and, if relevant, DTS cables. Take and annotate photographs.
- Be involved during drilling. Collect geophysical measurements from multiple wells including caliper logs, gamma logs, conductivity, and salinity. If possible, coordinate with your local geologic survey. Collect cuttings from wells, which can be excellent teaching resources for curriculum about the borefield. Record the specifics of borehole construction and fill.
- Consider groundwater flow when predicting the system's efficiency. Monitoring wells set up prior to construction could inform the system design. Modeling might help to ensure, for example, that the groundwater flow rate is appropriate for the desired system behavior (battery vs. sink).
- Create (or require the installers to create) a system for read-only access to campus energy information. Useful parameters include the temperature, pressure, and flow rate of the borehole fluid as it enters and exits each borefield.

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Registration

Standard registration rates end **2 October—reserve your place today!**

GSA offers a 50% discount on annual meeting registration fees for individuals who are both residing in and are citizens of low and low-middle-income countries as classified by the World Bank. The 50% discount does not apply to the K–12 Professional or Guest registration classes.

connects.geosociety.org/register

Important Dates

- **Standard Meeting Registration Rate Deadline:** 2 October
- **Late Meeting Registration Opens:** 3 October
- **Connects Icebreaker:** 18 October
- **Connects 2025:** 19-22 October

Don't Miss Out!

Add These Ticketed Events to Your Registration

GeoCareers Day

19 October | 9 a.m.–1 p.m.
$20; includes lunch

Success in Publishing: Navigating the Process

19 October | 10–11:30 a.m.

If you're an early-career geoscientist preparing a manuscript—or just want to improve your writing—this **free** workshop is for you! GSA editors **Nancy Riggs and Robinson Cecil** will share practical tips on structuring your paper, selecting the right journal, and understanding peer review. Gain insights from experienced editors and take the next step in your publishing journey—sign up today at **https://www.geosociety.org/GSA/GSA/Pubs/WritersResource.aspx.**

Paleontological Society (PS) Business Meeting and Awards Reception Buffet

19 October | 6:30 p.m.
$80

Night at the Museum: Briscoe Western Art Museum in San Antonio

19 October | 7:30 p.m.
$50: general; $30: ECPs; $25: students

Join fellow geoscientists for an evening of exhibits, networking, and light fare at the Briscoe Western Art Museum, one of San Antonio's most iconic cultural spaces. Just a short walk from the Henry B. González Convention Center, this event is open to all attendees. Sign up under "Ticketed Events" when you register for Connects.

Association for Women Geoscientists (AWG) Awards Breakfast and Networking Event

20 October | 6:30 a.m.
$50

Mineralogical Society of America Awards Lunch

21 October | Noon
$88

MGPV / MSA Joint Reception

21 October | 6 p.m.
$10

Planetary Geology Division Annual Banquet and Business Meeting

21 October | 7 p.m.
$75

Schedule at a Glance

PRE-MEETING

Events include field trips, short courses, and a variety of business and social events.

Pre-meeting in-person events in San Antonio will take place 14–18 October.

Short courses begin
online Friday, 10 October, and in person Friday, 17 October.

Field trips begin
Tuesday, 14 October.

SATURDAY, 18 OCTOBER

- Icebreaker Reception: 5–7 p.m.

SUNDAY, 19 OCTOBER

- Oral Technical Sessions: 8 a.m.–noon
- All-Day Poster Sessions: 8 a.m.–5:30 p.m., with presenting authors at their posters from either 9–11 a.m. or 3:30–5:30 p.m. Presentation times will be listed in the program.
- GeoCareers Day: 9 a.m.–1 p.m.
- GeoCareers Corner: 9 a.m.–5 p.m.
- Pre-Event Reception: 11:15 a.m.–noon
- GSA Presidential Address and Awards Ceremony: Noon–1:30 p.m.
- Oral Technical Sessions: 1:30–5:30 p.m.
- Pardee Keynote Symposium: 2:30–5:30 p.m.
- Exhibit Opening Reception: 4:30–7 p.m.
- Innovation Spotlight Stage: 4:30–7 p.m.
- Women in Geology Reception: 5:30–7 p.m.
- Night at the Museum: Briscoe Western Art Museum: 7:30–9:30 p.m.

MONDAY, 20 OCTOBER

- Oral Technical Sessions: 8 a.m.–noon
- All-Day Poster Sessions: 8 a.m.–5:30 p.m., with presenting authors at their posters from either 9–11 a.m. or 3:30–5:30 p.m. Presentation times will be listed in the program.
- GeoCareers Corner: 9 a.m.–5 p.m.
- Exhibits: 10 a.m.–6:30 p.m.
- Innovation Spotlight Stage: 10 a.m.–6:30 p.m.
- Noontime Lecture by Former Mayor of San Antonio Ron Nirenberg: 12:15–1 p.m.
- Pardee Keynote Symposium: 1:30–5:30 p.m.
- Oral Technical Sessions: 1:30–5:30 p.m.
- Afternoon Reception in the Exhibit Hall: 4:30–6:30 p.m.
- Alumni Receptions: Evening hours

TUESDAY, 21 OCTOBER

- Pardee Keynote Symposium: 8–11:30 a.m. and 1:30–5:30 p.m.
- Oral Technical Sessions: 8 a.m.–noon
- All-Day Poster Sessions: 8 a.m.–5:30 p.m., with presenting authors at their poster from either 9–11 a.m. or 3:30–5:30 p.m. Presentation times will be listed in the program.
- GeoCareers Corner: 9 a.m.–5 p.m.
- Exhibits: 10 a.m.–6:30 p.m.
- Innovation Spotlight Stage: 10 a.m.–6:30 p.m.
- Michel T. Halbouty Distinguished Lecture by Dr. Michael H. Young: 12:15–1:15 p.m.
- Oral Technical Sessions: 1:30–5:30 p.m.
- Afternoon Reception in the Exhibit Hall: 4:30–6:30 p.m.

WEDNESDAY, 22 OCTOBER

- Pardee Keynote Symposium: 8 a.m.–noon
- Oral Technical Sessions: 8 a.m.–noon
- All-Day Poster Sessions: 8 a.m.–5:30 p.m., with presenting authors at their posters from either 9–11 a.m. or 3:30–5:30 p.m. Presentation times will be listed in the program.
- Exhibits: 10 a.m.–2 p.m.
- Innovation Spotlight Stage: 10 a.m.–2 p.m.
- Noontime Lecture by Dr. Elizabeth Rampe: 12:15–1:15 p.m.
- Oral Technical Sessions: 1:30–5:30 p.m.

POST-MEETING

Post-meeting field trips run from Wednesday, 22 October, through Saturday, 25 October.

Technical Program

From Earth's systems to interdisciplinary insights—our technical program captures the evolving science of our planet and beyond. Explore the full program and start planning your conference experience at **https://gsa-meetings.secure-platform.com/connects25/**.

Download the Schedule App Guide to explore sessions and special events right from your phone.

Travel and Transportation

For all your travel needs please check out **https://connects.geosociety.org/travel/hotels-transportation.**

GSA Presidential Address and Awards Ceremony

The Future of Geoscience Field Education

Nathan Niemi, GSA President

Sunday, 19 October | Noon–1:30 p.m.

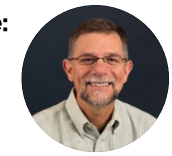
At Connects 2025, GSA focuses on themes of transition, dissolving borders, and reaching for the stars. These themes are reflected in the challenges and opportunities that face geoscience field education, as shifting student interests, technological advances, and barriers to participation require reconsideration of what experiential field training may look like. Attracting and inspiring the next generation of students to tackle the multi-faceted geoscience challenges our society faces is crucial.

Noontime Lectures

Whiskey's for Drinking and Water's for Fighting: How San Antonio Stays Ahead of the Battle Coming to Texas

Former Mayor of San Antonio
Ron Nirenberg

Monday, 20 October | 12:15–1:00 p.m



Michel T. Halbouty Distinguished Lecture: Comparing Life-Cycle Environmental Impacts and Costs of Electricity Generation Systems

Dr. Michael H. Young

Tuesday, 21 October | 12:15–1:15 p.m.

Mars Encoded: How Minerals Reveal the Red Planet's Geologic Evolution

Dr. Elizabeth Rampe

Wednesday, 22 October | 12:15–1:15 p.m.

Pardee Keynote Symposia

Make attending the Pardee Keynote Symposia a top priority! These high-profile symposia, held throughout the meeting, feature insights and inspiring new directions that are shaping the future of geoscience.

P1. Expanding Neurotypical Borders: Building a Future of Inclusion with Disabled and Neurodivergent Perspectives in Geoscience

Sunday, 19 October

Time: 2:30–6 p.m.

Conveners: Taormina Lepore, Jennifer Wagner, and Ian O. Castro

We invite contributors and audience participants of all backgrounds to learn, lead, and celebrate disability and neurodivergence as core to our fields and our collective and intersectional science identities.

Endorsed by: GSA Diversity in the Geosciences Committee; National Association of Geoscience Teachers (NAGT); Paleontological Society; International Association for Geoscience Diversity; GSA Geology and Society Division; National Earth Science Teachers Association; Mineralogical Society of the UK and Ireland; Mineralogical Society of America; Society of Vertebrate Paleontology; International Medical Geology Association; International Association for Promoting Geoethics (IAPG); American Geophysical Union (AGU); GSA Geoarchaeology

Division; GSA Planetary Geology Division; GSA Karst Division; GSA History, Philosophy, and Geoheritage Division; GSA Quaternary Geology and Geomorphology Division; Association for Women Geoscientists; NAGT Teacher Education Division (TED); NAGT Geoscience Two-Year College Division (Geo2YC); GSA Hydrogeology Division; GSA Geobiology and Geomicrobiology Division; History of Earth Science Society

P2. Groundwater in Achieving the Sustainable Development Goals

Monday, 20 October

Time: 1:30–5:30 p.m.

Conveners: Abhijit Mukherjee, David Kreamer, Prosun Bhattacharya, Timothy Parker, and Donald O. Rosenberry

The growing impact of changing climate and land use, and water pollution has underlined the link between groundwater, environment, and society. This Pardee Session reinforces the importance of groundwater in achieving the sustainable development goals.

Endorsed by: GSA Hydrogeology Division; International Association of Hydrogeologists; International Society of Groundwater for Sustainable Development (ISGSD); GSA International; GSA Geology and Society Division; Mineralogical Society of the UK and Ireland; International Medical Geology Association; International Association for Promoting Geoethics (IAPG); American Geophysical Union (AGU); GSA Continental Scientific Drilling Division; GSA Karst Division; GSA Geoinformatics and Data Science Division; GSA History, Philosophy, and Geoheritage Division; Association of American State Geologists (AASG); International Association of Geomorphologists (IAG); GSA Geobiology and Geomicrobiology Division; History of Earth Science Society

P3. Geoheritage Without Borders: International Perspectives on the Conservation and Celebration of Geodiversity

Tuesday, 21 October

Time: 1:30–5:30 p.m.

Conveners: Priscilla Grew, Jack J. Matthews, John H. Calder, Carles Canet, Mauricio Faraone Pimenta, Maria da Gloria Motta Garcia, and Sherene James-Williamson

Every nation has a story to tell about its geodiversity—but what are best practices to promote conservation of our geoheritage? This GSA-ProGEO Western Hemisphere session explores innovative partnerships to conserve geoheritage and celebrate geodiversity.

Endorsed by: GSA History, Philosophy, and Geoheritage Division; GSA International; GSA Geology and Society Division; GSA Environmental and Engineering Geology Division; GSA Geoscience Education Division; National Earth Science Teachers Association; International Association of Hydrogeologists; Mineralogical Society of the UK and Ireland; Society for American Archaeology; Mineralogical Society of America; International Medical Geology Association; International Association for Promoting Geoethics (IAPG); Spanish Geological Society - Geoheritage Commission; American Geosciences Institute; American Geophysical Union (AGU); GSA Geoarchaeology Division; GSA Planetary Geology Division; GSA Karst Division; GSA Quaternary Geology and Geomorphology Division; Association for Women Geoscientists; GSA Hydrogeology Division; Association of American State Geologists (AASG); International Association of Geomorphologists (IAG); History of Earth Science Society

P4. Impact Cratering and the Evolution of Life

Wednesday, 22 October

Time: 8–11:45 a.m.

Conveners: Nadja Drabon and David Kring

This session explores the role of impact cratering in life's evolution throughout Earth's history, from the origin of life to mass extinctions. It highlights connections between impacts, evolutionary change, and planetary processes.

Endorsed by: GSA Geobiology and Geomicrobiology Division; GSA Sedimentary Geology Division; GSA Planetary Geology Division; American Association of Petroleum Geologists; SEPM (Society for Sedimentary Geology); Mineralogical Society of the UK and Ireland; International Medical Geology Association; Cushman Foundation for Foraminiferal Research; American Geophysical Union (AGU); GSA Geophysics and Geodynamics Division; GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division; GSA Continental Scientific Drilling Division; GSA Geoinformatics and Data Science Division; GSA Geochronology Division; GSA History, Philosophy, and Geoheritage Division; Paleontological Society; History of Earth Science Society

Information for Presenters

https://connects.geosociety.org/program/technical-sessions/presenter-info

If you're presenting at GSA Connects 2025, we've got you covered. Find key details, important deadlines, presentation guidelines, and helpful tips to ensure you're fully prepared for your session.

General Guidelines

All presenters must register for the meeting. Sessions will be held at the Henry B. González Convention Center.

Recording Policy: GSA's Events Code of Conduct allows for recordings/photos of presentations UNLESS the presenter has communicated that recordings are not allowed. Use the "No Recording" logo if you do not want to allow recordings.

Expected Behavior: Abstract presenters agree to abide by the abstract conduct requirements.

https://www.geosociety.org/GSA/Events/EventConductCode/GSA/Events/Conduct.aspx

Oral Presenters

Duration: 15 minutes (12 minutes plus 3 minutes Q&A).

Equipment: PC with MS Office 2016, prepare presentations in 16:9 ratio.

Deadlines: Upload presentations by specified times.

File Types: Acceptable formats include PowerPoint, Word, and PDF.

Preparation: You must visit the Speaker Ready Room at least 24 hours before your scheduled presentation to upload your presentation, practice using the equipment, and find technical support.

Poster Presenters

Display: 8-ft-wide by 4-ft-high board, push pins and Velcro provided.

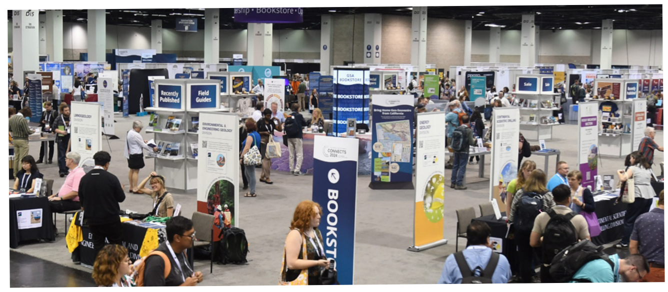
Poster Size: You can make a printed poster on any material and at any size that is not bigger than 4x8 feet (122x244 cm) in landscape orientation.

Session Times: 8 a.m.–5:30 p.m., with presenting slots 9–11 a.m. or 3:30–5:30 p.m.

Wi-Fi: Available in the poster hall.

Removal: Posters must be removed at the end of the day of your session.

Design: Check with colleagues or advisors for best practices or view our "How to Make Your Poster Stand Out" guide.



Exhibitors

Check out the interactive map of Connects exhibitors at **https://s2.goeshow.com/gsa/annual/2025/exhibitor_exhibit_map.cfm**.

Speaker Ready Room

Located at the Henry B. González Convention Center (Room 220).

If you are unable to get to the Speaker Ready Room to upload your presentation, please take your presentation directly to your session room at least 30 minutes before the session is scheduled to begin.

The Speaker Ready Room does not have internet service.

Test your Mac-produced presentation on a Windows-based system before coming to the meeting. The Keynote software is not supported as all presentations must run on a Windows-based system.

Explore the Geoscience Frontier with GSA Field Trips

https://connects.geosociety.org/program/field-trips

Step into the landscape and experience geology first-hand with Connects 2025 San Antonio field trips! This year's lineup brings you from the Permian reef of Guadalupe Mountains National Park to the carbonate platforms of the Trans-Pecos, the seismic fault zones of central Texas, and the K/Pg boundary along the Brazos River. Dive into topics like cave monitoring, energy production, planetary analogs, geoarchaeology, and hydrogeology—all led by top researchers and educators.

Whether you're interested in tectonics, volcanology, paleoclimate, sedimentology, or sustainable resource use, there's a trip for every interest and career stage. Many trips offer CEUs and are designed with students and early career professionals in mind—at accessible prices and incredible scientific value.

Level Up at GSA Connects 2025 with a Short Course!

https://connects.geosociety.org/program/short-courses

Advance your career with high-impact, hands-on learning. GSA short courses offer in-depth training led by experts across a wide range of geoscience topics—from field mapping and data analysis to science communication and geotourism. GSA short courses are the fastest way to sharpen your skills, grow your network, and stay current in the geosciences. Whether you're looking to explore digital outcrops, map landslides with LiDAR, or dive into the geochemistry of critical minerals, there's a course for you.

Student members save 50% on most courses—some are even free! Courses are held in person and online, with CEUs available for all. Spots fill fast, so don't miss your chance to join experts and peers in these dynamic, career-boosting sessions.

Earn CEUs and Explore the Field with GSA Connects 2025

Looking to boost your skills, gain field experience, and earn Continuing Education Units (CEUs)? GSA Connects 2025 in San Antonio has you covered. Earn CEUs by attending the meeting itself, plus add more through short courses and field trips. Choose from cutting-edge short courses—AI in geoscience, geospatial analysis, stratigraphy, science communication, and more—or step into the field to explore Texas' karst systems, impact craters, reef complexes, and geoarchaeological sites.

Advance your career, connect with peers, and experience geoscience in action. Learn more and register at **https://community.geosociety.org/gsa2025/home** or contact **shortcourse@geosociety.org** / **fieldtrip@geosociety.org.**

INTERNATIONAL MEMBERS:

Discount for Members of GSA's Associated Societies to Attend Connects 2025

GSA is proud to partner with 89 Associated Societies (AS) around the world—and to recognize their ongoing contributions to geoscience, we're offering a 15% registration discount for all AS members planning to attend GSA Connects 2025. This offer is still open—don't miss your chance to take advantage!

How to access your discount:

Each Associated Society has received a unique discount code to share with its members.

To claim the discount, contact your society for the code and enter it when registering for GSA Connects 2025. The 15% discount applies across all registration periods: early, standard, and late.

Not sure if your society is affiliated with GSA? Check the full list here: www.geosociety.org/GSA/GSA/About/Associated_Societies.aspx

Global Geoscientists—Your Invitation to Connects 2025 Just Got More Affordable!

Are you an international geoscientist? Don't miss this major opportunity to attend one of the world's leading geoscience conferences—at a fraction of the cost!

GSA is committed to making global scientific exchange more accessible. If you are from an upper-middle-income, lower-middle-income, or low-income country (the World Bank's economic classification), you are eligible for deeply discounted registration rates to attend GSA Connects 2025.

Here's what you get:

50% off for participants from upper-middle-income countries

75% off for participants from lower-middle-income and low-income countries

To claim your discount:

Check your eligibility here: geosociety.co/MembershipDues

Fill out this form before registering: geosociety.co/ConnectsDiscountCodeRequest

You'll receive a unique discount code via email within 1–2 business days.

Use the code during registration to unlock your discount!

Questions? Contact gsa_international@geosociety.org.

STUDENTS:

The Geological Society of America®
GEOCAREERS

GSA's GeoCareers program, one of GSA's most successful initiatives, helps students and early career professionals explore career options, build skills, and connect with mentors and employers.

GeoCareers Day

Sunday, 19 October | 9 a.m.–1 p.m.
$20 (includes lunch)

If you are entering the job market, supporting someone who is, or just want more information on the types of nonacademic geoscience careers available in industry or with the federal government, you'll want to attend this series of events. Registration is required—sign up under "Ticketed Events" when you register for GSA Connects online.

- Geoscience Career Workshop
- Company Connection
- Mentor Roundtables
- GeoCareers Panel Luncheon

Be a Mentor!

Meet with students to hear their stories, and share your own. Whether you are early or mid-career, or recently retired, you have wisdom that will help young geoscientists find their paths. GSA Connects offers many ways to get involved:

- 1:1 Résumé/CV Review
- 1:1 Mentoring Sessions
- GeoCareers Day Table Mentor
- Women in Geology Program Mentor

Sign up at https://bit.ly/3USbUNI.

GeoCareers Corner

Sunday–Tuesday,
19–21 October | 9 a.m.–5 p.m.
Open to All Attendees

Everyone registered for GSA Connects 2025 is welcome to visit the GeoCareers Corner, where you'll find one-on-one mentoring, career presentations, special networking events, and a space to pause and relax in the midst of a busy conference.

- Career Presentations
- 1:1 Résumé Review Sessions
- 1:1 Mentoring
- Early Career Professional Coffee
- Geology Club Meet-Up
- Women in Geology Reception
- Post or View Job Listings

Thank You Sponsors and Partners!*

Your support of GSA Connects 2025 continues a longstanding tradition of serving science and the profession.

The society appreciates your investment in the growth of current and future leaders in the geoscience community.

**as of 9 September 2025*

The Geological Society of America
Structural Geology & Tectonics Division

The Geological Society of America
Quaternary Geology & Geomorphology Division

The Geological Society of America
Geochronology Division

The Geological Society of America
Energy Geology Division

The Geological Society of America
Geoarchaeology Division

THE GEOLOGICAL SOCIETY OF AMERICA®

CONNECTS 2025

SAN ANTONIO, TEXAS, USA

19–22 OCTOBER

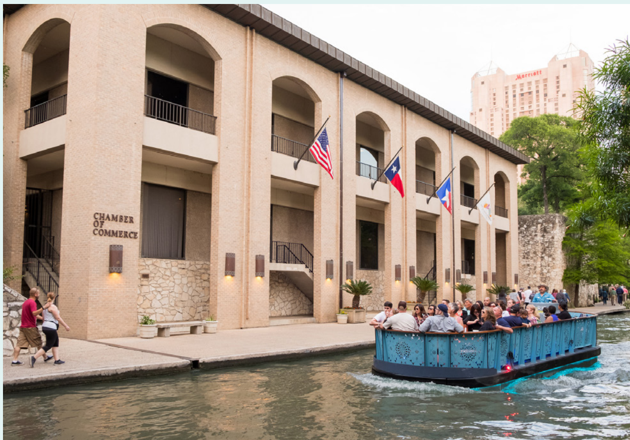
Join Geoscience Leaders at GSA Connects 2025 as an Exhibitor or Sponsor!

GSA Connects 2025, taking place 19–22 October in San Antonio, Texas, USA, will bring together a broad cross section of scientists from the international geoscience community. As an exhibitor, you will connect with industry representatives, professors, researchers, government employees, and talented students—the future leaders in the geoscience industry and academia.

Showcase your latest technologies, services, and innovations to:

- Develop Partnerships: 50% of attendees have 11+ years of experience
- Build Talent: 40% of attendees are students seeking opportunities
- Gain Global Recognition: Attendees from 49 countries in 2024

Purchase your booth in the Exhibit Hall, amplify your brand through sponsorship, or advertise to approximately 34,000 geoscience professionals and students at https://s2.goeshow.com/gsa/annual/2025/ or contact exhibits@geosociety.org.



On to the Future

The **On To the Future (OTF)** program will be hosting several events for OTF scholars at Connects!

On To the Future: Pre-Icebreaker Meetup
Saturday, 18 October | 3:30–4:30 p.m.

OTF scholars will have a chance to connect and mingle with their cohort before heading to the GSA Icebreaker.

On To the Future: Meet-Up
Sunday, 19 October | 6–7:30 p.m.

OTF scholars will connect with their OTF mentors to continue discussions and activities initiated in the OTF Orientation.

On To the Future: Associated Societies Exposition
Monday, 20 October | 5–7 p.m.

OTF scholars will have the opportunity to speak and network with GSA associated societies representatives and gain a deeper understanding of the importance of associated societies and how they can support career development.

Diversity in the Geosciences & OTF Reception
Tuesday, 21 October | 6–7:30 p.m.

OTF scholars are invited to attend the annual OTF and Diversity Reception where they will be recognized as a 2025 OTF scholar.

Receptions are free and all are invited, but preregistration is required! Reach out to **excel@geosociety.org** by midnight Sunday October 19th.

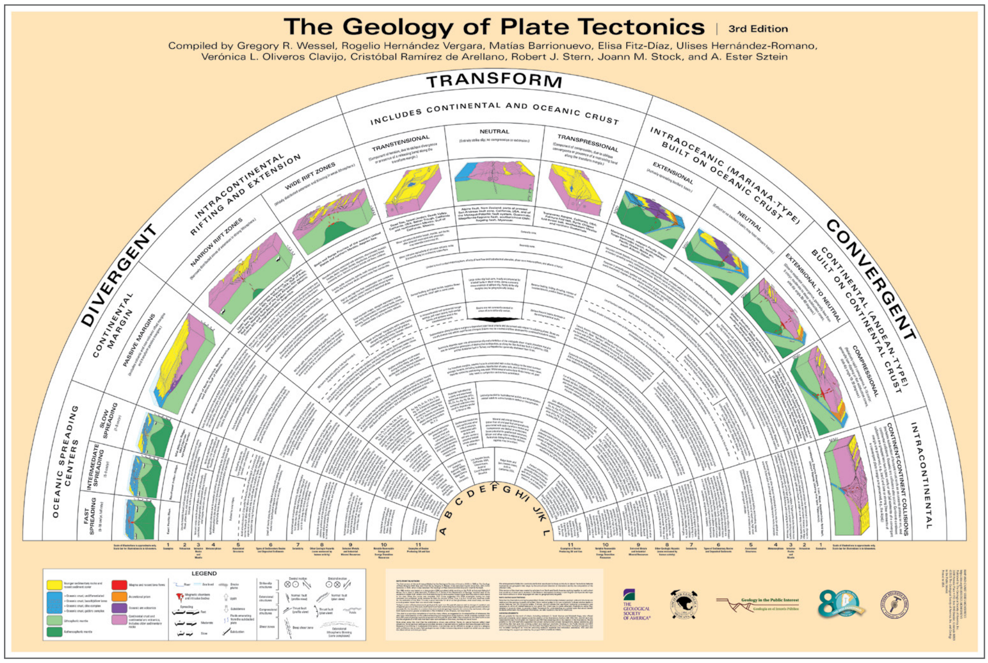
Congratulations to all of our OTF scholars for 2025! We look forward to seeing you at Connects!

OTF Silent Auction

The **On To the Future (OTF)** program will once again be hosting a silent auction with photographic works submitted by OTF scholars and alumni! All proceeds will benefit the OTF program. The auction will take place outside the ballroom at Connects. Come join us in celebrating the talent of our OTF scholars and support the mission of the program!

Photo by Samuel Bona, previous OTF Silent Auction participant.

Updating a Landmark Geoscience Resource



The *Geology of Plate Tectonics* chart has long been a trusted educational tool for understanding Earth's dynamic processes. This year, a diverse team of international authors—representing the Mexican Geological Society, Chilean Geological Society, Argentinian Geological Association, Geology in the Public Interest, and the Geological Society of America—worked together to produce a fully updated version. The new chart incorporates the latest scientific advances, is peer reviewed, and now also available in Spanish to support teaching and outreach across Latin America. Both English and Spanish editions will debut at the GSA Connects 2025 bookstore, accompanied by a special talk from the chart's original author, Gregory R. Wessel.

Authors: Gregory R. Wessel, Rogelio Hernández Vergara, Matías Barrionuevo, Elisa Fitz-Díaz, Ulises Hernández-Romano, Verónica Oliveros Clavijo, Cristóbal Ramirez de Arellano, Robert J. Stern, Joann M. Stock, and A. Ester Sztein.

To capture the story behind this collaborative effort, we spoke with the authors about their experience updating the chart and its significance for the geoscience community.

CAN YOU TELL US A BIT ABOUT THE ORIGINAL PLATE TECTONICS CHART—HOW AND WHEN IT WAS CREATED?

"I was working on my PhD in geology at Colorado School of Mines in the mid-1980s when I took a class on plate tectonics from Prof. T.L.T. Grose. A class project that he assigned for the semester was for each student to create a summary chart of plate tectonic features, including margin types and other significant structures, that he would be covering in lectures and through referenced articles that he assigned for reading. He showed some examples of past charts, and all looked like standard Excel spreadsheets. I thought at the time that a semicircular arrangement would be more appealing, so I submitted a version to him that looked very much like what was later published in 1986. Prof. Grose liked it so much that he told me that I should investigate to see if I could get it published, and he suggested the CSM Press, which was then publishing its *Quarterly*. They agreed to print it but could not print it in color. Instead, I went to the GSA's Map and Charts Editor at that time, J.C. Reed, Jr., and he told me that they would accept it in color, but that it would need further review and editing. It was then that I embarked on a greater effort to assemble reviewers, drawing from contacts in the USGS, industry, and academia. I found 16 esteemed reviewers who were happy to assist, and who are listed in the acknowledgments of the 1986 edition. The final approved draft, which was roughly drawn by me, was turned into a camera-ready copy by Ann Priestman of Littleton, Colorado, an artist and meticulous draftsman. She created a handmade version that was a little larger than the finished print, to be reduced to the proper scale when printed. The GSA received support from the USGS for the color separation, and we were off and running. That this chart has been in print since 1986 just amazes the heck out of me. Based on that history, I can predict that the new edition should last for another 25 years at least." —Greg Wessel

HOW DID THE IDEA OF UPDATING AND TRANSLATING THE CHART COME ABOUT?

“The idea of translating it came from a discussion with GSA staff before the pandemic. We all thought that given the nature of the chart and its long history, it would be natural to translate, at least into Spanish. I think it was the pandemic that kept us from doing it sooner, and by then it was also clear that we’d need to update the text significantly, because some of the science was outdated.” —Greg Wessel

WHY WAS NOW THE RIGHT TIME TO REVISE THE PLATE TECTONICS CHART?

“It was clear even before the pandemic that the chart was overdue for a revision. In the first two decades of the 2000s, a lot of new work was published that resulted in modifications to our general view of plate tectonics and added details that were not apparent before. In addition, the emphasis of the 1986 chart with respect to applied geology was mining and petroleum, reflective of the priorities at that time. Since then, the emphasis has changed to include engineering and environmental geology, geologic hazards, and selected natural resources necessary for the transition away from fossil fuels, with less emphasis on fossil fuels and mining in general.” —Greg Wessel

“It’s crucial to have a translation carried out by Spanish-speaking specialists. This also offers practical benefits: if a new edition of the tectonic chart is produced, the translation time will be optimized.” —Rogelio Hernández Vergara

“Over the last 25 years, substantial progress across various earth sciences disciplines—including sedimentology, geochemistry, seismic modelling, geochronology, petrology, and structural geology—as well as diverse ocean drilling programs has significantly advanced our comprehension of tectonic processes and plate anatomy. To ensure this knowledge remains current, it must be periodically synthesized into educational tools, such as the plate tectonics chart, across the U.S. and overseas. This comprehensive reference will prove invaluable by providing a theoretical framework for natural resource exploration, geological hazards, and providing essential foundational knowledge for earth science students and professionals embarking on the energy transition.” —Elisa Fitz Díaz

“I believe that after 40 years since the first edition and 20 years since the last update, the chart required some changes, not because of inaccuracies but to incorporate new information related to tectonics, hazards, critical resources, etc.” —Matías Barrionuevo

WHAT WAS THE MOST CHALLENGING ASPECT OF UPDATING AND TRANSLATING THE CHART?

“For me, all of it was equally challenging but also rewarding in that I was able to work with an amazing group of co-authors and learn from them the latest in plate tectonics. I think in the wider scheme of things, the person who really had the most challenging task was Ester Sztein, who assembled co-authors from two continents and herded us through the process.” —Greg Wessel

“The development of updated drawings and models, incorporating new criteria and specifications, is also a key part of this process.” —Rogelio Hernández Vergara

“Agreeing on the content of the chart and translating some words that, at least among Spanish-speaking geoscientists, are commonly used in English.” —Verónica Laura Oliveros Clavijo

“To create a self-explanatory figure illustrating the main elements and processes at key stages of plate margin evolution, a deep understanding of how convergence, rifting, and transcurrent faulting affect tectonic plate anatomy is crucial. Envisioning such rich and integrated images as a group was, perhaps, the biggest challenge in this exercise.” —Elisa Fitz-Díaz

“Probably trying to fit the words, and reducing the text while keeping its content accurate. Also, I think the excellent updates in figures done by our colleagues Rogelio and Greg were a remarkable piece of work.” —Matías Barrionuevo

WERE THERE ANY SURPRISING DISCOVERIES OR INSIGHTS THAT EMERGED DURING THE PROCESS? ANYTHING THAT CHALLENGED YOUR EXPECTATIONS OR SPARKED NEW THINKING?

“Yes, in that I had to shift my frame of reference about 20 years (at least) forward and incorporate changes in the definition and characteristics of some of the described geologic features to accommodate a contemporary view of the planet. A good example was shifting my thinking around what used to be called ‘intracontinental backarc spreading,’ the example being North America’s Basin and Range Province. It’s now referred to as an example of ‘wide rifting,’ with which I still struggle.” —Greg Wessel

“Honestly, I didn’t know much about tectonics, and the entire process was incredibly significant for me. I learned a great deal and gained insights from the opinions of experts from various parts of the

Americas. I believe the most important thing I learned from this exercise was how closely the dynamics of the Earth's crust are linked to mantle activity, and how this has very significant repercussions for all the surface processes we observe." —Rogelio Hernández Vergara

"It was amazing to review the chart's content alongside its author, Greg Wessel, and deep-thinking tectonics specialists like Joann Stock and Bob Stern, as well as my colleagues from South America. I gained significant insights from every section of the chart." —Elisa Fitz-Díaz

"While looking at the PDF version of the previous chart, I realized that developing an app or interactive content developed based on it would be highly beneficial, especially for students in Latin America. Purchasing the physical chart might be inaccessible to many, but having it on the palm of the hand would be valuable. I imagine the app with both versions, in English and Spanish, as a complementary tool to help students learn geology terms in English." —Matías Barrionuevo

WHY IS TRANSLATING THE CHART INTO SPANISH IMPORTANT? DO YOU FORESEE TRANSLATIONS INTO ADDITIONAL LANGUAGES IN THE FUTURE?

"It's an important publication for educational purposes, and as such it will have a much wider audience translated into languages other than English. I think that we could do versions in Hindi, Arabic, French, Portuguese, and Chinese, but there might also be markets for other languages. Once we have the digital file created, our only limit may be finding people who can do the translating." —Greg Wessel

"The translation into Spanish is of utmost importance because it's the third most spoken language in the world, after Chinese and English. It's essential that these updated concepts reach all earth science and geology students, as we're talking about a revolution in knowledge. It's vital that this information is as accessible and easy to understand for everyone as possible." —Rogelio Hernández Vergara

"I can answer that question only from the perspective of a non-U.S. scientist: because Spanish-speaking students outside the U.S. are not so familiar with English." —Verónica Laura Oliveros Clavijo

"Although Latin America produces globally competitive science, we still lack the quantity and diversity of research resources available in the United States for cutting-edge scientific work. Consequently, professors in this region heavily rely on English-language texts, which we then have to translate to update our course content. The simultaneous translation of this text into Spanish, alongside the update of its English content, is essential. It means that Earth science students in Latin America will gain direct access to a current and concise reference framework on plate tectonics—something that, to my knowledge, hasn't happened before with learning material produced by the GSA. This initiative therefore marks a milestone in the global impact a GSA publication can achieve. For this reason, I believe it should also be translated into other languages." —Elisa Fitz-Díaz

"I wasn't aware of the chart and sadly never saw it hanging on a wall in a classroom in Argentina. But I found the chart a nice tool for students where they can have a grasp of several key concepts about tectonics in a nicely designed poster. So having it translated to Spanish is very important to reach Spanish-speaking audiences. Probably, translating into Portuguese could be valuable as well." —Matías Barrionuevo

"I'm sure that this translated chart will be very helpful for our students in Chile. It's common to see them using incorrect terms from Google translator or ChatGPT." —Cristóbal Ramírez de Arellano Melo

HOW DO YOU ENVISION THIS CHART BEING USED?

"Mostly as a classroom exhibit and reference, but also as a display in office settings and as a personal reference for geoscientists and anyone interested in the topic. It should be inexpensive enough to be of value to a wide audience within the general population." —Greg Wessel

"This chart can be used in many ways: in basic classes, at conferences, in scientific articles, and at science fairs. It has the advantage of explaining very technical and sophisticated earth science concepts in a very approachable manner." —Rogelio Hernández Vergara

"I would love to see the plate tectonics chart framed and prominently displayed in many professors' offices, and adorning the bedrooms and study spaces of students. It would serve as an invaluable summary for studying for midterm and final exams. I envision the chart gracing the hallways of earth sciences departments, becoming the focal point of interesting and even passionate discussions, and sparking countless individual scientific epiphanies." —Elisa Fitz-Díaz

"Hopefully in classrooms as a teaching and learning tool. Also in companies related to geology (water, oil, mining, etc.)." —Matías Barrionuevo

WHAT DOES THIS PROJECT MEAN TO YOU PERSONALLY AS A SCIENTIST?

"For me, it's a way to leave a legacy. It's a small contribution, really, but it's a way for me to leverage a part of my geology experience to benefit the common good." —Greg Wessel

"For me, this project represents a very noble and human form of international collaboration, focused solely on the improvement of science, education, and teaching, without economic interests. It also means a lot that everyone shares their vision as experts on the topic without any desire to impose their views." —Rogelio Hernández Vergara

"I'm honoured to have had the chance of taking part in this project, because I think the chart will be useful for Chilean students." —Verónica Laura Oliveros Clavijo

"It meant so much to share a semester of intermittent meetings, diving deep into a fascinating subject I first learned about 27 years ago in Mexico. Back then, the plate tectonics theory was still gaining acceptance, with more doubts than certainties surrounding it. Reviewing these concepts alongside remarkable, world-class scientists was an invaluable experience for me, both as a Structural Geologist and as a professor. It helped me connect previously scattered ideas and concepts, and truly fill in the gaps in my understanding of plate tectonics. The group was absolutely fantastic; it's been my privilege spending this time with Greg, Joann, Bob, Cristóbal, Matías, Verónica, Rogelio, and Ester. Ester, especially, was an outstanding group coordinator and the perfect 'glue' connecting the American and Latin American scientists on this project." —Elisa Fitz-Díaz

"I am a senior scientist, and I am concerned about how many things new students have to learn. Something like this makes it easier for them I think. At least that is the hope." —Robert Stern

"I'm truly thankful for the opportunity to be part of this nice international and diverse team. I learned a lot, and I found a question that emerged several times: 'Who is this chart for, and what do we aim to communicate?' [It] made me realize that I should keep these questions in mind for every talk, manuscript, project I prepare in the future." —Matías Barrionuevo

CAN YOU SHARE A MEMORABLE OR EVEN HUMOROUS MOMENT FROM WORKING TOGETHER ON THIS PROJECT?

"Because of adverse political conditions surrounding science in general and funding of scientific research, Americans are now greatly hampered when working in international settings. We feel less than adequate and are worried that our actions may be misinterpreted. What I find most memorable about my work on this project is the generosity and understanding of those outside the U.S. when working with us. Everyone was friendly and happy to be there. They all seemed to understand how we felt. We said little about it, concentrating on the tasks at hand, and although it was never openly stated, we all recognized that it is more important now than ever to find ways to share our science and work toward a greater good. We must reinforce those connections between us and make new ones, and this project is one example." —Greg Wessel

"The most memorable aspect was everyone's accessibility when proposing something. Even when there were mistakes, or outdated terms or ideas, colleagues always helped explain the 'why' and the reasons behind the new ideas or trends." —Rogelio Hernández Vergara

"I liked the process of commenting on the sketches a lot. Rogelio did a great job by putting together people's ideas." —Verónica Laura Oliveros Clavijo

"I value every bit of the experience, as this group included not only very intelligent people, but also first class human beings." —Elisa Fitz-Díaz

"Continuing discussions about deadlines and quality. The unusual design made it complicated to figure out the optimum numbers of words for each entry. Discussions about who the intended audience is were also illuminating." —Robert Stern

"I recall how our dear shepherd (Ester) kept us on track with a clear focus to accomplish this task. I appreciate her vision for this project and enjoyed our work also with the translating team. I appreciate how Greg humbly opened the chart to all of us to contribute to this update, as it was—and it is—his creation, one that has had a lasting impact on the geoscience community." —Matías Barrionuevo

THE GEOLOGICAL SOCIETY OF AMERICA®

Introducing participants to field geology and geological mapping was part of the strategy to build confidence and self-efficacy to help them navigate their geoscience journey.

Broadening Participation in the Geosciences: Insights and Recommendations from Recent Efforts Focusing on Transfer Students in Oregon

Shanaka de Silva,[1,*] Deron Carter,[2] Susan Eriksson,[3] Eduardo Guerrero,[1,4] Lynette de Silva,[1] Robert Duncan,[1] and Dawn Wright[1,5]

INTRODUCTION

Underrepresentation of minority groups in science, technology, engineering, and mathematics (STEM) fields, particularly in the geosciences, remains a systemic issue in the United States, resulting in low college enrollment and workforce representation (Bernard and Cooperdock, 2018; Dutt, 2020). Addressing this issue is critical for a workforce that reflects the population and enhances economic competitiveness and fosters innovation. Two-year colleges (2YCs) have diverse student populations (AACC, 2024) who are critical to the geosciences pipeline, as transfer students constitute ~27% of geoscience degree earners (Wilson, 2018). However, this can be improved since many 2YC students drop out of the pipeline because of the significant challenges faced by first-generation college attendees, single parents, and those balancing work and education, and they often experience delayed graduation rates (Wolfe, 2018).

Mentored, paid research internships are key strategies for engaging transfer students and enhancing their success (Blake et al., 2013; Hodder et al., 2015; Karsten, 2019; Di Leonardo et al., 2022). At Oregon State University, a four-year college/university (4YCU), 46% of geoscience majors from 2010 to 2020 were transfer students. During this period, two programs in Oregon funded by the U.S. National Science Foundation (NSF)—Increasing Diversity in Earth Sciences (IDES) and Linn-Benton–Oregon State Geobridge—sought to enhance the success of some of these students, thereby contributing to broadened participation in the geosciences. Herein, we share our approach and outcomes and offer insights and recommendations as a community resource.

THE PROGRAMS

Our programs used holistic application evaluations and were intentionally designed to recruit participants who were potentially "at risk" due to challenges such as financial insecurity, family commitments, and the academic and social disorientation known as "transfer shock" (Thurmond, 2007).

*desilvsh@oregonstate.edu
[1]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, Oregon 97331, USA
[2]Department of Physical Sciences, Linn-Benton Community College, Albany, Oregon 97321, USA
[3]Eriksson and Associates, Davis, California 95618, USA
[4]Department of Geology and Mineral Industries, Portland, Oregon 97232, USA
[5]Environmental Systems Research Institute (ESRI), Redlands, California 92373, USA

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Table 1. Key elements of the Increasing Diversity in Earth Sciences (IDES) and Linn-Benton-Oregon State Geobridge (LBOS-Geobridge) Programs

	IDES	LBOS Geobridge
Provide continuous, multiyear, funded engagement	• Individual mentored research on themes that resonate with stated student interest • Academic, state and federal agency, and informal education/ outreach institution mentors	Cohort research project in first year; subsequent employment in the same laboratory or individual research projects with mentors
Enhance soft and hard skills to reduce transfer shock and increase their self-efficacy	• Initial geographic information systems (GIS) "Boot Camp" • Field trips • Seminar series • Team-building activities • Peer mentoring in classwork	• Short courses in mineralogy, petrology, introduction to field geology • Field trips • All the above, emphasizing connections to cognate sciences • Peer mentoring in classwork
Inculcate technical and marketable skills related to geoscience employment	• Initial GIS Boot Camp • Professional soft skills through project reports, theses, presentations	• Advising to take GIS courses or certificates • Training in Python coding • Professional soft skills
Increase participant access to academic and professional networks	• Research seminars and topical geological career seminars • Interning with academic institutions, state and federal agencies, informal education outreach institutes	Research seminars and topical geological career seminars

IDES and Geobridge programming (Table 1) emphasized multiyear, funded engagement to provide stability and reduce financial pressures. To help students build confidence and self-efficacy in the geosciences, the program offered focused training to develop both soft and hard skills as well as technical and marketable skills for future geoscience careers, while also expanding their academic and professional networks. Peer-mentoring and team-building activities were central efforts to fostering a sense of community, addressing the isolation many transfer students experience.

IDES, operating from 2010 to 2013 at Oregon State University, brought together two- and four-year colleges, government agencies, and outreach centers. It introduced participants to geospatial tools for exploring earth science topics and then provided two-year, individual mentored research experiences. The program recruited 41 students, 83% of whom were from underrepresented groups. Nearly 60% were female, and 47% identified as ethnic minorities. The participants' pre-entry grade point averages (GPAs) ranged from 2.5 to 4.0, reflecting a wide range of academic backgrounds.

Building on IDES, from 2016 to 2019, Geobridge connected Linn-Benton Community College (LBCC) students to Oregon State University (OSU) through extracurricular activities to ease the transition. Cohorts worked on place-based group research projects. Participants included veterans, first-generation college students, individuals re-entering higher education, and students with disabilities. Of this diverse group, 15% were underrepresented minorities, 61% were female, and pre-entry GPAs ranged from 2.5 to 4.0.

OUTCOMES

Evaluation through a mixed-method approach revealed the value of tailored, supportive approaches in addressing the needs of transfer students. In both programs, students excelled in gateway geology courses, surpassing the course average, and participants reported feeling better prepared and less disoriented upon transfer, contributing to their success in subsequent courses. In IDES, 83% of participants completed two or more years in the program, with 30 (73%) graduating with a bachelor of science (B.S.) degree within 2.5 yr. In the Geobridge program, 11 of 13 students completed two years in the program, with 7 (54%) eventually earning their B.S. degree.

In both programs, long-term research experiences improved participants' career outlook. The continuity provided by multiyear funding provided deeper mentoring, enhanced research skills, and increased academic success. Many participants expressed heightened aspirations for graduate school and research careers, with experiences solidifying their academic interests and competitiveness. Likewise, 21 (57%) of the participants are known to have continued in earth science after obtaining their B.S. degree.

The programs strengthened students' self-efficacy in geoscience. By introducing students to OSU faculty and peers before transferring, they developed a stronger sense of belonging, increasing their likelihood of persistence in the geoscience major. All participants reported increased confidence and clearer career pathways. Mentors recognized the value of including transfer students in research, noting their significant contributions. This led to a broader understanding of the need for inclusive recruitment, beyond traditional metrics.

The impact of IDES and Geobridge extended to the culture at both institutions, LBCC and OSU. Faculty collaboration on grant writing and program development enhanced support for transfer students. These efforts influenced OSU's initiatives, with core elements incorporated into new programs like OSU STEM Leaders (https://stemleaders.oregonstate.edu/) and the ARC-Learn project (https://ceoas.oregonstate.edu/arc-learn).

INSIGHTS AND RECOMMENDATIONS

IDES and Geobridge demonstrated how partnerships between 2YCs and 4YCUs can support transfer students in geosciences, providing a supportive community and strategies to help students navigate transfer shock and succeed academically (e.g., Hodder et al., 2015). We found that:

Successful partnerships require significant investments of time and resources from both institutions, along with strong transfer agreements to ease credit transfers and lower systemic barriers.

Collaboration between 2YC and 4YCU geoscience departments is crucial for curriculum development, advising, and fostering relationships.

Involving geoscience employers and nonacademic institutions, such as museums and K–12 schools, exposes students to diverse career paths and professional networks, aiding their workforce transition.

Research experiences should be tailored to meet the particular needs of transfer students. Offering local or remote participation options, along with stipends, can help to address these challenges.

Adequate funding is vital for these programs' success, particularly for multiyear engagements. Students often lack the resources to cover program costs and need full financial support. Funding can come from external sources, institutional support, and/or private philanthropy.

Sustainability is a key challenge. Whereas partnerships can help to sustain efforts, continued hard support is essential once external funding ends. Embedding these initiatives into the culture and strategic plans of institutions, and incentivizing faculty involvement, is crucial for ensuring long-term success.

We hope this contribution may be useful to others seeking to foster collaborations between 2YC and 4YCU geoscience programs (SAGE, 2020) and broaden participation in geosciences as well as other STEM and non-STEM fields.

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MANUSCRIPT RECEIVED 6 FEBRUARY 2025
MANUSCRIPT ACCEPTED 20 AUGUST 2025

Call for Nominations

2026 GSA Awards & Medals

GSA selects individuals based on track record and commitment to integrity and promise to continue living up to the ethical standards embodied in GSA's Code of Ethics & Professional Conduct, in addition to their many accomplishments.

The deadline for receipt of all medal, award, and recognition nominations is 15 February 2026. Please see required documents for each award nomination at https://www.geosociety.org/GSA/About/awards/nomination/GSA/Awards/Nominate.aspx
Contact: awards@geosociety.org

HOW TO NOMINATE

To ensure thorough consideration by the respective committees, please follow these nomination instructions carefully; additional information supplied will not enhance the nomination.
Nomination Form: Complete the online form at **https://bit.ly/ 3XkfzXl** for all awards.
Supporting Documents: Submit via email to **awards@geosociety.org** unless specified otherwise.

Required supporting documents include:
- Curriculum vitae
- Letter of nomination (300 words or less)
- Additional supporting documents as listed for each award below.

PENROSE MEDAL

The Penrose Medal was established in 1927 by R.A.F. Penrose Jr. to be awarded in recognition of eminent research in pure geology, for outstanding original contributions, or for achievements that mark a major advance in the science of geology. This award is made only at the discretion of the GSA Council, and nominees may or may not be members of the Society. Penrose's sole objective was to encourage original work in purely scientific geology, which is interpreted as applying to all scientific disciplines represented by GSA. Scientific achievements should be considered rather than contributions in teaching, administration, or service.

Mid-career scientists who have already made exceptional contributions should be given full consideration for the award.

Additional Supporting Documents
- Selected bibliography of no more than 20 titles.
- Letters of support from each of five GSA Fellows or Members in addition to the person making the nomination.

ARTHUR L. DAY MEDAL

The Day Medal was established in 1948 through a donation by Arthur L. Day, founding director of the Geophysical Laboratory of the Carnegie Institution of Washington. It is awarded annually, or less frequently at the discretion of the Council, to recognize outstanding distinction in the application of physics and chemistry to the solution of geologic problems, with no restriction to the particular field of geologic research. It was Dr. Day's wish to provide an award to recognize outstanding achievement in research and to inspire further effort, rather than to reward a distinguished career, and so it has been the longstanding practice of the Society to award this medal to geoscientists actively pursuing a research career.
Additional Supporting Documents
- Selected bibliography of no more than 20 titles.
- Letters from five scientists with at least three of those being from GSA Fellows.

YOUNG SCIENTIST AWARD (DONATH MEDAL)

The Young Scientist Award was established in 1988 to be awarded to a young scientist (35 years or younger throughout the year in which the award is to be presented—for 2026, only those candidates born ***on or after 1 January 1991*** are eligible) for outstanding achievement in contributing to geologic knowledge through original research that marks a major advance in the earth sciences. The award consists of a gold medal (the Donath Medal) and an honorarium.

Additional Supporting Documents
- Selected bibliography of at least 10 titles.
- Letters of support from each of five GSA Fellows or Members in addition to the person making the nomination.

GSA GEOLOGIC MAPPING AWARD in HONOR OF FLORENCE BASCOM

The Florence Bascom Geologic Mapping Award was approved by GSA Council in October 2013, and the first award was presented in 2015. This award acknowledges contributions in published high-quality geologic mapping that led the recipient to publish significant new scientific discoveries, to bring about greater understanding of fundamental geologic processes and concepts, and to contribute to the application of new knowledge to societal needs and opportunities in such areas as mineral resources, water resources, and the environment.
The recipient will have authored high-quality geologic maps, cross sections, and summary reports that have received scientific acclaim and are available to both peers and the public, through Federal or State agencies or major scientific societies. In evaluating the merits of nominees for this award, scientific achievements should be considered rather than contributions in teaching, administration, or service. Nominees may or may not be members of the Society, and they may be from any nation.

The selection criteria employed by the Geologic Mapping Award Committee are as follows: (A) excellence of the nominee's published geologic maps; (B) clear record of greater understanding of fundamental geologic processes and/or concepts, and high-quality publication of same, emerging directly from the meritorious quality of the geologic mapping; and (C) peer acclaim of the practical usefulness of the geologic mapping and the new discoveries that emerged from the mapping.

Additional Supporting Documents
- Selected bibliography of geologic maps (15 titles or less).
- Selected bibliography of peer-reviewed publications (20 titles or less).
- PDFs or website links to several key geologic maps authored by the nominee.
- Letters of support from three (3) GSA Fellows or Members in addition to the nominator letter. Diverse supporters (i.e., including individuals who are not currently/recently associated with the nominee's institution) are strongly encouraged.

RANDOLPH W. "BILL" AND CECILE T. BROMERY AWARD

The Bromery Award for Minorities should be given to any minority, preferably African Americans, who qualify under at least one of these two categories:

1. **Nominee has made significant contributions to research in the geological sciences, as exemplified by one or more of the following:**
   - Publications which have had a measurable impact on the geosciences
   - Outstanding original contributions or achievements that mark a major advance in the geosciences
   - Outstanding lifetime career which demonstrates leadership in geoscience research
2. **Nominee has been instrumental in opening the geoscience field to other minorities, as exemplified by one or more of the following:**
   - Demonstrable contributions in teaching or mentoring which have enhanced the professional growth of minority geoscientists
   - Outstanding lifetime career service in a role which has highlighted the contributions of minorities in advancing the geosciences
   - Authorship of educational materials of high scientific quality that have enjoyed widespread use and acclaim among educators or the general public

Additional Supporting Documents
- Letters of support from three (3) scientists with at least two (2) from GSA Fellows or Members and one (1) from a member of another professional geoscience organization.
- Optional selected bibliography of no more than 10 titles.

DORIS M. CURTIS OUTSTANDING WOMAN IN SCIENCE AWARD

The Doris M. Curtis Outstanding Woman in Science Award recognizes a woman who has had a major impact on the field of the geosciences based on her PhD research. The generous support of the Doris M. Curtis Memorial Fund makes this award possible. GSA's 103rd president, Doris Curtis, pioneered many new directions for geology, not the least of which was her tenure as GSA president after an unbroken chain of 102 men. Causes dear to her were women, public awareness, minorities, and education. Women are eligible for this award the first five years following their PhD degree.

Additional Supporting Documents

- Curriculum vitae including dissertation title and abstract.
- Letter of nomination that clearly states how the PhD research has impacted the geosciences in a major way. DEI promotion activities are to be included in the submitted letter of nomination.
- Letters of support from three (3) scientists with at least two (2) from GSA Fellows or Members and one (1) from a member of another professional geoscience organization. DEI promotion activities are to be included in the submitted letters of support.
- Additionally, Nominators and Support Letter Writers are requested to address the continued impact of the nominee and their PhD research to the scientific community by including the following:
  - Relevance of the work to the specialty field and more broadly to the geosciences and society.
  - Discussion of the impact of the PhD work via altered ways of thinking, new techniques, new citation data of resulting publications, etc.
  - Efforts by the nominee to impact the geosciences through activities such as mentoring, teaching, and initiatives promoting diversity in the field.
  - Selected bibliography of no more than 10 titles.

GSA DISTINGUISHED SERVICE AWARD

GSA Council established the GSA Distinguished Service Award in 1988 to recognize individuals for their exceptional service to the Society. GSA members, Fellows, associates, and employees may be nominated for consideration, and any GSA member or employee may submit a nomination for the award. GSA's Executive Committee will select awardees, and GSA Council must ratify all selections. Awards may be made annually, or less frequently, at the discretion of Council.

Additional Supporting Documents

- Brief biographical sketch that clearly demonstrates the applicability of the selection criteria.
- Optional selected bibliography of no more than 10 titles.

GSA PUBLIC SERVICE AWARD

GSA Council established the GSA Public Service Award in 1998 in honor of Eugene and Carolyn Shoemaker. This annual award recognizes contributions that have materially enhanced the public's understanding of the earth sciences or have significantly served decision makers in the application of scientific and technical information to public affairs and earth science–related public policy. This may be accomplished by individual achievement in:

- Authorship of education materials of high scientific quality that have enjoyed widespread use and acclaim among educators or the general public;
- Acclaimed presentations (books and other publications, mass and electronic media, or public presentations, including lectures) that have expanded public awareness of the earth sciences;
- Authorship of technical publications that have significantly advanced scientific concepts or techniques applicable to the resolution of earth-resource or environmental issues of public concern; and/or
- Other individual accomplishments that have advanced the earth sciences in the public interest

The award will normally go to a GSA member of any nation, with exceptions approved by Council, and may be presented posthumously to a descendant of the awardee.

Additional Supporting Documents

- Brief biographical sketch that clearly demonstrates the applicability of the selection criteria.
- Selected bibliography of no more than 10 titles.

GSA MICHEL T. HALBOUTY DISTINGUISHED LECTURER AWARD

The GSA Foundation is pleased to have established the Michel T. Halbouty Distinguished Lecturer Fund. The intent of the fund is to provide an honorarium for a Halbouty Distinguished Lecturer at GSA annual meetings. The fund was established to select a top lecturer on a topic of relevance to natural resources (i.e., water, land, energy, and minerals). Selection of the lecturer will be on the basis of career accomplishments and reputation, as well as the topic of the lecture.

The Halbouty Lecture topic of natural resources encompasses a broad swath of geology. Nominations of scholars across this range of topics are encouraged. The list of former lecture topics provides specific examples of potential breadth.

Nomination topics taken into account when selecting a lecturer:

- Finite limits on worldwide availability;
- Regional overviews (U.S.) of availability, quality, quantity, and use;
- Environmental damage from extraction or exploitation;

- Geologic aspects of environmental remediation;
- Overarching government policies concerning natural resources;
- Regional exploration; and
- New exploration tools.

INTERNATIONAL HONORARY FELLOW AWARD

Established by the GSA Council in 1909, Honorary Fellowship may be bestowed on individuals who have made outstanding and internationally recognized contributions to geoscience, or in rare circumstances, provided notable service to the Society. In practice, nearly all candidates are non–North Americans who live and work outside of North America. The most noteworthy exceptions were astronauts. The awardee does not have to be a member of the Society to receive the award. Honorary Fellows will be recognized during the GSA Annual Meeting and will receive complimentary lifetime membership to the Society.

Additional Supporting Documents
Letters of support from three (3) scientists with at least two (2) from GSA Fellows and one (1) from a GSA Fellow or a person of equivalent international stature.
Selected bibliography of no more than 20 titles.

Other 2026 Awards

INTERNATIONAL DISTINGUISHED CAREER AWARD

The Distinguished Career Award will be given to a GSA member who has made numerous, distinguished, and significant contributions that have clearly advanced the international geological sciences through both scientific investigations and service. The award will consist of a plaque inscribed with the name of the recipient, the name of the award, the name of the nominee's Section, and the emblem of The Geological Society of America. The award will be presented to the awardee at the national GSA meeting. GSA International encourages the membership to submit names of qualified candidates for this honor.

Additional Supporting Documents
- Optional letters of support.
- Selected bibliography of no more than 20 titles.

JAMES B. THOMPSON, JR. DISTINGUISHED INTERNATIONAL LECTURE AWARD

The lecture tours are made possible through a gift to the GSA Foundation by James B. Thompson, Jr., whose bequest contributed to the endowment of two lecture tours by distinguished geologists, one a non-North American scientist to tour academic and related institutions within North America, and the other a North American scientist to tour foreign universities and geological institutions. Both tours are arranged under the guidance of GSA International.

To submit a nomination, go to: **https://www.geosociety.org/GSA/About/GSA_International/GSA/International/Lecture_Tour/Home.aspx**.

JOHN C. FRYE ENVIRONMENTAL GEOLOGY AWARD

In cooperation with the Association of American State Geologists (AASG), GSA makes an annual award for the best paper on environmental geology published either by GSA or by one of the state geological surveys.

Anyone can nominate a paper as long as it is selected from a GSA or state geological survey publication and published during the preceding three full calendar years. The nomination letter must include a paragraph stating the importance of the paper. Up to three (3) letters from users of the publication can be included to support the nomination.

Each nominated paper will be judged on its uniqueness or significance as a model of its type of work and its overall worthiness for the award. The paper must (1) establish an environmental problem or need; (2) provide substantive information on the basic geology or geologic process pertinent to the problem; (3) relate the geology to the problem or need; (4) suggest solutions or provide appropriate land-use recommendations based on the geology; (5) present the information in a manner that is understandable and directly usable by geologists; and (6) address the environmental need or resolve the problem. It is preferred that the paper be directly applicable to informed laypersons (e.g., planners, engineers).

Please send your nominations to GSA Grants and Awards, P.O. Box 9140, Boulder, Colorado 80301-9140, USA. For more information, please visit **https://www.geosociety.org/GSA/About/awards/GSA/Awards/Frye.aspx**.

AGI MEDAL IN MEMORY OF IAN CAMPBELL

The AGI Medal in Memory of Ian Campbell recognizes singular performance in and contribution to the profession of geology. Candidates are measured against the distinguished career of Ian Campbell, whose service to the profession touched virtually every facet of the geosciences. Campbell was a most uncommon man of remarkable accomplishment and widespread influence, and in his career as a geologist, educator, administrator, and public servant, he was noted for his candor and integrity. To submit a nomination, go to **https://www.americangeosciences.org/awards/iancampbell**.

COLE RESEARCH AWARDS

The **W. Storrs Cole Memorial Research Award** was established to support research in invertebrate micropaleontology. It will be given each year to a GSA Member or Fellow between 30 and 65 years of age who has published one or more significant papers on micropaleontology. Funds cannot be used for work already accomplished, but recipients of a previous award may reapply if additional support is needed to complete their work.

W. Storrs Cole passed away on June 14, 1989, at the age of 86. Dr. Cole had been a Fellow of GSA for 58 years and was one of the Society's leading benefactors. The first presentation of this award was in 1991.
To submit a nomination, go to: **https://www.geosociety.org/GSA/About/awards/GSA/grants/postdoc.aspx**.

The **Gladys W. Cole Memorial Research Award** is restricted to investigation of the **geomorphology of semiarid and arid terrains in the United States and Mexico.** It will be given each year to a GSA Member or Fellow between 30 and 65 years of age who has published one or more significant papers in geomorphology. Funds cannot be used for work already accomplished, but recipients of a previous award may reapply if additional support is needed to complete their work.

The Gladys W. Cole Memorial Research Fund was established in 1980 by Dr. W. Storrs Cole in memory of his wife. The first award was presented in 1982. Dr. Cole passed away in 1989. He had been a fellow of GSA for 58 years and was one of the Society's leading benefactors.
To submit a nomination, go to: **https://www.geosociety.org/GSA/About/awards/GSA/grants/postdoc.aspx**.

2025 GSA Research Grant Recipients

THE GEOLOGICAL SOCIETY OF AMERICA®

GSA FOUNDATION

The 2025 GSA Committee on Research Grants awarded **US$904,375 to 354 graduate students** (~52% of the 679 who applied), with an **average grant of US$2,554.** The GSA Graduate Student Research Grant Program is funded by GSA, the GSA Foundation, GSA Divisions, and GSA Sections.

Committee members:

Sarah N. Heinlein, Ann Sullivan Ojeda, Alessandro Zanazzi, William Holt, Emily Frances Smith, Sonia Esperanca, Paulo J. Hidalgo, Glenn R. Bruck, Mauricio Ibanez-Mejia, Chris Spencer, Alexander Pullen, Tenley J. Banik, Sarah M. Jacquet, Alberto V. Reyes, Donna Surge, KT Moran, Alexander Michael Morgan, James Riley, Kelly E. Hattori, Zhiyang Li, Amy L. Weislogel, Brad T. Carter, Ben M. Frieman, Joann M. Stock, Eugene Szymanski, Stefanie A. Brachfeld, James P. Evans, Li Jin, Maria Rose Petrizzo, Aranzazu Pinan Llamas, May Sas, Ashraf Uddin, Richard S. Vachula, Guangsheng Zhuang

2025 Outstanding Mentions

(proposals having exceptional merit in conception and presentation)

Gabby Mann, San Diego State University
Bryan Lee, Indiana University
Trenton Meier, Indiana University Bloomington
Bethany Remian, Indiana University
Ravi Kiran Koorapati, State University of New York at Binghamton
Patricia Cox, Bowling Green State University
Timothy Suder, University of Pittsburgh
Rowan Terra, Duquesne University
August Aalto, University of Texas at Austin
Kat Springer, Stephen F. Austin State University

2025 Named Awards

Funded by the GSA Foundation

John A. Black Award
Bering Tse, University of Washington
The John A. Black Award supports graduate student field-based research on coastal processes. All field-based coastal geomorphology research should be located in the USA, Puerto Rico, or Canada. In the event there are no worthy graduate student field-based research projects in coastal geomorphology, the award may be used to support graduate student field-based research in volcanology. All field-based volcanology research should be located in the USA, New Zealand. or Iceland.

Gretchen L. Blechschmidt Award
Erin Kim, University of Michigan
The Gretchen Louise Blechschmidt Award Fund was established for women in the geological sciences who have an interest in achieving a PhD in the fields of biostratigraphy and/or paleoceanography, sequence stratigraphy analysis, particularly in conjunction with research in deep-sea sedimentology, and a career in academic research.

Sam Bowring Geochronology Research Grant
Lindsay Worden, University of Victoria
Maximilian Ehrenfels, University of Texas at Austin
The Sam Bowring Geochronology Fund supports graduate student field work in geochronology. The recipient is determined by the Geochronology Division of GSA.

John T. Dillon Alaska Research Award
Minh Pham, University of Florida
George Geier, Dartmouth College
The John T. Dillon Alaska Research Award honors the memory of Dr. Dillon who was particularly noted for his radiometric age-dating work in the Brooks Range, Alaska. Two areas which serve as guidelines for selection of the award are field-based studies dealing with the structural and tectonic development of Alaska, and studies which include some aspect of geochronology

(either paleontologic or radiometric) to provide new age control for significant rock units in Alaska.

Robert K. Fahnestock Award
Justin Cerv, Texas A&M University
The Robert K. Fahnestock Award honors the memory of Dr. Fahnestock, a former member of the Research Grants Committee, who died indirectly as a result of service on the committee. The grant is awarded for the best proposal in sediment transport or related aspects of fluvial geomorphology, Dr. Fahnestock's field.

Gould Research Grant
Dongyi Guo, Miami University
Cristina Leschhorn, University of Memphis
The Gould Research Grant supports graduate student research in the geosciences.

Robert D. Hatcher Research Award
Hannah Tebbens, University of Minnesota
The Robert D. Hatcher Research Award supports field-based research and geologic mapping through an annual award to an outstanding graduate student in the earth sciences to conduct research for that student's master's thesis of PhD dissertation. Preference may be given to students working in the Appalachian orogeny broadly construed, but is not restricted to this region.

Grant and Jody Heiken Research Grant
Olivia Schladt, North Carolina State University
Kevin Mulcahy, The University of Kansas
The Grant & Jody Heiken Research Grant supports graduate student research in any field work–oriented geoscience-related discipline.

William B. & Dorothy Heroy Research Grant
Aman K C, Boise State University
Nepali Jayasinghe, University of Massachusetts
Linus Anyanna, Missouri University of Science and Technology
S. Kirby Mills, Mississippi State University
The William B. & Dorothy Heroy Research Grant supports graduate student research in the geosciences.

Roscoe G. Jackson II Award
Alexandra Arimes, The University of Kansas
Jonathan Anaya, New Mexico Institute of Mining and Technology
The Roscoe G. Jackson II Award funds one recipient per year in the field of sedimentology.

John T. and Carol G. McGill Award
Michael Powers, University of Delaware
Alejandro Alvarez, University of Alberta
Jessie McClellan, University of Massachusetts Amherst
Joseph Borg, University of Utah
The John T. and Carol G. McGill Award, which is in the memory of John T. McGill, supports graduate student scholarships and research grants in engineering geology and geomorphology.

Bruce L. "Biff" Reed Scholarship Award
McKenzie Miller, University of Alaska Fairbanks
The Bruce L. "Biff" Reed Scholarship Fund was established to provide research grants to graduate students pursuing studies in the tectonic and magmatic evolution of Alaska primarily, and also can fund other geologic research.

Charles A. & June R.P. Ross Research Award
Haley Brumberger, University of Colorado Boulder
Niall Whalen, Florida State University
Kaitlyn Gooch, Louisiana State University
Nicholas Borders, University of Idaho
Abigail Portwood, University of Kentucky
Ahmed Alshakr, Western Michigan University
Sarah Brown, The Ohio State University
Momotaj Begum, McGill University
Shankhadeep Baul, University of Texas at Arlington
Arjun Bhandari, University of Mississippi
The Charles A. & June R.P. Ross Research Fund is awarded to support research projects for graduate students, post-graduate students, and post-doctorate researchers in the fields of biostratigraphy (including, but not limited to, fossil age dating and the study of evolutionary faunal successions), stratigraphy and stratigraphic correlation, paleogeography and paleobiogeography, interpreting past environments of deposition and their biological significance, and the integration of these research areas into better global understanding of (1) past plate motions (plate tectonics and sea-floor spreading); (2) past sea-level events, including their identification and ages; and/or (3) climate changes and effects of those climate changes on Earth's inhabitants through geologic time.

Alexander Sisson Research Award
Juliana Ruef, University of Colorado Boulder
Emma Hughes, University of South Florida

Family members of Alexander Sisson established a fund in his memory to promote and support research for students pursuing studies in Alaska and the Caribbean.

Parke D. Snavely, Jr., Cascadia Research Award
Camille Sullivan, University of North Carolina, Wilmington
Ariel Williams, Central Washington University
The Parke D. Snavely, Jr., Cascadia Research Award Fund provides support for field-oriented graduate student research that contributes to the understanding of the geologic processes and history of the Pacific Northwest convergent margin, or to the evaluation of its hazard or resource potential.

Harold T. Stearns Fellowship Award
Julia Daniel, University of Connecticut
Helena Kwarteng, State University of New York at Binghamton
Dr. Stearns established the Harold T. Stearns Fellowship Award in 1973 for student research on aspects of the geology of the Pacific Islands and the circum-Pacific region.

Alexander and Geraldine Wanek Research Award
Marwa Elshebli, Oklahoma State University
Niloofar Mesbah, University of Texas at Dallas
For research dealing with coal and petroleum resources, mapping and engineering geology, marine resources, petroleum economics, appraisal and evaluation, and the geology of phosphate resources.

Tim F. Wawrzyniec Research Grant
Ceyhan Sahinkaya Akyol, Colorado School of Mines
The purpose of the Tim F. Wawrzyniec Fund is to support graduate and undergraduate student research field work in the Rockies and the Colorado Plateau, with preference for projects in the following areas; structure, tectonics, paleomagnetism, petrology, petroleum geology, and Quaternary geomorphology.

Lauren A. Wright & Bennie W. Troxel Student Research Award
Rebecca Bertel, Northern Arizona University
Alexander Brettmann, University of Utah
The Lauren A. Wright & Bennie W. Troxel Student Research Fund supports two graduate students in Master's or PhD programs conducting field-based research (1) in the region broadly centered on Death Valley National Park or (2) in the western and southern Basin and Range Tectonic Province.

2025 GSA Graduate Student Research Grant Recipients

(Students are listed in alphabetical order by university.)

American Museum of Natural History
Owen Goodchild

Arizona State University
Jayde Hirniak

Binghamton University
Jeanette deCuba
Kathryn Graham
Gretl King

Boise State University
James Hada
Coleman Kane

Brown University
Desmond Yeo

California State Polytechnic University
Daniel Abel

California State Polytechnic University, Humboldt
Jane Martinez

California State Polytechnic University, Northridge
Maya Feldberg-Bannatyne

California State Polytechnic University, San Bernardino
Jilliam Bottini

Central Washington University
Sabrina Ansari
Hailey Finch

City University of New York, Graduate Center
Jody Creel

Colorado School of Mines
Zoë Bowers
Victor Fakeye

Colorado State University
Taylor Bennett
Rachel Bernstein
Lindsey Blehm
Samantha Malavarca
Gabriela Sanchez Ortiz
Drew White
Dylan Frawley
Phillip Kondracki

Columbia University
George Okoko
Meritxell Colet

Cornell University
William Hooker
Jenna Hynes

Dalhousie University
Nicole LeRoux

Dartmouth College
Emma Rogers
Jannitta Yao

Duke University
Robert Hill

Ensenada Center for Scientific Research and Higher Education CICESE
Karina Fuentes

George Mason University
Allison Burgess

Georgia State University
Sofia Weinstein

Idaho State University
Caden Anderson
Zachary Ellia

Indiana University Bloomington
Annika Jorgenson
Garrett O'Hara

Indiana University Indianapolis
Gloria Alejandra

Kansas State University
Matthew Arana

Kent State University
Hailey Connor
Alyssa Reinhardt

Michigan State University
Devika Padmakumar

Michigan Technological University
Helen Foldenauer

Mississippi State University
Sk Nafiz Rahaman

Missouri University of Science and Technology
Suvrajit Ghosh

National Autonomous University of Mexico (UNAM)
Juan Camilo Valencia Gomez

New Mexico State University
Katie Allbright
Luke Horsu

Oklahoma State University
Debarpita Paul
Bryston Smith

Oklahoma State University Center for Health Sciences
Colin Boisvert

The Ohio State University
Batoul Saad

Pennsylvania State University
Luis Rivera-Gabriel
Segun Oladele

Portland State University
Sandra Schwarzbart
Jacob Madore

Queen's University
Byongsuk Chun

Rutgers, The State University of New Jersey
Kathryn Hendrickson

Saint Mary's University
Victoria Watson

San Jose State University
Colin Chamberlin

South Dakota School of Mines and Technology
Rebecca Braun
Morgan Nystuen

Stephen F. Austin State University
Emmanuel Darko

Stony Brook University
Rupert Ikeh

Syracuse University
Tyler Logie

Texas A&M University
Queen Kalu
Raya Tarannum
Xiaolei Xu

Texas A&M University Corpus Christi
Allyson Girard

Texas State University
Tristan Goedert

Texas Tech University
Sabrina Fisher
Tusher Mohanta

Tulane University
Britt Johnson
Kaetlyn Rodriguez

Universidad Autónoma de México
Jorge Enrique Ruiz Urena

Universidad Nacional Autónoma de México (UNAM)
Cynthia Bermúdez
Yessica Viridiana Carrazco

University of Alabama
Bethany Cobb Faulk

University of Alaska Fairbanks
Kyra Bornong
David Doorenbos
Abhishek Singh

University of Alberta
Xueqi Liang

University of Arizona
Adela Maria Reynoso
William Mccraine

University of Arkansas
Ethan Oleson
Anurag Kulkarni

University of California, San Diego
Megan Ferrell

University of California, Davis
Sierra Rack

University of California, Riverside
Andrew Kennedy

University of California, San Diego - Scripps Institution of Oceanography
Chloe Weeks

University of Cincinnati
Mason Doyle
Lindsey Howard
Michael Schenk

University of Colorado Boulder
James Gutoski
Maya McDonough
Nicole Mizrahi
Tyler Wickland
Tyler Lincoln

University of Connecticut
Sethe Brown
Akshay Jayachandran
Ozan Sinoplu

University of Georgia
Raymond Aderoju
Haley Hubert
Luqman Olawale
Elise Bortell
Olajide Oladipo

University of Hawai'i at Manoa
Reed Mershon

University of Houston
Ali Raza

University of Idaho
Amanda Balogh
Bruno Belotti
Kathleen Farr

University of Illinois Chicago
Jennifer Yeack

University of Iowa
Kiersten Hottendorf

University of Kansas
Colleen Sullivan
Ellie Biebesheimer
Joshua Colasante
Precious Oso
Sunday Siomades

University of Kentucky
Benjamin Schafler

University of Maine
Morgan Anderson

University of Maryland Center for Environmental Science (UMCES)
Kathryn Bickerstaff

University of Massachusetts Amherst
Kailey Elson
Julia Rogerson

University of Massachusetts Lowell
Mika Bighin

University of Memphis
Devin Richards

University of Minnesota
Theodore Herring

University of Minnesota, Duluth
Eva Muscatello
Michael Park

University of Minnesota, Twin Cities
Jarred Asselta
Christof Zweifel

University of Mississippi
Santosh Adhikari
Ayotunde Babalola
Jodi Murray
Sagar Sapkota

University of Nevada, Las Vegas
Mary Clarich
Cole Jacobs
Henry Schatz

University of Nevada, Reno
Ryan Parkyn
Ian Adams

University of New Mexico
Catherine Peshek

University of North Carolina, Wilmington
Cody Allen
Mira Anderberg
Bentley Pitarra
Daniel Portelli
Ryan Riggs
Jonathan Vasquez

University of Notre Dame
Mirko Alessandro
Hannah Spero

University of Oklahoma
Maria Reinoso
Alysha Zazubec

University of Ottawa
Christina Bakowsky

University of Pittsburgh
Abby Yancy

University of Regina
Julian Hidalgo

University of Saskatchewan
Dmitri Ponomarenko

University of Sonora
Andrew Becuar

University of South Florida
Felipe Stanchak

University of Southern California
Samuel Little
James Pinto
Priyanka Soni

University of Texas at Arlington
Christopher McCauley

University of Texas at Austin
Mitchell Casazza
Susan Cook
Talita Gomes Daniel
Remi Kurita
Emily Launderville
Sewon Ohr
Madison Preece
John St.Peter
Sage Turek

University of Texas at Dallas
Mojtaba Shams soulari

University of Texas Rio Grande Valley
Waqid Nabi
Ana Casillas Rodriguez

University of Texas at San Antonio
Ashley Aguilar
Elizabeth Beauchamp

University of Toledo
Olawale Ogunsola
Phebe Olabode

University of Toronto
Milagros Gutierrez Seia

University of Toronto Mississauga
Zaid Qureshi

University of Victoria
Taryn Neligan

University of Washington
Benjamin Lloyd

University of Waterloo
Boyao Tian

University of Wisconsin–Madison
Mackenzie Carlton
Logan Goulette
Eleanor McFarlan
Thais Altenberg Vas

University of Wisconsin-Milwaukee
Carson McFarland

University of Wyoming
Rachel Harris
Andrew Miller
Sergei Nadeev
Lena Schwebs
Zachary Tenney

Utah State University
Micah Hernandez

Virginia Polytechnic Institute and State University
Brynden Perkins
Amy Hagen
Delaney Kirr
Mark Nohomovich

Wesleyan University
Jasmine Fridman

West Virginia University
Comfort Onah

Western Michigan University
Hassan Saleh

Western Washington University
Sydney Rayburn

Wilfrid Laurier University
William Bender

Yale University
Kate Pippenger

2025 GSA International, GSA Division, and GSA Section Student Research Grant Recipients

GSA International, GSA Divisions, and GSA Sections have recognized the following student research grant recipients who submitted proposals of exceptionally high merit in conception and presentation in their fields.

GSA International Graduate Student Research Grants

Farouk El-Baz Student Research Grants

Hannah Franke, University of Texas at San Antonio
Fan Gao, University of Pittsburgh
Tyler Deshong, University of Massachusetts Amherst
Owen McCaffrey, University of Texas at Dallas

This grant is to encourage and support desert studies by students world-wide either in their senior year of their undergraduate studies, or at the Master's or PhD level.

Division Graduate Student Research Grants

Continental Scientific Drilling Division

Continental Scientific Drilling Division Student Research Grant

Médéric Lorry, University of Alberta
Zachary Clore, University of Connecticut
Cameron Greaves, Dalhousie University
Adeel Jehangir, University of Pittsburgh
Chris Ploetz, University of Texas at Austin
Kiri Maza, University of Utah

Geochronology Division

Sam Bowring Geochronology Research Grant

Lindsay Worden, University of Victoria
Maximilian Ehrenfels, University of Texas at Austin

Geophysics & Geodynamics Division

Allan V. Cox Research Award

Alejandro Aguilar, Utah State University

Geophysics Student Research Grant Award

Saadatu Abdullah, Missouri State University
Lindsay Stark, Boise State University

Hydrogeology Division

Dr. Thomas C. Winter Graduate Student Research Award

Luke Alder, Utah State University

Hydrogeology Division Student Research Grant Awards and Travel Grants

Nicholas Januario, California State University, Long Beach
Anna Sniadach, Idaho State University
Thisura Chanuka Indralal Ilukgoda Gedara, Kansas State University
Morgan Johannesen, The University of Kansas
Raymond Hess, Rutgers University

Karst Division

John W. Hess Research Grant

Maria Jhonnie Villareal, Northwestern University

Mineralogy, Geochemistry, Petrology, and Volcanology Division

Ian S.E. Carmichael Research Award

Mabel Adansi, Ohio University

Lincoln S. & Sarah W. Hollister Graduate Student Research Award

Sarah Brandt, University of Minnesota, Twin Cities
Sofia Jiménez Barranco, Universidad Nacional Autónoma de México (UNAM)
Nandana Goswami, University of South Carolina
Nicole Ferrie, University of Texas at Austin

Lipman Research Award

Madeline Bartels, University of Calgary
Serhat Sevgen, University of Calgary
Brice Liedtke, Northern Arizona University
Sze Yui Fung, University of British Columbia
Elly Thistlethwaite, University of British Columbia
Fan Liu, University of California, Santa Barbara
Joseph Scrivner, California State University, Sacramento
Juliana Curtis, Colorado State University
Erica Fancher, University of South Florida
Alexandra Daniels, Boise State University
Frank Wroblewski, University of Idaho
Logan Erichsen, Kansas State University
Andrew Hindall, Kansas State University
Scott Furlong, University of Kentucky
Mary Roach, Louisiana State University
Dominic Hildebrandt, Massachusetts Institute of Technology
Oceana Apollo, University of Missouri
Josephine Dankwa, Missouri State University
Bezali Kwame Danso, Missouri State University
Megan Melgren, Kansas State University

Juliet Liscomb, Montana State University
Liv Wheeler, Montana State University
Alexis Lopez, University of North Carolina, Chapel Hill
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Southeastern Section Graduate Research Grants
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Tracy Chukwuma, University of Georgia
Oyindamola Oseni, University of Georgia
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Mark Your Calendar for the

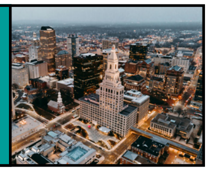
2026 GSA Section Meetings! Contribute to the Conversation—Submit Your Abstract

GSA's Geographic Sections are gearing up for an exciting slate of 2026 meetings, and you won't want to miss out. These smaller, regional gatherings offer big opportunities: cutting-edge research presentations, student-friendly networking, and accessible travel options.

Abstract submissions open this month for GSA's 2026 Section Meetings! Start planning now to share your research and ideas with a global community of geoscientists.

Section Abstract Submission Deadlines: 13 January 2026

GSA Triple Joint Southeastern / North-Central / South-Central Section Meeting
Memphis, Tennessee, USA
8–11 March 2026
https://www.geosociety.org/se-mtg



GSA Northeastern Section Meeting
Hartford, Connecticut, USA
21–24 March 2026
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GSA Cordilleran Section Meeting
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GSA Rocky Mountain Section Meeting
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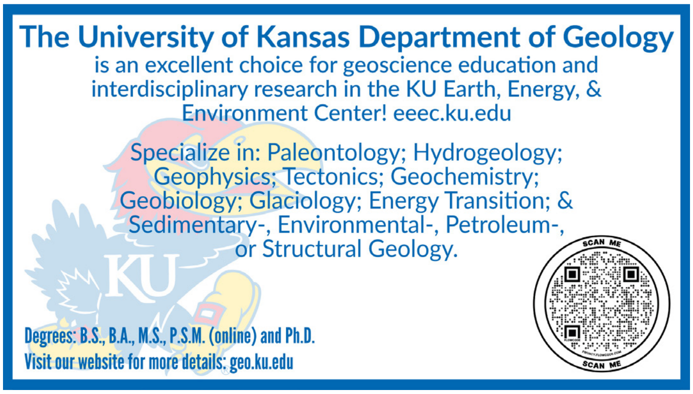
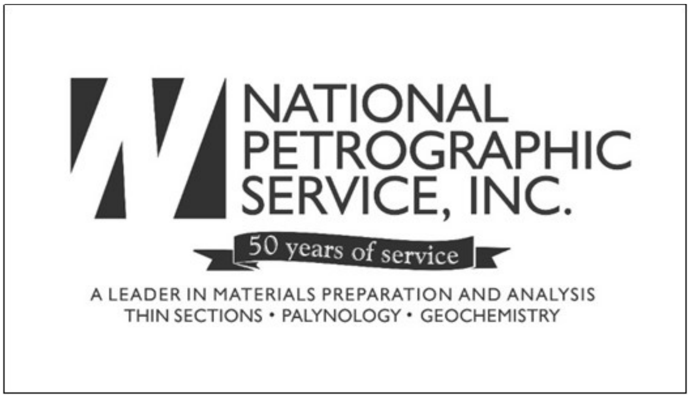




Earth Science Week 2025:
Energy Resources for Our Future

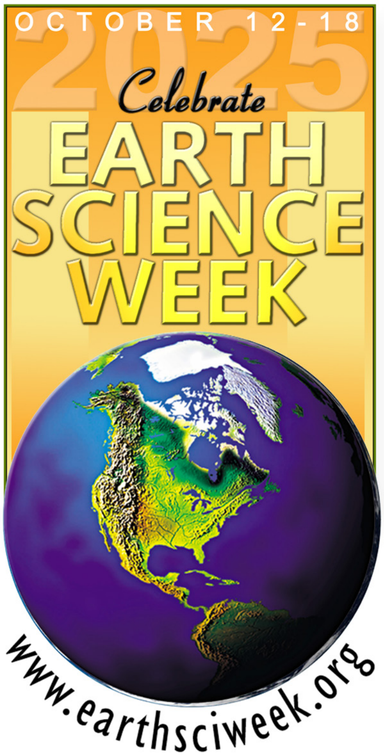
Lindsay Mossa, Lauren Brase, Sequoyah McGee, and Ed Robeck

For over 25 years, the American Geosciences Institute (AGI) has organized Earth Science Week (ESW), an annual outreach program in which we partner with geoscience organizations in ways that promote their work by engaging teachers, students, and the general public in earth science. The success of ESW is highly dependent on the efforts of our partners, like GSA. By hosting outreach events, GSA members can help spark curiosity about Earth processes and resources, as well as how they affect human populations, and vice versa.

ESW 2025 will be held from 12–18 October—the week before GSA Connects—and will celebrate the theme, "Energy Resources for Our Future." This celebration will highlight how energy resources are integral to Earth's interconnected systems and impact every aspect of our daily lives, from powering homes and transportation to fueling industries. The educational materials that AGI and our partners have created can all be used at outreach events or can be distributed to teachers so they have a variety of materials that they can use to teach about energy.

The ESW Toolkit, which includes resources from over 50 partners, is developed annually to provide earth science activities. One resource in the toolkit is the ESW Calendar, in which GSA has been involved for over a decade. The 2025 calendar activity developed on behalf of GSA asks middle and high school students to create a model that shows how geothermal exchange systems work (https://www.earthsciweek.org/resources/january/). This activity could be used by members of GSA during classroom visits or outreach events so that students and the public can see how the work of geoscientists contributes to locating and harnessing energy resources.

Additional items in the ESW Toolkit that could be used during outreach events include the annual posters created by the Education & Outreach Department of AGI. To celebrate Geologic Map Day, GSA contributes to the development of an annual poster and related learning activities. The 2025 Geologic Map Day Poster showcases the new Cooperative National Geologic Map from USGS. GSA is one of the founders of Geologic Map Day, which is the focus day for the Friday of ESW. The ESW 2025 Poster features images and information about the 10 primary energy sources used in the U.S., as identified by the National Energy Education Development (NEED) Project, which are designed to evoke ideas about the different ways we power our cities, industries, and transportation, as well as how shifts in how we use energy can contribute to sustainability. All of these resources can be accessed at the 2025 Earth Science Week webpage at **https://www.earthsciweek.org/resources/2025/**.



We also encourage GSA members to attend our ESW Webinars, which premiere at 1 p.m. ET each day of ESW, and will focus on a variety of energy topics. Each webinar also has a segment on how energy topics relate to educational standards and settings, which can help in planning for outreach events. For more information about Earth Science Week, related educational materials, and for tips on hosting ESW events, please visit www.earthsciweek.org or e-mail info@earthsciweek.org.

Figure 1. The 1080 Ma Enchanted Rock Batholith is one of many late-stage, A-type intrusive rocks across the Llano Uplift that stitch together the several rock packages that were metamorphosed during the Grenville Orogeny. Credit: Jmbuytaert via Wikimedia Commons.

Central Texas' Llano Uplift:
The Keystone for Reconstructing the Mesoproterozoic through Cambrian History of Southern Laurentia

Lon D. Abbott,[*,1] **and Terri L. Cook**[2]

The Llano Uplift is an "island" of Mesoproterozoic crystalline rocks (Fig. 1) surrounded by an Early Paleozoic apron standing in Central Texas' vast expanse of Pennsylvanian through Cretaceous sedimentary rocks. Located less than 150 km north of San Antonio and a similar distance west of Austin, the 9000 km^2 Llano Uplift possesses a geoheritage unique in Texas. It contains an invaluable record of the Grenville Orogeny in southern Laurentia when that continent was surrounded by others, becoming the center of the global Rodinian supercontinent at 1100 Ma. Researchers debate when plate tectonics began on Earth; the Grenville rocks of the Llano Uplift shed light on that debate. The distinctive isotopic fingerprint of the Uplift's Mesoproterozoic rocks also gives it a starring role in studies that decipher the shifting sediment dispersal patterns as the supercontinent broke up during the Neoproterozoic through Cambrian and the Great Unconformity was created.

*lon.abbott@colorado.edu
[1]Department of Geological Sciences, University of Colorado, Boulder, Colorado 80309, USA
[2]Down to Earth Science, Boulder, Colorado 80305, USA
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WHEN DID PLATE TECTONICS BEGIN?

When did plate tectonics begin on Earth? Few geoscience questions are as fundamental, and it might seem surprising that even now, 60 years after the plate tectonic revolution, it remains unresolved. But expert interpretations for the onset of plate tectonics span most of Earth history, from the Hadean (4200 Ma; Hopkins et al., 2008) to the Neoproterozoic (850 Ma; Hamilton, 2011; Stern, 2020). The answer to this question clearly has profound implications for our understanding of Earth history, but its import is broader still; it furthers our comprehension of how silicate bodies in our solar system and beyond behave (Palin et al., 2020, and numerous references therein).

Llano rocks were deformed and metamorphosed during a Mesoproterozoic orogenic event that unfolded between ca. 1300–1000 Ma and is known in North America as the Grenville Orogeny. The type area for the Grenville Orogeny lies in eastern Canada. The Llano Uplift stands at the opposite end of the belt and provides the southernmost large exposure of Grenville rocks, making it a key location for deducing what transpired during the orogeny and afterwards (Kyle et al., 2022). Tracts of contemporaneously deformed rocks exist on every continent and together comprise the Global Grenville Orogeny (Stern, 2020). This global orogeny is commonly interpreted, using the lens of plate tectonic theory, as recording a series of continent–continent collisions that sequentially assembled all the continental material then in existence into the global supercontinent Rodinia (e.g., Mosher, 1998; Li et al., 2008). Other workers conclude that the Grenville mountain-building episode differed in fundamental ways from Phanerozoic orogens and was instead the product of a "single-lid" tectonic regime, with Earth enveloped by a continuous lithospheric shell instead of today's mosaic of tectonic plates (Stern, 2020, and references therein).

Stern (2020) pointed out that single-lid tectonics is the norm for the five tectonically active silicate bodies in our solar system; Venus, Mars, Io, and Europa all possess different forms of single-lid tectonics, with Earth constituting the only exception. He posited that Earth progressed through different phases of single-lid tectonics, and one brief phase of plate tectonics between ca. 2000–1800 Ma, before settling into a protracted single-lid regime in the Mesoproterozoic. This single-lid regime culminated in the Grenville Orogeny before the modern plate tectonic regime was established in the Neoproterozoic.

Stern (2020) compiled a list of positive and negative indicators in support of the Mesoproterozoic single-lid hypothesis. As negative evidence, he claimed that the presence of ophiolites, blueschists/eclogites, and ultra-high pressure (UHP) metamorphic rocks are all clear signs of plate tectonic processes, and he argued that the Mesoproterozoic lacks evidence for any of them. Positive indicators for a single-lid regime are an abundance of Mesoproterozoic A-type granites and anorthosites, an unusually hot Mesoproterozoic lithosphere, and a paucity of passive continental margins at that time. The reasoning is that plate tectonics delivers abundant water to the mantle, so magmas generated by plate tectonics should be "wetter" than the anhydrous A-type granites and anorthosites that dominate the Mesoproterozoic; plate tectonics cools the planet's interior more than single-lid tectonics can, so higher geotherms should exist during single-lid episodes; and passive margins form in response to plate tectonic processes but not from single-lid tectonics, so the relative lack of identified Mesoproterozoic passive margins supports the single-lid hypothesis for the Grenville. Articulation of this list makes the hypothesis testable, so the hunt is on to find ophiolites, high pressure–low temperature metamorphic rocks, and low geothermal gradients in rocks of the Global Grenville Orogeny; their discovery would cast doubt on the hypothesis that the Grenville Orogeny was a product of single-lid tectonics instead of plate tectonics.

THE NATURE OF GRENVILLE TECTONISM: CLUES FROM THE LLANO UPLIFT

Given the global distribution of rocks that record the Grenville Orogeny, plenty of locations exist where the plate tectonic versus single-lid hypotheses can be tested. But most other Grenville-aged exposures are superimposed on older orogenic elements and/or have been overprinted by younger orogenic episodes, both of which obscure or complicate their Grenville histories. The Llano Uplift doesn't suffer from either of these confounding scenarios, making it an especially high-fidelity tracer of Grenville-aged tectonism (Mosher and Gillis, 2025) and thus an ideal location to test the competing hypotheses.

Evidence gathered in the Llano Uplift tests presence versus absence for several of Stern's (2020) single-lid indicators. The orogen contains multiply deformed Mesoproterozoic metasedimentary, metavolcanic, and metaplutonic rocks that were intruded by late-stage granitic plutons (Mosher et al., 2008). Paleozoic normal faults later segmented the Llano's Mesoproterozoic rocks into eastern, central, and western regions, which display broadly similar tectonic histories but also possess important differences. The eastern segment possesses three rock packages thrust one atop the next, with the southwestern most Coal Creek package on top. Coal Creek rocks are older than (1326–1275 Ma compared to 1288–1232 Ma) and geochemically and isotopically distinct from all other Llano Uplift rocks. The eastern segment also possesses the largest serpentinite body known from any Grenville-aged rock sequence. Mosher and colleagues interpreted the Coal Creek rocks as an exotic volcanic arc that was thrust atop the Laurentian continental margin during an arc-continent collision, with the serpentinite interpreted as an ophiolite marking the suture zone (Mosher et al., 2008; Mosher and Gillis, 2025). If that interpretation is correct, then Mesoproterozoic ophiolites do exist after all.

The western segment of the Llano Uplift possesses high-pressure eclogites that reached peak metamorphic conditions of ~775 °C and 2.4 GPa of pressure. Those conditions indicate the rocks reached depths exceeding 70 km and experienced a very low geothermal gradient of only ~10 °C/km (Mosher et al., 2008; Levine and Mosher, 2010). The Llano Uplift thus contains eclogites and documents the existence of a cool mantle, both attributes whose Mesoproterozoic absence Stern (2020) argued support the single-lid hypothesis. Their presence, along with the ophiolite farther east, supports a plate tectonic rather than single-lid regime for the Grenville Orogeny. After all, low geothermal gradients are typical in Phanerozoic collision zones, where subduction of thick continental lithosphere cools the surrounding mantle. High-pressure rocks are also typically exposed in parts of those collision zones thanks to later uplift and exhumation driven by the buoyancy of the once-subducted continental crust. By contrast, the Llano's voluminous late-stage granitoids (Fig. 1) are all A-type granites (Smith et al., 1997), supporting Stern's (2020) contention that the Mesoproterozoic mantle was comparatively dry.

Viewed as a whole, the Llano Uplift rock assemblage appears to favor the hypothesis that plate tectonics operated during the Mesoproterozoic. In fact, its rock record is strikingly similar to that produced by the Cenozoic plate collision that raised the Alps. Figure 2 illustrates how that record is interpretated through a plate tectonic lens. Southward-directed subduction carried the Laurentian continental margin beneath an exotic island arc (the Coal Creek Domain) at 1150–1120 Ma, followed soon thereafter by collision with a southern continent during assembly of Rodinia (Mosher et al., 2008; Levine and Mosher, 2010). The identity of that southern continent is debated, with the Kalahari Craton (Dalziel et al., 2000) and the Amazon Craton (Tohver et al., 2002; Spencer et al., 2014) being the leading candidates.

SEDIMENT DISPERSAL PATTERNS BEFORE AND AFTER THE GREAT UNCONFORMITY

Although scientists disagree whether the Rodinian supercontinent was assembled by plate tectonic or single-lid processes and where some cratonic pieces fit into the Rodinian puzzle, everyone agrees that the supercontinent existed and that plate tectonics was operating during the Neoproterozoic, when it broke apart. Breakup of Rodinia coincided with formation of the Great Unconformity, which separates Phanerozoic (commonly Cambrian) sedimentary rocks above from Precambrian ones (commonly crystalline basement) below. John Wesley Powell coined the term during his first descent of the Colorado River through Grand Canyon (Powell et al., 1875), but because the boundary is seen globally, the term's geographic usage has expanded accordingly.

The global ubiquity of the Great Unconformity marks it as a singular event in Earth history, so naturally many geoscientists have searched for a global explanation. One prominent idea is that during the Cryogenian (720–635 Ma) Snowball Earth episode, the unconformity was formed by glacial erosion of 3–5 km of rock, resulting in widespread exposure of crystalline basement (e.g., Keller et al., 2019). Others argue that no single event is responsible for development of the global Great Unconformity, which is instead an amalgam of many smaller unconformities that developed during the assembly and breakup of Rodinia (e.g., Peak et al., 2021). Whatever the cause(s) for its development, geoscientists are keenly interested in tracking the evolution of sediment dispersal patterns through its formation and aftermath. The Llano Uplift plays a prominent role in tracing that evolution across the Laurentian portion of Rodinia (Fig. 3).

Grenville-aged detrital zircons are abundant in Neoproterozoic (1000–541 Ma) and Early Cambrian (541–521 Ma) sandstones across western Laurentia (today's American West). But the supply was abruptly cut off ca.521 Ma as the Sauk Sea (Sloss, 1963) transgressed across Laurentia throughout the Middle Cambrian (521–497 Ma). So how and why did that sediment dispersal network change?

By pairing Hf-isotope analysis with detrital zircon geochronology, researchers have been able to locate more specifically where in the Grenville Orogen those zircons came from (Fig. 3). That's because Grenville rocks from the Appalachian Mountains possess low εHf(0) zircon values (<-20) and Llano Uplift igneous rocks have high εHf(0) values (>-20). The reason for this difference is that the zircon-producing magmas in the Appalachians incorporated more preexisting Precambrian crust than did the Llano ones (Hantsche et al., 2021).

Rodinia began to break up ca.780 Ma (Spencer et al., 2014) during the Neoproterozoic's Tonian Period. The abundant Grenville-aged detrital zircons that filled the few western Laurentian Tonian sedimentary basins that still survive possess low εHf(0) values, indicating that the Tonian drainage network headed in the Appalachians, not the Llano Uplift (Fig. 3A; Hantsche et al., 2021). That situation changed in the Cryogenian, with high εHf(0) zircons sourced from the Llano Uplift dominating in sedimentary basins from present-day Colorado to the Grand Canyon, to Death Valley and beyond (Fig. 3B; Hantsche et al., 2021; Holland et al., 2024).

The advent of this new Llano Uplift source of detrital zircons is consistent with (U-Th)/He dating of zircons from Llano Uplift crystalline rocks that documents more than 6 km of Llano exhumation between 800 and 750 Ma (Kyle et al., 2022). A likely reason for that exhumation is that Llano rocks were uplifted and exposed on a rift flank during the breakup of Rodinia. By the Middle Cambrian, the Sauk Sea was well on its way to inundating Laurentia, drowning the Llano rocks and all other sources of Grenville-aged zircons; only a trickle of them reached the extensive sand bodies that accumulated on its shores (Fig. 3C). The exception is in the Llano Uplift itself, where the Hickory Sandstone, the ca. 500 Ma sandstone that unconformably overlies the Uplift's Mesoproterozoic crystalline rocks, is full of Grenville-aged zircons derived from the north, likely in response to gentle flexural uplift of the Transcontinental Arch (Kyle et al., 2022).

One important attribute that distinguishes a place as a valuable geoheritage site is the significance its rock record has for answering the most profound questions that the

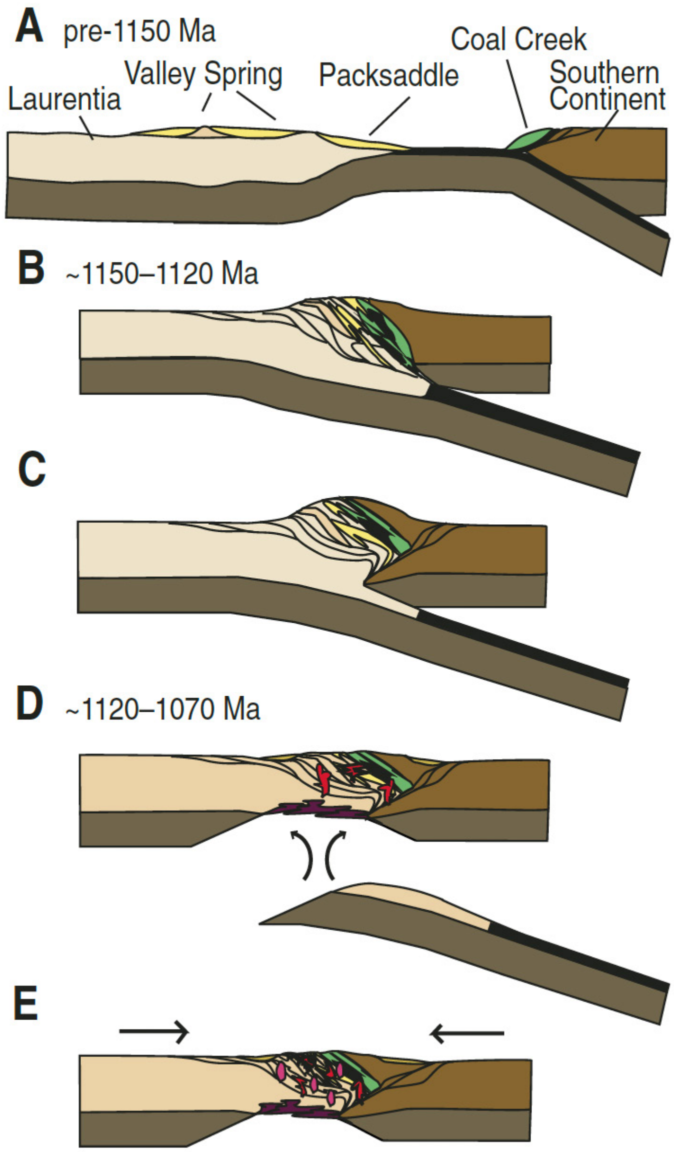

Figure 2. A plate tectonic reconstruction of the events that affected southern Laurentia during the Grenville Orogeny. (A) Southward-directed subduction of Laurentian oceanic lithosphere beneath the Coal Creek volcanic arc and a southern continent began before 1150 Ma. (B) and (C) Arc-continent collision, followed soon thereafter by continent-continent collision thrust the Coal Creek Packsaddle, and Valley Spring domains of the Llano Uplift toward the NE, stacking the Coal Creek atop the pile and the Valley Spring domain at the base. This stacking sandwiched ophiolitic rocks along the suture zone and subjected Laurentian continental crustal rocks to high-pressure metamorphism at depth. (D) Further convergence led to development of a SW-verging retrowedge to form a doubly-vergent orogen similar to that of the Cenozoic Alpine Orogeny. Breakoff of the subducted slab led to lithospheric thinning and intrusion of late-stage granites (red). (E) Uplift caused by the buoyancy of the deeply buried continental crust produced exhumation and erosion that exposed the deepest portions of the orogen on Earth's surface by the Cambrian. From Mosher et al. (2008).

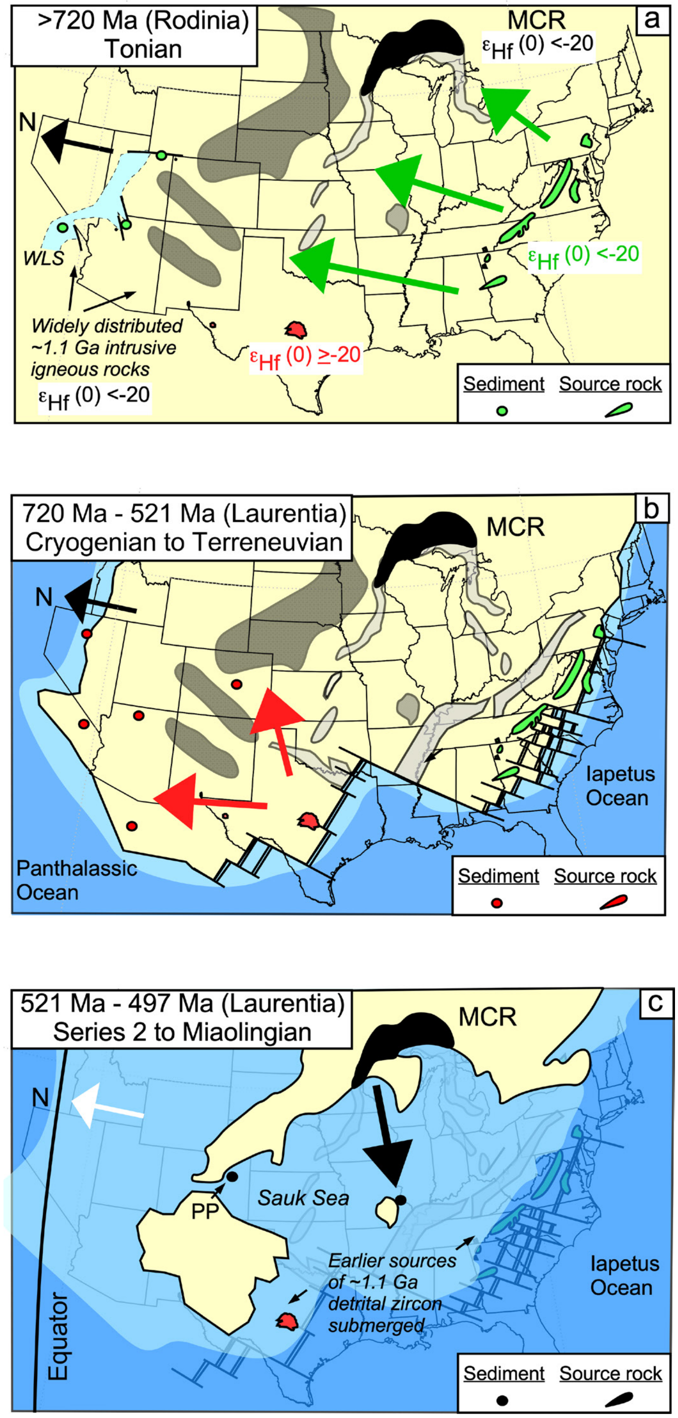

Figure 3. Evolution of the Neoproterozoic through Cambrian sediment dispersal network of southern Laurentia from combined U-Pb dating and εHf(0)-isotopic analysis of detrital zircons. (A) Abundant Grenville-aged zircons possessing low (<-20) εHf(0) isotopic values were shed from the Appalachian Mountains (green arrows) to Tonian-aged depocenters in western Laurentia (green dots). MCR = Mid-continent rift, WLS = Western Laurentian Seaway. (B) The dominant source of Grenville-aged sediment shifted to the Llano Uplift (red arrows) in response to rift-flank uplift there as Rodina rifted apart between 720 and 521 Ma during the Cryogenian through Early Cambrian (Terreneuvian Epoch), as recorded by detrital zircons in Colorado, the Grand Canyon, Death Valley, and elsewhere (red dots). (C) Transgression of the Sauk Sea in the Middle and Late Cambrian drowned nearly all sources of Grenville-aged detrital zircons, including the Llano Uplift. PP = Pikes Peak Batholith. From Hantsche et al. (2021).

study of Earth history serves up. The Llano Uplift fits the bill; its rocks provide clues that help address such fundamental questions as: When did plate tectonics begin? And how did sediment dispersal patterns change during formation of the Great Unconformity?

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Bridging Science and Policy: GSA's Congressional Science Fellowship

Each year, The Geological Society of America (GSA), in partnership with the U.S. Geological Survey, offers a transformative opportunity for geoscientists through the Congressional Science Fellowship. For one year, an earth scientist steps out of the field and into the halls of Congress, serving as a staff member to a Member of Congress or a congressional committee.

Purpose and Impact

The fellowship was created with three clear goals:

- **Bring science into government.** Fellows help lawmakers access and apply scientific knowledge to create effective, evidence-based policy.
- **Educate scientists about policy.** Participants experience the legislative process firsthand, learning how decisions are made and how science can influence outcomes.
- **Foster lasting connections.** The program strengthens ties between the scientific and policy communities, encouraging long-term collaboration.

At a time when society faces pressing challenges—from climate change to natural hazards to resource management—bridging the gap between science and policy has never been more critical. Fellows serve as translators, helping policymakers understand the complexities of earth science while also preparing scientists to better engage with the policy world.

A Unique Learning Experience

For the fellow, this year-long assignment is life-changing. Beyond analyzing data or publishing papers, fellows write legislation, brief policymakers, and advise on issues where science plays a pivotal role. They become trusted members of congressional teams and experience the fast-paced reality of policymaking from the inside.

The benefits extend far beyond one individual. When fellows return to academia, government, or industry, they bring back invaluable insights into how science informs policy. Many alumni have gone on to leadership positions, carrying with them a perspective that strengthens both the geoscience and policy communities.

Why Your Support Matters

The fellowship is made possible through the Congressional Science Fellowship Fund, which ensures that GSA can continue sending talented geoscientists to Capitol Hill. Supporting this fund means investing in the future of science-informed policymaking. Every donation helps maintain this vital bridge between earth science and government, enabling fellows to bring their expertise where it is needed most.

Learn More and Give Back

The GSA–U.S. Geological Survey Congressional Science Fellowship is shaping the future of science-policy dialogue and creating leaders who make a difference. To explore the program, meet past fellows, and contribute to the Congressional Science Fellowship Fund at **https://gsa-foundation.org/donate-congressional-science-fellow/.**

How to Build Complex Life: Understanding Ediacaran–Cambrian Environmental Change and the Emergence of Animals

25 May–2 June 2026 | University of Namibia Southern Campus, Namibia

https://www.geosociety.org/GSA/Events/Thompson/GSA/thompson/home.aspx

Figure 1. Field pictures near drilling and outcrop localities: (A) Flat-lying Kuibis Subgroup (on tilted Namaqua metamorphic complex) and (B) Schwarzrand rocks. (C) Sub-vertical planar normal fault (left center of photo). Photographs by Tony Prave.

Conveners

Emmy Smith, John Hopkins University, efsmith@jhu.edu
Catherine Rose, University of St Andrews, cvr@st-andrews.ac.uk
Francis Macdonald, UC Berkeley, francism@berkeley.edu

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GRIND
Geological Research Integrated through Neoproterozoic Drilling

Description and Objectives

Since Darwin (1859) first observed the seemingly abrupt appearance of fossils in Cambrian strata, the cause and tempo of the “Cambrian Explosion” have remained among the most compelling research topics in geobiology. Many questions surrounding the Ediacaran–Cambrian Transition (ECT) remain unresolved: What were Earth’s first macroscopic life forms, how did they live, and why did they go extinct at the base of the Cambrian Period? What is the significance of large carbon isotope excursions at the ECT for both the carbon and oxygen cycles? What is the source of anomalous Ediacaran paleomagnetic data? How rapid was the Cambrian radiation of animals? Much of the data addressing these questions comes from field sites in southern Namibia, the location of the proposed paired conference and Thompson Field Forum. This event will bring together an international and interdisciplinary community of ECT researchers to discuss key questions and visit outcrop and recent International Continental Scientific Drilling Program (ICDP) cores through Geological Research Integrated through Neoproterozoic Drilling (GRIND-ECT), offering a timely opportunity to discuss, interrogate, and build upon research accomplished during the past five years.

Preliminary Outline of Thematic Sessions

Geochronology

What are the timing, duration, and causal mechanisms of major ECT biological and geochemical events? This thematic session will examine the current state of knowledge on the chronology, persistence, and underlying drivers of environmental change.

Geochemistry

What is the significance and reproducibility of the basal Cambrian carbon isotope excursion? How did biological innovations and expansion of food webs alter both inorganic and organic carbon export and influence biogeochemical change? What was the pattern of oxygenation at global and regional scales, and how significant was oxygenation as a driver during the ECT? This thematic session will explore recent advances in our understanding of these processes from outcrop and the GRIND-ECT drill core.

Paleontology

How do biotic evolution patterns relate to environmental change based on fossil data? What can core and outcrop data reveal about changes in morphology and mineralogy over time? How are body size, ecological complexity, and structural defenses linked to oxygen levels and biological innovation? This session will focus on integrating fossil assemblages with age constraints, geochemical signatures, and paleoenvironmental data from newly recovered cores.

Paleomagnetism and Paleography

What is the source of enigmatic Ediacaran paleomagnetic data—inner core formation, cyclic reversal frequency changes, or episodes of large-scale true polar wander? How do these data constrain our understanding of ECT paleogeography? What global paleogeographic changes occurred across the ECT, and how might they have perturbed geochemical cycles and influenced the biosphere? This thematic session will highlight new findings from outcrop and drillcore data that shed light on these fundamental questions.

Venue Details

The event will take place from 25 May to 2 June 2026 at the University of Namibia in Keetmanshoop, Namibia. The conference will run from 25–29 May, followed by a Thompson Field Forum from 29 May to 2 June. Keetmanshoop is ideally situated near key sites of the GRIND-ECT drilling program and classic outcrop localities, which will be featured in a post-conference field trip. The university campus offers an excellent venue for the event, with facilities for oral and poster sessions, as well as both indoor and outdoor spaces for informal networking and discussion. Keetmanshoop is within a one-day drive of Hosea Kutako International Airport (SFO) and offers a range of accommodation options to suit all budgets. The conference program will include oral presentations, poster sessions, breakout discussions, and mentoring opportunities tailored for early career researchers. Attendees will be expected to observe the GSA Code of Ethics & Professional Conduct throughout the meeting.

Applications and Registration

GSA and the meeting conveners are committed to promoting diversity, equity, inclusion, and belonging within the geoscience community. We strongly encourage applications from individuals of all backgrounds, especially those from groups underrepresented in Earth sciences. Participation in the Thompson Field Forum is limited to 40 participants.

As part of the application process, participants are asked to submit a brief statement (maximum 300 words) outlining your research interests and how your work aligns with the conference themes, along with a tentative title for your proposed presentation. Applicants will be notified of acceptance and presentation format (oral or poster) by **15 January 2026**. Full abstracts will be required at the time of registration. The program will include invited keynote speakers, lightning talks, and focused discussion sessions designed to encourage broad participation and engagement.

Participants will be responsible for covering their own travel expenses to the venue and are expected to arrive by the evening of **24 May 2026**. The registration fee for the Thompson Field Forum will include four nights of lodging, meals, field trip transportation, and facility use. Limited funding will be available to partially offset registration costs for selected early career researchers and students.

Application Period Opens: 15 September 2025
Application Deadline: 15 November 2025
Acceptance Notices: 15 January 2026
Registration Deadline: 15 March 2026

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FIELD FORUM

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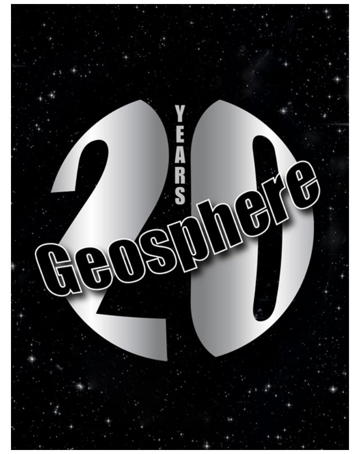

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2025 Outstanding Associate Editors

Associate editors play a key role in helping *GSA Bulletin* and *Geosphere* science editors make decisions on submitted manuscripts by guiding these papers through the review process. Associate editors invite reviewers, summarize reviewers' findings, and make a recommendation to the science editor based on those reviews and their own evaluation of a manuscript.

To those who have volunteered to serve as associate editors and contributed their time and expertise to ensure that GSA's publications are scientifically of the highest quality, GSA thanks you. The GSA journal science editors have selected the following associate editors for special recognition of the quality of their recommendations and/or the level of their involvement in revision.

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