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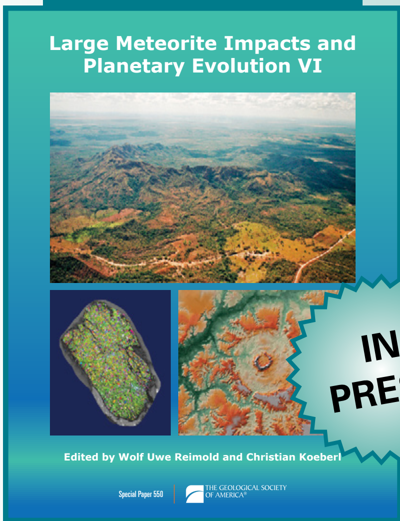
Active Uplift of Southern Tibet Revealed

Special Paper 550



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Large Meteorite Impacts and Planetary Evolution VI

Edited by Wolf Uwe Reimold and Christian Koeberl

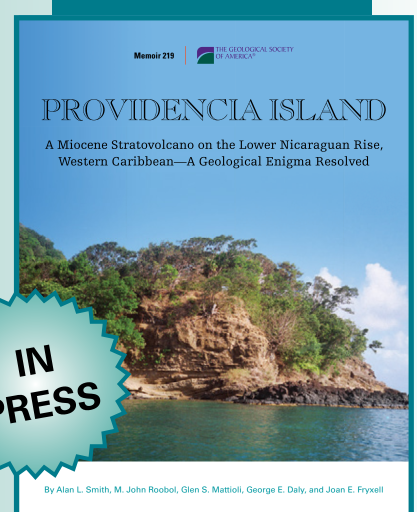
This volume represents the proceedings of the homonymous international conference on all aspects of impact cratering and planetary science, which was held in October 2019 in Brasília, Brazil. The volume contains a sizable suite of contributions dealing with regional impact records (Australia, Sweden), impact craters and impactites, early Archean impacts and geophysical characteristics of impact structures, shock metamorphic investigations, post-impact hydrothermalism, and structural geology and morphometry of impact structures—on Earth and Mars. Many contributions report results from state-of-the-art investigations, for example, several that are based on electron backscatter diffraction studies, and deal with new potential chronometers and shock barometers (e.g., apatite). Established impact cratering workers and newcomers to this field will both appreciate this multifaceted, multidisciplinary collection of impact cratering studies.

PROVIDENCIA ISLAND: A Miocene Stratovolcano on the Lower Nicaraguan Rise, Western Caribbean—A Geological Enigma Resolved

By Alan L. Smith, M. John Roobol, Glen S. Mattioli, George E. Daly, and Joan E. Fryxell

Providencia is the only example of subaerial volcanism on the Lower Nicaraguan Rise. In this volume, the authors examine this volcanism and the geological history of the western Caribbean and the Lower Nicaraguan Rise, whose origin and role in the development of the Caribbean plate has been described as enigmatic and poorly understood. While the Providencia alkaline suite is similar to others within the Western Caribbean Alkaline Province, its subalkaline suite is unique, having no equivalent within the province. In order to unravel its complex history and evolution, this volume presents new and previously published results for the geology, geochemistry, petrology, and isotopic ages from the Providencia island group.

Memoir 219



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SCIENCE

Cover: View to the Northeast of the Lopu Kangri massif of the Gangdese Range with Kailas Formation rocks folded and faulted by the Great Counter Thrust system in the foreground. Photo by Andrew Laskowski. For the related article, see pages 4–10.

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GSA NEWS

THE GEOLOGICAL SOCIETY OF AMERICA®

Active Uplift of Southern Tibet Revealed

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ABSTRACT

North of the Himalayas is the Tibetan plateau—the largest physiographic feature on Earth related to intercontinental collision. Here, we study the rugged Gangdese Range along the southern drainage divide of the Tibetan plateau using a synthesis of geologic, thermochronologic, and interseismic geodetic observations that reveal that southern Tibet's Gangdese Range is undergoing active surface uplift at present-day rates rivaling the Himalaya. Uplift has likely been sustained since the early Miocene, and we hypothesize that surface uplift of the Gangdese Mountains led to the development of Tibet's internally drained plateau, as well as potentially reversed the course of the paleo Yarlung River, in tandem with exhumation of the Himalayan gneiss domes. We suggest the data are consistent with active thrust duplexing, balanced by upper crustal extension, effectively extending the active décollement between the underthrusting Indian plate and the Eurasian upper plate more than 200 km north of the High Himalayas.

INTRODUCTION

The Himalayan-Tibetan orogen hosts the tallest and largest area of high topography, and thickest crust, on Earth, representing a dramatic expression of crustal shortening (Fielding et al., 1994) (Figs. 1–4). A topographic swath profile between longitudes 85–90°E (Figs. 1–4) illustrates from south to north the flat Indo-Gangetic plain, the foothills of the sub-Himalaya, the extreme relief of the High Himalayas, the broad east-west topographic trough of the Yarlung River valley, and the high crest of the Gangdese Range with its gentle north-facing slope. Regionally, geomorphic features north of the Yarlung River are superimposed upon the internally drained portion of the Tibetan plateau, which by area is the plateau's largest surficial feature, forming a long wavelength depression encompassing ~600,000 km^2 (Fielding et al., 1994) (Fig. 4). Given such vastness, the question of how the internally drained Tibetan plateau formed is a matter of pressing interest, although research to-date has been unable to determine a conclusive cause (Sobel et al., 2003; Horton et al., 2002; Kapp and DeCelles, 2019). In the following, we present preliminary results of ongoing work along the southern drainage divide of the Tibetan plateau, which coincides with the Gangdese Range. Compilations of low-temperature thermochronology, global positioning system (GPS), and terrain analysis reveal that the Gangdese Range has experienced recent surface uplift and is likely active today. This critical new observation sheds light on the style of active shortening across the India-Asia collision zone, with implications for large-scale drainage reorganizations for the Himalayas and Tibetan plateau. We begin with the neotectonic setting for the Himalayan-Tibetan orogen, followed by a discussion of potentially active structures, which suggest the Gangdese as a potential candidate to explain recent fluvial reorganizations across southern Tibet.

THE INDIA-ASIA COLLISION ZONE AND THE GANGDESE RANGE

The India-Asia collision zone presently absorbs ~4 cm/yr of geodetic convergence as India moves in the N20E direction relative to stable Eurasia (Zhang et al., 2004). Most agree that the Main Himalayan Thrust (MHT) and its updip imbricate fault splays accommodate the majority of convergence at depth at geodetic and millennial time scales (18–22 cm/yr) (Ader et al., 2012; Lavé and Avouac, 2000). However, disagreement exists on whether the downdip geometry of the MHT is planar, involves crustal ramps beneath the high-relief topographic steps (e.g., Whipple et al., 2016; Ghoshal et al., 2020), or if surface breaking splay faults accommodate a significant portion of India-Asia convergence (e.g., Murphy et al., 2013). Seismic imaging is consistent with a low-angle (10–20°) north-dipping décollement for the MHT, with its northward extent occurring below the main Himalayan peaks at ~50 km depth (Makovsky and Klemperer, 1999). North of the main Himalayan peaks are the northern Himalayan gneiss domes, which are exposed between the South Tibetan fault system in the south and the Indus-Yarlung suture (IYS) zone to the north (Figs. 2 and 3). The gneiss domes are cored by variably deformed orthogneiss and locally are intruded by leucogranites, emplaced between 37 and 34 Ma (e.g., Lee et al., 2000; Larson et al., 2010). The gneiss domes are juxtaposed against Tethyan sedimentary rocks in the hanging wall, with rapid cooling regionally initiating by 12 ± 4 Ma (Lee et al., 2004) (Figs. 2 and 3).

The remainder of active convergence is accommodated throughout the Tibetan plateau by north-striking normal faults and generally northeast- and northwest-striking strike-slip structures (e.g., Taylor and Yin, 2009). The geometry and kinematics of active structures accommodating east-west extension across southern Tibet and fault scarps are consistent with recent seismogenic activity (Taylor and Yin, 2009). Since the onset of extension may date when the Tibetan plateau attained its maximum elevation, this timing has been determined

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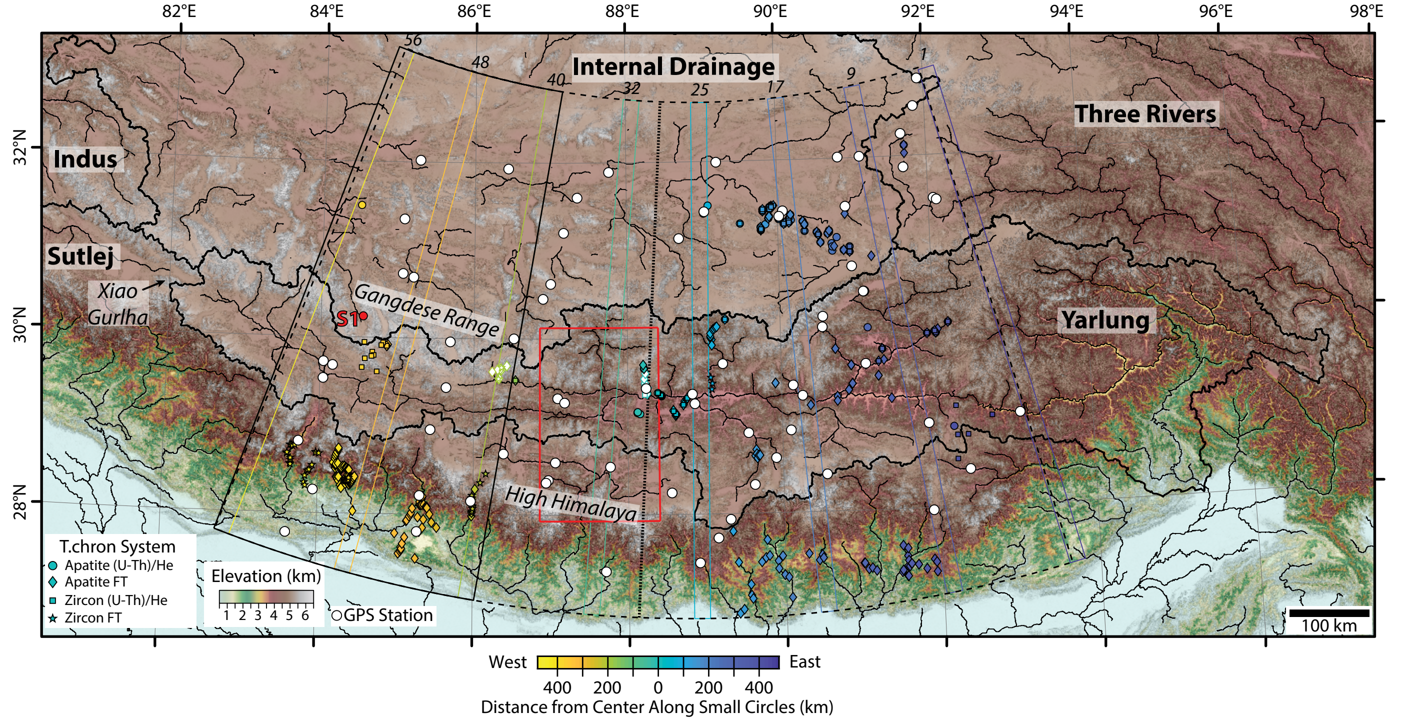

Figure 1. Shuttle Radar Topography Mission 90-m color shaded elevation map. Thermochronology data (Laskowski et al., 2018; Thiede and Ehlers, 2013) in Figure 4 are shown with thermochronometer type. Color scale bar indicates east-west position from swath profile in Figure 4. Open symbols—location in the hanging wall of a normal fault; white circles—GPS stations from Liang et al. (2013); dashed outlines—areas sampled for Figure 4; solid lines mark topography and precipitation in Figure 4A. Thick dotted lines mark centerline for distance measured along small circles in Figure 4A. Individual colored swaths sample dominant rivers in Figure 4B. Thick black lines are rivers and catchment areas for Sutlej, Indus, Yarlung, and Three Rivers, and zone of Internal Drainage. Red box shows location of Figure 2. Red symbol shows location of Figure S1 [see text footnote 1].

primarily by understanding the exhumation history of the footwalls of north-striking normal faults. One example is the northern Lunggar Rift that locally has up to 25 km of top-to-the-east displacement and initiated in the middle Miocene with uniformly low slip rates (<1 mm/yr) (Sundell et al., 2013). In the late Miocene, slip rates of rift bounding faults increased up to 5 mm/yr beginning in the southern Lunggar Rift, and accelerated northward, perhaps in response to the northward underthrusting of India (Sundell et al., 2013; Styron et al., 2015). Rift-bounding normal faults in the Yadong Gulu section of the Nyainqentanglha initiated at ca. 8 Ma based on results using ^{40}Ar/^{39}Ar thermochronology (Harrison et al., 1992). In southernmost Tibet near Xigaze, a north-trending dike was dated at 18 Ma and is thought to represent the time when east-directed extension initiated (Yin et al., 1994), but whether diking represents a regional extensional event is debated. The dynamic causes for the development of the active structures accommodating east-west–directed extension are discussed by Blisniuk et al. (2001), Kali et al. (2010), Langille et al. (2010), Yin and Taylor (2011), Sundell et al. (2013), and Styron et al. (2015).

Here we focus on the Gangdese Range of southern Tibet that locally has nine active NNW-striking normal faults we refer to as the Gangdese Rifts, located north of the IYS zone and west of Tangra Yum Co (Figs. 1 and 3). A potential mechanism for their formation is discussed in Yin (2000).

GEOLOGY OF THE GANGDESE RANGE

Locally, elevations for the Gangdese Range exceed 7500 m, forming the southern boundary of the internally drained region of the Tibetan plateau (Figs. 1 and 5). The Gangdese Rifts are active structures and are shorter in length than the seven more well-studied longer rifts cutting the entire Lhasa terrane (e.g., Tangra Yum Co Rift)—along-strike lengths of the Gangdese Rifts are between 30 and 50 km. Detailed studies of the Gangdese Rifts are lacking, but a recent study concludes that the initiation age for one Gangdese Rift is ca. 16 Ma using zircon U-Th/He data (Burke et al., 2021). The Gangdese Rifts become more northwest striking in the western Lhasa terrane, and rift-bounding faults are more linear in map pattern with the westernmost rifts, suggesting an increase in oblique (i.e., dextral strike-slip) motion (see Fig. S1 in the Supplementary Material[1]). The Gangdese Rifts cut several regional structures, including the north-directed Great Counter Thrust (GCT) and the south-directed Gangdese Thrust (GT) (Yin et al., 1994) (Figs. 1 and 2). Crosscutting relationships—including the timing of Kailas Formation deposition between 26 and 23 Ma (Leary et al., 2016), the timing of slip across north-striking normal faults that cut the GCT (Sundell et al., 2013), and the age of a crosscutting pluton near the town of Lazi at ca. 10 Ma (Laskowski et al., 2018)—are consistent with the GCT being active between 23 and 16 Ma.

The south-directed GT (e.g., Yin et al., 1994) carries plutonic rocks across a north-dipping shear zone. ^{40}Ar/^{39}Ar thermochro-

[1]Supplemental Material. Description of the methodology for projecting various data types onto the swath profiles in Fig. 4 along with Google Earth imagery for evidence of an increase in the strike-slip component of faulting along the Gangdese Rifts in western Tibet. Go to https://doi.org/10.1130/GSAT.S.14681367 to access the supplemental material; contact editing@geosociety.org with any questions.

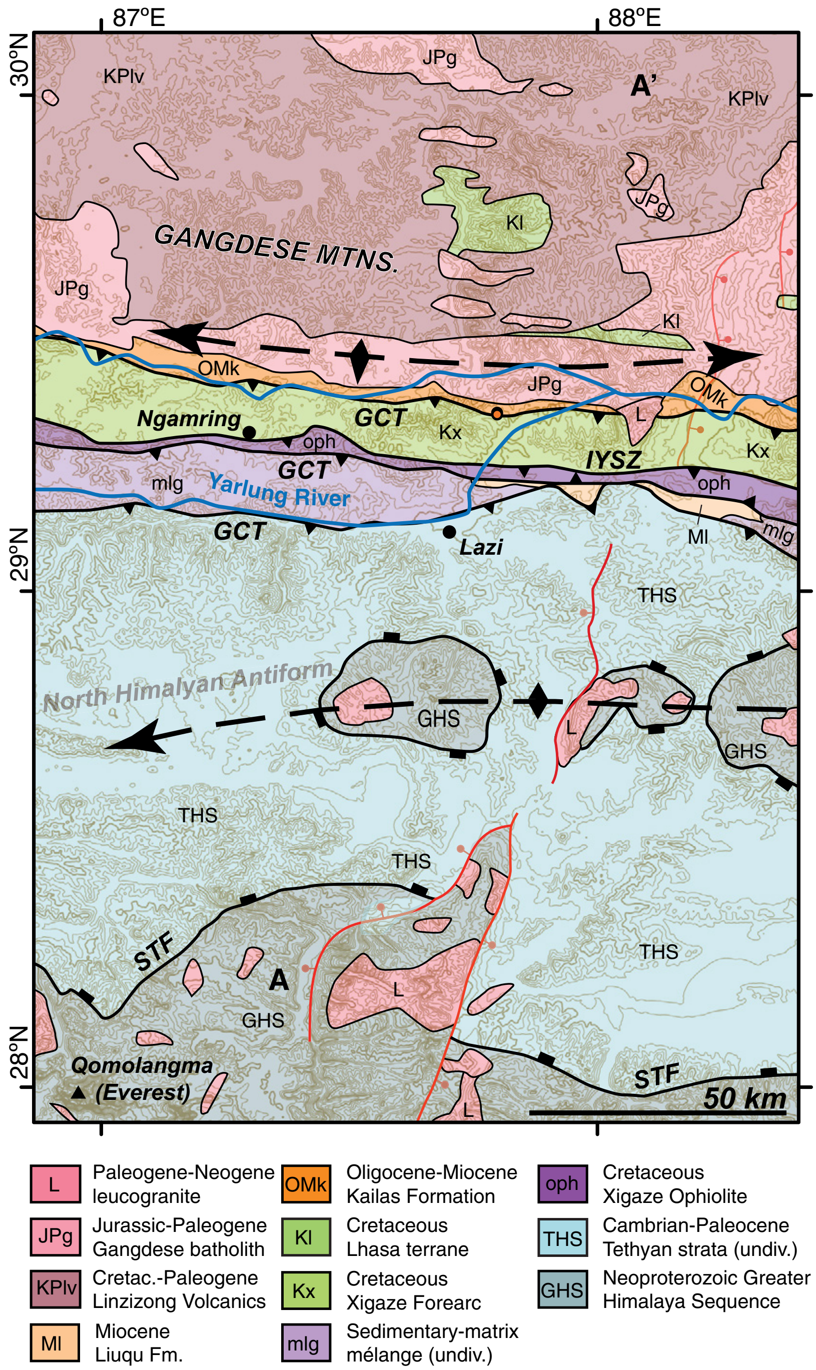

Figure 2. Geologic map with rock units (see Fig. 1). GCT—Great Counter Thrust system; IYSZ—Indus-Yarlung suture zone; STF—South Tibetan Fault. Bold dashed lines with arrows are antiforms—fold axis for the Gangdese Range with the long axis of asymmetric diamond indicates steeply south-dipping Kailas Formation. Red lines—active normal faults. Elevation contours are 200 m and 500 m (bold). Modified from Laskowski et al. (2018).

nology data near Lhasa suggest the GT was active between 27 and 23 Ma (Harrison et al., 1992). However, other studies argue that the GT is not exposed along the IYS zone, and therefore is not a mechanism for accommodating large-magnitude crustal thickening (Aitchison et al., 2003). Alternatively, the GT may be a shear zone difficult to identify in the field because it is either largely buried under the Kailas Formation, the GT occurs in the footwall of the GCT, or the GCT forms a branch line with the GT, forming a roof and floor thrust respectively, to a north-dipping duplex beneath the Gangdese Range. The map pattern is consistent with the Gangdese duplex forming an asymmetric south-verging antiform (Figs. 2 and 3), with a steeply south-dipping forelimb of Kailas Formation in the south, and a gently north-dipping backlimb of Linzizong volcanic rocks to the north (Figs. 2 and 3). The crest of the antiform is located at the southern Tibet drainage divide and locally is cut by the north-striking Gangdese Rifts (Figs. 1 and 5).

To better understand the structural and geomorphological complexities associated with the Gangdese Range, we compiled topographic (Lehner et al., 2008), low-temperature thermochronometer (Thiede and Ehlers, 2013; Laskowski et al., 2018), geodetic (Liang et al., 2013), and rainfall (Bookhagen and Burbank, 2006) data for the Himalaya and Tibet onto a single, composite north-south swath profile (Fig. 4). A full description of the data projections for assembling Figure 4 is provided in the supplemental material (see footnote 1).

IS GANGDESE DUPLEXING ACTIVE?

A recent structural model links the GCT with the Gangdese Thrust, interpreted as the largely buried roof thrust of a north-dipping duplex (Laskowski et al., 2018). The Gangdese duplex model is consistent with seismic reflection data gathered during the INDEPTH active-source and Hi-CLIMB experiments, with seismic imaging showing imbricated, north-dipping reflectors becoming shallower at upper structural levels (Makovsky and Klemperer, 1999; Nábělek et al., 2009). In the following, we suggest that the Gangdese duplex may be an active structure.

Elevations in Figure 4 illustrate the well-known high relief of the Himalaya rising from the Indian subcontinent. As noted previously (e.g., Bookhagen and Burbank, 2006), mean annual precipitation values are inversely correlated with elevation—this is clear in the low-elevation regions located south of the Himalaya receiving large amounts of precipitation (up to 4 m/year), compared to the arid interior of Tibet to the north.

Low-temperature thermochronologic data (Laskowski et al., 2018) show dominantly Miocene cooling ages over most of southern Tibet, with 23–15 Ma cooling, overlapping in time with development of the GCT (Fig. 4). North of the Gangdese Range and south of the Bangong-Nujiang suture zone, thermochronologic data show dominantly late Cretaceous cooling ages for central Tibet, consistent with little to no late Cenozoic exhumation. The thermochronometric data are also consistent with more recent exhumation across the ~150

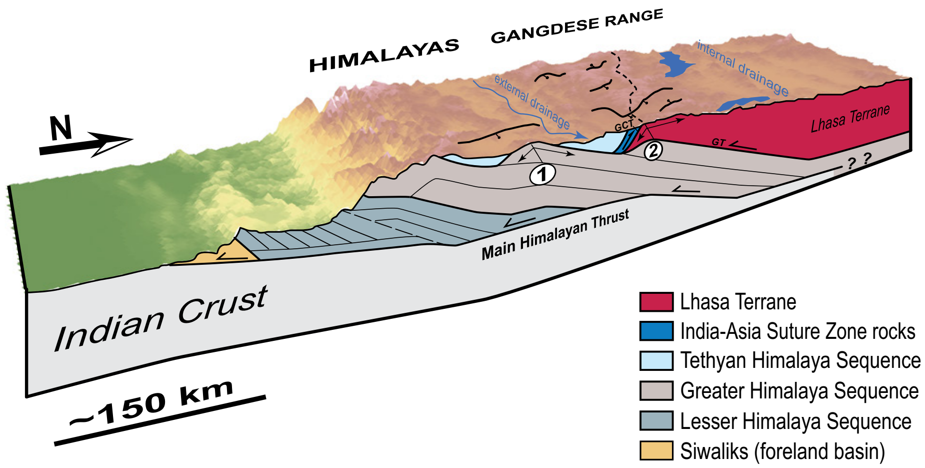

Figure 3. Model of the Indo-Asian collision illustrating rock uplift above thrust ramps (Main Himalayan Thrust) or duplexes forming topographic relief for the Gangdese Range, and a topographic divide between internal and external drainage (dashed black line) controlling flow direction of the Yarlung River (solid blue line). Himalayan gneiss domes (1) and the Gangdese Duplex (2). Structures adapted from Laskowski et al. (2018), Long et al. (2011), and Nábělek et al. (2009). (VE = 5.) GCT—Great Counter Thrust system; GT—Gangdese Thrust.

km width of the Gangdese Range. Areas of focused exhumation across the Gangdese are co-located with GPS data showing significant positive vertical velocities, consistent with active exhumation.

A comprehensive data set of GPS velocities is presented in Liang et al. (2013), including sparse information about the vertical component of the velocity field (Fig. 4). The horizontal north-south component of the velocity field indicates north-south convergence ~40 mm/yr relative to stable Eurasia, with a velocity gradient of ~20 mm/yr across the Himalaya and the IYS zone, consistent with previous results (e.g., Bilham et al., 1997; Zhang et al., 2004). The vertical component of the interseismic velocity field also shows that the Himalayas are rising at 2.56 ± 1.23 mm/yr, consistent with both previous geodetic studies (e.g., Bilham et al., 1997; Liang et al., 2013) and surface uplift rates determined from geomorphology

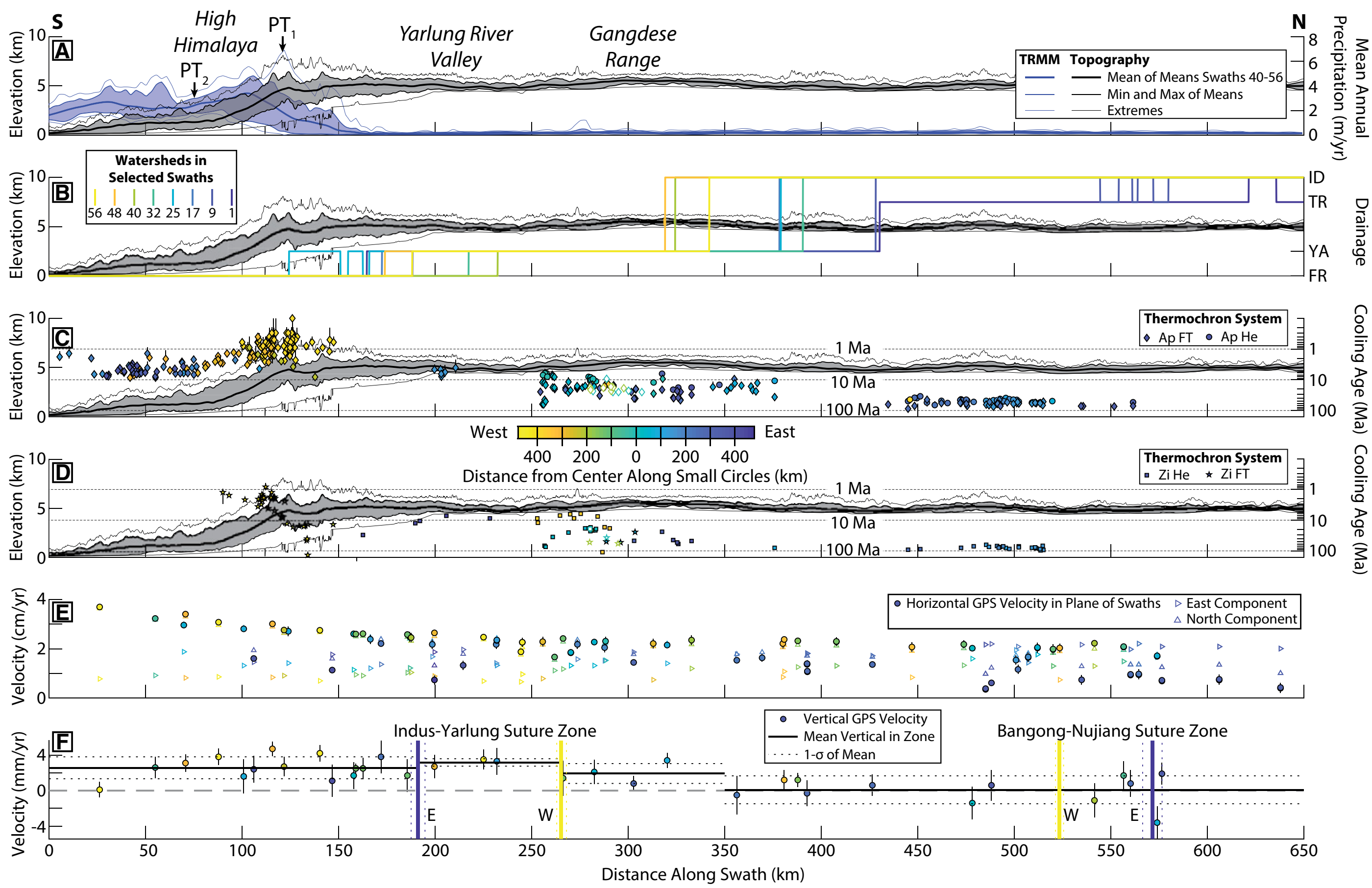

Figure 4. Swath profile of areas in Figure 1. (A) Averages of sixteen 20-km-wide swaths through Shuttle Radar Topography Mission 90 m elevation and Tropical Rainfall Measurement Mission 2B31 (Bookhagen and Burbank, 2006) mean annual precipitation. Topographic swath is the same for panels B, C, and D. PT—physiographic transition. (B) 20-km-wide swaths showing the location of major divides between the internally drained Tibet (ID), three rivers (TR), Yarlung (YA), and frontal Himalaya rivers (FR). Swath locations are shown in Figure 1 and colored by distance from swath center. (C) Apatite and (D) zircon thermochronology data from Thiede and Ehlers (2013) and Laskowski et al. (2018), colored by distance from the centerline, with *y*-axis position for cooling age. (E) Projected horizontal global positioning system (GPS) velocities in the plane of individual swaths (solid symbols) and the corresponding N and E components (Liang et al., 2013). (F) All available data for the vertical component of GPS velocities (Liang et al., 2013). Solid black lines—average of defined zones; dotted lines—one standard deviation of the mean.

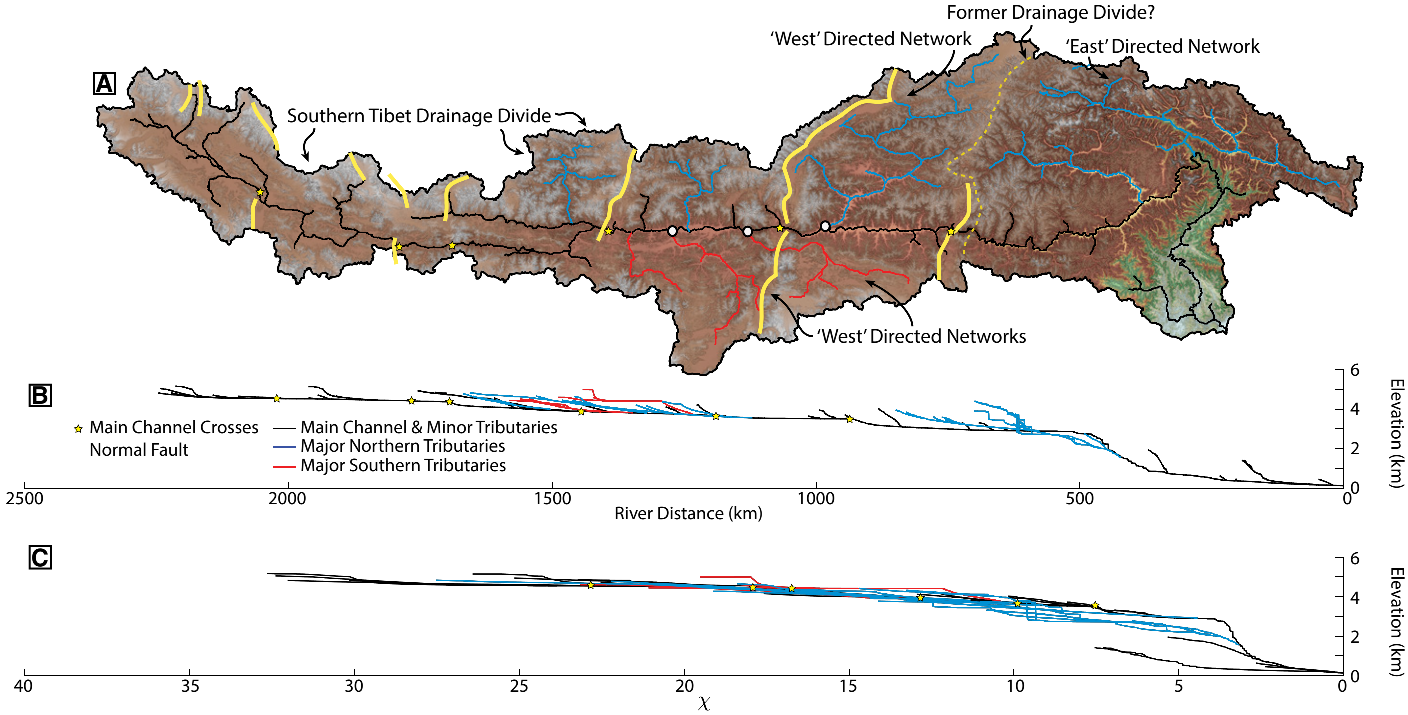

Figure 5. (A) Yarlung catchment with stream network. See Figure 1 for location. White dots indicate large junction angles consistent with west-directed paleoflow of the Yarlung River. Yellow stars mark reference locations on panels B and C. (B) Long profile with tributaries north (blue) and south (red) of the main river. (C) χ-elevation profile of B. Thick yellow lines—active normal faults.

and leveling data (i.e., Lavé and Avouac, 2000). Surprisingly, the mean of the vertical component of the velocity field across an ~170-km-wide zone spanning the IYS zone and the Gangdese Range (Fig. 4) is 3.17 ± 0.46 mm/yr, which is similar within error to the vertical velocity measured for the Himalayas. The mean of the vertical velocity north of the Gangdese Range and south of the Bangong-Nuijiang suture zone gradually decreases from ~3 mm/year in the south, to 0.09 ± 1.57 mm/yr to the north. Locally, vertical velocities related to freeze-thaw cycles and other surface processes may occur in the proximity of the large saline lakes north of the Gangdese Range. However, because all of the available values of the vertical velocity field in the Liang et al. (2013) data set are positive across the Gangdese Range and show a significant velocity gradient, we view the data as consistent with active surface uplift across the entirety of the Gangdese (Fig. 4).

HYPOTHESIZED MECHANISM FOR INTERNAL DRAINAGE DEVELOPMENT

If surface uplift across the Gangdese Range is active, we posit the following hypothesis: fluvial reorganization of previously trans-Himalayan rivers with headwaters located in central Tibet, rerouted from a southward flow to northward into Tibet's interior, by the creation of high topography across the Gangdese Range. The resulting high topography across the Gangdese Range led to development of the internally drained Tibetan plateau and drainage integration along the Indus-Yarlung suture zone, creating the modern headwaters for the Yarlung River. The GPS vertical velocity field is consistent with surface uplift of the Gangdese Range ongoing today, and that deep-seated crustal shortening (e.g., DeCelles et al., 2002; Styron et al., 2015) is balanced by upper crustal extension, rather than surface lowering due to pure shear deformation that occurs to the north in central Tibet (Taylor and Yin, 2009). Pure shear dilation, crustal thinning, and surface lowering is a key prediction arising from models of extensional collapse for the entire Tibetan plateau (e.g., Ge et al., 2015), but is inconsistent with results of active surface uplift across the Gangdese Range.

The vertical component of the GPS velocity field and geologic observations described in the previous sections suggests that active crustal thickening is occurring ~150 km north of the High Himalayan physiographic transition (e.g., PT2, Fig. 4A; Hodges et al., 2004). This is incompatible with all current models of Himalayan shortening, where the active thrust wedge does not extend into Tibet. Our findings effectively extend the orogenic thrust wedge well into Tibet, where the MHT soles into a north-dipping thrust ramp below the Gangdese Range (Fig. 2). Our model, combined with the geometry of the Gangdese Rift and Great Counter Thrust systems, explains the GPS, topographic, and exhumation patterns of the Tibetan plateau (Figs. 2 and 4).

In addition to causing a flow reversal of previously trans-Himalayan rivers, we suggest the same process likely elevated surface topography to a critical threshold in the western region of the southern Gangdese Range and IYS zone (Fig. 1), also resulting in the reversal of the paleo west-flowing Yarlung River to its modern eastward course. Locally, the geomorphology of the east-flowing Yarlung River and its tributaries is paradoxical, with much of its drainage network topology consistent with paleo-westward flow. One example is a large (~180°) junction angle between the Yarlung and Lhasa rivers (Burrard and Hayden, 1907) with at least three additional and exceptionally large junction angles farther west, up to river distance of ~1300 km (Fig. 5). A recent alternative hypothesis for this junction angle involves antecedence (Laskowski et al., 2019), but this interpretation is not mutually exclusive. Additionally, former significant (now breached) drainage divides preserved in the eastern half of the Yarlung network divide nominally east-directed tributaries from west-directed tributaries (Fig. 5A). The timing of an inferred westward flow for the Yarlung River is unknown. However, a recent study using detrital zircons suggests a connection between the Indus River and the Gangdese Range (Bhattacharya et al., 2021)—if correct, this is consistent with a west-flowing Yarlung River by ca. 27 Ma. Finer-scale evidence for past drainage network instability is observed for the Yarlung River and its tributaries, with several prominent knickpoints located downstream where the Yarlung River flows across the footwalls of several active north-striking normal faults related to the Tibetan rift systems—the most prominent occurs at river distance ~900 km, which resembles a now-breached former drainage divide (Fig. 5). The Yarlung River continues its flow path into the well-known Tsangpo gorge at the eastern Himalayan syntaxis (Fig. 5) (Zeitler et al., 2001; Lang and Huntington, 2014). Our hypothesized evolution for the topography of southern Tibet and the Himalayas is largely consistent with available provenance work from the Himalayan foreland (e.g., Lang and Huntington, 2014; Zhang et al., 2012), though in detail differs with many prior hypothesized scenarios for integration of the Yarlung River by the early Miocene. Ultimately, constraining the history of the Yarlung will require linking detailed new geologic and geomorphic observations along the Yarlung and its tributaries with these downstream records.

Geologic and geomorphic observations in tandem with interseismic geodetic velocities show that southern Tibet is undergoing surface uplift at a rate comparable to the Himalayas along the north side of the Yarlung River, and that this uplift has been sustained potentially, since at least middle Miocene time based on recent exhumation patterns revealed from thermochronology. Our synthesis is consistent with the growth of topography associated with the development of thrust duplexing, playing an integral role in shaping the internally drained Tibetan plateau. Our preliminary work on this active project has likely raised more questions than answers, and we plan to host special sessions at a future Geological Society of America meeting to better understand processes associated with fluvial reorganizations in active orogens.

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THE GEOLOGICAL SOCIETY OF AMERICA®

CONNECTS 2021

10–13 October
Portland, Oregon, USA

Registration and Information

Deadline: 11:59 p.m. MDT on 7 Sept.
Cancelation deadline: 11:59 p.m. MDT on 1 Oct.
https://community.geosociety.org/gsa2021/registration

GSA Connects 2021 registration is open. Take advantage of early registration prices and assure your spot on field trips, short courses, and events by registering now. **Risk-free registration:** Fully recognizing that every individual's situation is in flux—between job losses, company travel freezes, etc.—GSA's goal is to make it easier for you to attend GSA Connects 2021. As a result, we have implemented a risk-free registration. Once you register, if you are not able to attend the live event, full refunds will be available if you cancel by 1 Oct. You can also change your registration to the online experience and receive a refund for the difference in registration rates. **Refund policy:** The deadline to request a full refund or transfer your registration to the online experience is Friday, 1 Oct. Cancelations must be received by the stated cancelation deadline and will be accepted in writing only. No-shows for the event will not receive a refund.

EVENTS REQUIRING TICKETS/ ADVANCE REGISTRATION

Several GSA Divisions and Associated Societies will hold breakfasts, lunches, receptions, and awards presentations that require a ticket and/or advance registration (see the meeting website for a complete list). Ticketed events are open to everyone, and tickets can be purchased in advance when you register. If you are not attending the meeting but would like to purchase a ticket to one of these events, please contact the GSA meetings department at meetings@geosociety.org. **Event space requests:** 31 August is the LAST day to submit a request for event space and event listing. GSA will not assign any additional meeting space after this date and cannot guarantee to list your event on the website or mobile app. Go to **https://community.geosociety.org/gsa2021/connect/events/plan** to register your request today.

TRAVEL GRANTS

Various groups are offering grants to help defray your costs for registration, field trips, travel, etc., for GSA Connects 2021. Check the website at **https://community.geosociety.org/gsa2021/connect/student-ecp/travel-grants** for application and deadline information. Note: Eligibility criteria and deadline dates may vary by grant. The deadline to apply for the GSA Student Travel Grant is 7 Sept.

STUDENT VOLUNTEERS

Earn complimentary registration when you volunteer to work for at least ten hours, plus get an insider's view of the meeting. Please wait to register for the meeting until you sign up as a volunteer unless you want to reserve a space in a Field Trip or Short Course. Details: **https://community.geosociety.org/gsa2021/registration/volunteers.**

ACCOMMODATIONS & SERVICES

GSA strives to create a pleasant and rewarding experience for every attendee. Let us know in advance of the meeting if you have needs that require further attention. Most dietary considerations can be met without any extra charge. Be sure to check the appropriate box when registering online, and a GSA staff member will contact you. GSA will also have a self-care room and nursing pods on site.

CRITICAL HOUSING DATES

7 Sept.: The last day to cancel rooms without a penalty;
15 Sept.: Room rates are guaranteed as long as there are rooms available in the GSA room block;
1 Oct.: All changes, cancelations, and name substitutions must be finalized through Connections Housing by this date; and
After 1 Oct.: Beginning on this date, you must contact the hotel directly for all changes, cancelations, and new reservations.

Once you receive your hotel acknowledgment and have booked your travel, please review your hotel arrival/departure dates for accuracy. If you do not show up on the date of your scheduled arrival, the hotel will release your room and you will be charged for one night's room and tax. If you have travel delays and cannot arrive on your scheduled arrival date, please contact the hotel directly to make the hotel aware of your new arrival date.

ROOM SHARING/RIDE SHARING

Use the GSA Roommates and Rides at **https://community.geosociety.org/gsa2021/travel/rooms-rides** to share housing, airport shuttles, and/or carpool. You can also use this service to meet up with your colleagues at the meeting.

CHILDCARE BY KIDDIECORP

KiddieCorp will provide childcare services for GSA attendees on Sun.–Wed., 7 a.m.–6 p.m. The program is open to children six months to 12 years. The cost is US$10 per hour per child for children two years or older and US$12 per hour per child for children under two with a one-hour minimum per child. Register now at **https://community.geosociety.org/gsa2021/information/family.** Availability is limited and handled on a first-come, first-served basis. Deadline: 13 Sept.

Noontime Lectures

Both presentations will also be available via live-streaming.


José Gámez


Marek Ranis


Missy Eppes

Tuesday, 12 Oct., 12:15–1:15 p.m.
José Gámez, Marek Ranis, Missy Eppes: "Bringing Art to Your Science and Thus Your Science to the People: Joining Visual Culture and Scientific Evidence." *Endorsed by GSA's Geology and Society Division, Geoscience Education Division, History and Philosophy of Geology Division, and Quaternary Geology and Geomorphology Division.*

Description: There is a long tradition of merging art with science, originating from both fields of study, with good reason. The idea that truth can be made visible has a long history directly affecting both disciplines. For example, in the rise of the natural sciences in the nineteenth century, vision was understood as a primary avenue to knowledge, and sight takes precedence over the other senses as a primary tool in the analysis and ordering of living things—opening doors to collaborations between artists and scientists even then. Communication in both art and science is dependent on cooperative and collaborative methods in lab-, field-, virtual-, and three-dimensional space and time. Finally, art is perfectly positioned to bring science to the world beyond scientists, filling a crucial need for more effective science communication to the public. Projects merging geoscience, in particular, with art can also serve as an effective link between natural history and human history. The aim of this event is to provide concrete examples of how combining art with science can serve a need for more effective science communication and to provide practical information about how to go about it. For example, through Broader Impacts in NSF grants, there are opportunities for earth scientists to collaborate with artists in research and pedagogy, with the result of an enrichment of communication, understanding, and revelation.


Katie Stack Morgan

Wednesday, 13 Oct., 12:15–1:15 p.m.
Katie Stack Morgan: "The Mars 2020 Perseverance Rover in Jezero Crater."

Description: The Mars 2020 Perseverance rover, NASA's newest flagship Mars rover mission, landed in Jezero crater in February 2021. Perseverance is seeking signs of ancient life on Mars and is the first of a multi-mission effort to return samples from Mars back to Earth. This talk will review highlights from the first eight months of Perseverance's mission to Mars.

Commitment to Care

The Geological Society of America considers the safety and well-being of all those on site at GSA Connects 2021 in Portland, Oregon, USA, as our top priority. Our Commitment to Care is a living document that will continue to evolve as updates become available from the Oregon Convention Center (OCC), the Centers for Disease Control (CDC), and local government. We are incorporating innovative features that will further enhance the on-site experience and safety for everyone in attendance.

Name badges will be printed using on-demand print kiosks throughout the pre-function area at the convention center. Seamlessly scan your QR code, and your badge will be printed in a touchless system. Grab a lanyard off the rack and be on your way.

On-Site Medical: We will be hiring local EMTs and providing a dedicated space for EMTs to meet with attendees who feel ill.

Hand Sanitizer: Touchless hand sanitizer dispensers will be placed at key guest and employee entrances, as well as in high-use areas, such as public lobby spaces, restroom entrances, stairs, elevators, escalators, employee work areas, and offices.

IN PARTNERSHIP WITH THE OCC, WE WILL BE PROVIDING:

- Responsible food & beverage/seating/barriers for meeting spaces.
- Appropriate signage/floor decals to reinforce social distancing and other safety reminders.
- Enhanced cleaning, including using electrostatic disinfectant sprayers in each meeting room between morning and afternoon technical sessions, in addition to the OCC's standard overnight cleaning services.

The OCC has obtained the Global Biorisk Advisory Council (GBAC) Star Accreditation (**https://gbac.issa.com/gbac-star-facility-accreditation/**). View the OCC's Reimaged Opening & Innovation Strategy for more details (**https://bit.ly/2QsqzSZ** [PDF]).

Oregon Convention Center. Credit: Travel Portland.

HEALTHSHIELD BY 42CHAT

As part of GSA's Commitment to Care program, GSA is introducing a SMS text–based COVID-19 symptom screening. We will be asking attendees to click on the link that is sent via text to their cell phones every morning starting on Sunday, 10 Oct., and complete the three-question screening recommended by the CDC before entering the Oregon Convention Center. You can also complete the screening at the entrance doors of the convention center; however, completing it beforehand will be much faster. GSA is offering this to continue to provide confidence in safety for meeting attendees and to help ensure that every arriving attendee can attest to their current health status. For more information on the process, go to **https://www.42chat.com/bots/healthshield.**

PERSONAL ACCOUNTABILITY COMMITMENT

By attending GSA Connects 2021, you agree to abide by and engage in certain health-and-safety precautions while attending the event. This includes, but is not limited to, wearing a mask (if unvaccinated) at all times within the convention center and hotels when not consuming food or beverage, minimizing face touching, frequently washing hands, sneezing and/or coughing into your elbow, engaging in appropriate physical distancing, respecting others' requests for space, and avoiding risky environments, such as overcrowded bars or restaurants. You agree to not attend any GSA event if you feel ill or had recent exposure to a COVID-19 case.

Scientific Field Trips

Unique and outstanding experiences await when you attend a field trip at GSA Connects 2021.

• Earn continuing education units (CEUs)
• Explore a new area
• Engage with colleagues and fellow geologists
• Learn and grow your expertise

Register for a field trip today! Field trips will only run if they meet the minimum number of attendees before the early registration deadline, 7 Sept.

https://community.geosociety.org/gsa2021/program/field

Short Courses

Earn continuing education units (CEUs) when you attend a short course at GSA Connects 2021.

Both online and in-person courses are available.

• Learn a new topic
• Build your skills
• Network
• Take courses taught by industry professionals

Register for a short course today! Course costs go up US$30 after 7 Sept.

https://community.geosociety.org/gsa2021/program/short

Geoheritage: Geology *of* the Community, *for* the Community, *by* the Community

William Andrews, *Kentucky Geological Survey, University of Kentucky, Lexington, Kentucky 40506-0107, USA, wandrews@uky.edu; and* ***Renee M. Clary,*** *Dept. of Geosciences, Mississippi State University, Mississippi State, Mississippi 39762, USA, RClary@geosci.msstate.edu*

Geoheritage identifies and seeks to protect our geodiversity through geoconservation. Through a three-pronged approach, Geoheritage (1) acknowledges the ***scientific*** value of the geodiversity in global localities; (2) addresses ***economic*** sustainable development in geotourism; and (3) facilitates the ***educational*** impact of geoscience in both informal and K–16 classroom settings. Geoheritage makes explicit connections between our natural and cultural heritage.

In 2012 (revised in 2017), the Geological Society of America released its position statement on Geoheritage, supporting the Geoheritage designation and the appropriate, respectful management of scientifically, culturally, educationally, and/or aesthetically significant Geoheritage sites. Currently, many GSA members engage with sites of unique geodiversity—scientifically, economically, and/or educationally—and participate in Geoheritage efforts, often without an awareness of existing networks, resources, and opportunities to integrate and optimize their impact. We endeavor to change this: A Pardee Keynote Symposium (P3: Geoheritage: Celebrating Our Past, Protecting Our Future) at the upcoming GSA Connects 2021 in Portland, Oregon, USA, explores a spectrum of opportunities for geoscientists and educators to professionally participate and integrate within this exciting and bold enterprise (Fig. 1).

Figure 1. Kentucky Geological Survey geologists lead field education and professional development in the Red River Gorge Geological Area in eastern Kentucky, USA. Photograph provided by the Kentucky Geological Survey.

WHAT QUALIFIES AS A GEOHERITAGE SITE?

Geoheritage sites are locations where geology can be well illustrated and relevant interpretations can be communicated to the public. The hope is to facilitate a deeper understanding of landscapes, resources, hazards, history, and culture. The U.S. National Park Service (NPS) is an obvious leader in preserving and managing Geoheritage sites (see NPS Geologic Resources Division and American Geosciences Institute, 2015), but innumerable other agencies also contribute to this critical effort. Geoheritage sites can exist on widely different scales and sizes, ranging from international geoparks (McKeever et al., 2010) to state parks and local nature preserves or even single outcrops. These sites can be administered by either public or private entities at individual, local, state, federal, or international levels (Fig. 2).

Figure 2. Geoheritage sites range from federally protected National Park sites to smaller sites of which many local citizens are often unaware. *Left:* Students on a field course to Yellowstone National Park enjoy Old Faithful Geyser. *Right:* The Principles of Paleoecology course partnered with Friends of the Black Belt Prairie and the local school board for research and community-engaged learning within Osborn Prairie, a remnant of the Black Belt Prairie found in Oktibbeha County, Mississippi, USA, that hosts marine Cretaceous fossils eroding from chalk outcrops, as well as modern biodiversity in the form of disjunct and endemic species. Photographs by Renee Clary.

Geoheritage sites serve as valuable public resources. They provide opportunities for public recreation or tourism and can have a major impact on local economies. They also can provide a critical educational resource through opportunities for informal and formal teaching in geology, biology, ecology, and other environmental sciences, and they have the potential to increase public understanding and geoliteracy in critical climate and sustainability issues facing our planet (Clary, 2021). Entire classes and curricula can be, and have been, developed using the features and processes visible at Geoheritage sites.

Geoheritage sites rely heavily on geologic research, both as a foundation for interpretation and as a basis for responsible site management (Chan and Kamola, 2017). Also, Geoheritage sites can provide spectacular platforms for research, using the marquee illustrations of geologic features and phenomena often displayed at these sites. When protected and well managed, these sites can

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Figure 3. Washington 100 is a new geotourism website from the Department of Natural Resources, Washington State, USA, that features 100 great places to view geology in the state (https://wa100.dnr.wa.gov). Image from the Washington Geological Survey (Washington Department of Natural Resources).

provide a relatively secure location for longitudinal research, through well-documented site management and sustainable use.

Importantly, Geoheritage sites provide a needed and highly visible platform for demonstrating inclusivity, respect, and accessibility (Semken, 2005). The identification and development of culturally sensitive and respectful interpretation of Geoheritage sites necessitates the active engagement of multiple voices and stakeholders, and inclusion of the widest possible spectrum of those communities with connections to the site. Multiple voices, especially those of local Indigenous peoples and local landholders, contribute to the conversation that navigates toward a public awareness about such sites. Compromise and careful adaptation of initial ideas or draft protection plans are often necessary. Making these critical and enlightening sites as accessible as possible, while still respecting and preserving the often-fragile nature of these sites, is an ongoing challenge.

AN INVITATION TO SHOWCASE YOUR GEOHERITAGE

The 2021 Geoheritage Pardee Keynote Symposium celebrates Geoheritage by highlighting successes, opportunities, best practices, and available informational resources. We also showcase geodiversity—at GSA Portland and beyond—through archived short video contributions, StoryMaps©, and virtual field trips that can be explored online (Fig. 3). We seek all input, feedback, and concerns through a moderated town-hall conversation to strengthen an integrated, multivocal Geoheritage initiative.

Our Geoheritage Challenge: Do you want YOUR favorite Geoheritage site to be considered for the Geoheritage Pardee showcase of geodiversity? We invite you to submit a short video celebrating your favorite Geoheritage site or share a virtual field trip or StoryMap© you find particularly useful or informative. We welcome both established, protected sites as well as new Geoheritage opportunities. Even if you are unable to attend GSA Connects 2021, you may share your Geoheritage site video and join our Geoheritage efforts! Register your interest at **https://forms.gle/KwgjDGMdA3f5cPUq9** by **15 Sept.** to receive guidelines on how to record and submit your 3–5 min mp4 video. The Geoscientists' Choice Geoheritage Video Awards—as determined by the GSA Connects 2021 participants—will be named in Portland. If you need additional information, please do not hesitate to contact the authors.

SUMMARY

Undoubtedly, Geoheritage positively influences our professional, public, and personal lives. It encompasses the intersection of geologic research, site preservation, formal education, public outreach, landscape management, recreation, tourism, and personal inspiration—and it is most successful when a wide spectrum of community voices are engaged and acknowledged. We invite you to participate and ensure that your voice is heard.

ACKNOWLEDGMENTS

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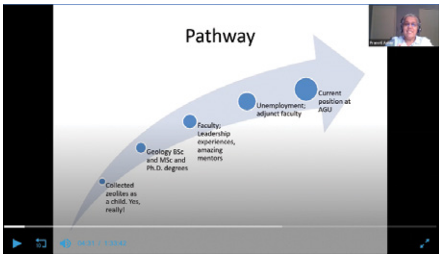
The Geological Society of America®

GEOCAREERS

If you are entering the job market or are supporting someone who is and want more information about career pathways in the geosciences, plan to attend one or more these events.



ONLINE GEOCAREERS PROGRAMS

Before the Meeting

Go to **https://community.geosociety.org/gsa2021/connect/student-ecp/geocareers** for event details.

GeoCareers Résumé Workshop, 4 Oct., noon–1 p.m. PDT

Women in Geology, 4 Oct., 2–3 p.m. PDT

GeoCareers Company & Agency Information Session, 5 Oct., noon–1 p.m. PDT

Networking Event, 5 Oct., 2–3 p.m. PDT

GeoCareers Career Pathways Webinar, 6 Oct., noon–1:30 p.m. PDT

Early Career Networking Event, 6 Oct., 2–3 p.m. PDT

ON-SITE GEOCAREERS CENTER

Open Sun.–Tues., 9 a.m.–5 p.m. during the meeting

GSA will provide a safe environment for participants by following health and safety guidelines as outlined by the Oregon Convention Center in addition to using plexiglass partitions and other interventions to reduce transmission risk.

The GeoCareers Center offers:

- Posting or Viewing Jobs
- Drop-in Mentoring
- Résumé/CV Review Clinic

Mentoring Tomorrow's Geoscience Leaders at the 2021 Section Meetings

The Geological Society of America (GSA) GeoCareers Program provides mentoring and career pathway events at all meetings. At Section Meetings, students are invited to participate in the Roy J. Shlemon Mentor Program in Applied Geology and the John Mann Mentors in Applied Hydrogeology Program. These popular events, supported by the GSA Foundation through gifts from Roy J. Shlemon and John Mann, are designed to extend the mentoring reach of individual professionals. Together, mentor volunteers and students meet in a relaxed, informal setting, to discuss careers in geology.

In 2021, all the Section Meetings were online, but there were still Shlemon and Mann events for each meeting. Thirty students and 15 mentors participated in the Shlemon Program and 21 students and 12 mentors attended the Mann Program. As a result of these events, new friendships were made, and professional contacts were established that will last well into the future. Additionally, both mentors and students left the events expressing feelings of personal and professional growth.

"I enjoyed mentoring and found it interesting to reflect on my career." —Brian Aubry

"It is great that the GSA conference is including several ways for these early career/student members to interact with other members, have the opportunity to ask questions, and hear about a variety of personal career paths. What a great opportunity for the early career and student participants!" —Cindy Pridmore

GSA gratefully acknowledges the following mentors for their individual gifts of time and for sharing their insight with students. To learn more about these programs, or to be a mentor at a future Section Meeting, please contact Jennifer Nocerino, jnocerino@geosociety.org.

THE ROY J. SHLEMON MENTOR PROGRAM IN APPLIED GEOLOGY

Helping Mentor Students Since 1996

NORTHEASTERN SECTION
Erika Amir-Lin, American Water Works Association
Janet Barclay, U.S. Geological Survey
Julia Boyles, Vermont Geological Survey
Lindsay Spigel, Maine Geological Survey
Marjorie Zeff, AECOM

SOUTHEASTERN SECTION
Mark Carter, U.S. Geological Survey
Richard Esposito, Southern Company
Susan Hall, U.S. Geological Survey
Judd Mahan, SynTerra
Diana Ortega-Ariza, Kansas Geological Survey

NORTH-CENTRAL–SOUTH-CENTRAL SECTION
Paul Mayer, The Field Museum
Brittany Parrick, Ohio Department of Natural Resources

CORDILLERAN SECTION
Russell Graymer, U.S. Geological Survey
Cynthia Pridmore, California Geological Survey
Jennifer Wilson, Six Rivers Geosciences

THE JOHN MANN MENTORS IN APPLIED HYDROGEOLOGY PROGRAM

Helping Mentor Students Since 2004

NORTHEASTERN SECTION
Erika Amir-Lin, American Water Works Association
Matt Dawson, Geological Society of America
Helen Delano, DCNR–Pennsylvania Geological Survey
John (Jack) H. Guswa, JG Environmental Inc.

SOUTHEASTERN SECTION
Edwin Andrews, Edwin Andrews & Associates PLLC
Jim Heller, Alabama Department of Environmental Management
Eric Johnson, WSP USA Inc.

NORTH-CENTRAL–SOUTH-CENTRAL SECTION
Raymond Johnson, RSI Entech
Amber Steele, Missouri Geological Survey

CORDILLERAN SECTION
Brian Aubry, Surrey Associates
Matthew Pendleton, EKI Environment & Water Inc.
Aaron Wieting, City of Portland Bureau of Environmental Services

David Dale Owen (1807–1860): Frontier Geologist

William Elliott, *Dept. of Geology and Physics, University of Southern Indiana, 8600 University Boulevard, Evansville, Indiana 47712, USA*

David Dale Owen at about 40 years of age from a self-portrait included with the *Report of a Geological Survey of Wisconsin, Iowa, and Minnesota, and Incidentally of a Portion of Nebraska Territory,* published in 1852.

NEW HARMONY

In 1825, Robert Owen, noted Scottish social reformer and philanthropist, collaborated with William Maclure, "Father of American Geology," to establish an experimental utopian community in the United States. Coincidently, the Harmonist Society led by Father Johann Georg Rapp was entertaining potential offers for their self-sufficient town of New Harmony, founded in 1814 along the Wabash River in Posey County, Indiana, USA. After Owen and Maclure purchased the town from the Harmonists in 1825, Maclure recruited many artists, educators, and scientists from Philadelphia to participate in their social experiment, including Virginia Poullard DuPalais (artist), Marie Duclos Fretageot (educator), Charles Alexandre Lesueur (artist and zoologist), Thomas Say (entomologist and conchologist), and Gerard Troost (geologist).

On 8 December 1825, this group began their journey to New Harmony from Pittsburgh, Pennsylvania, USA, navigating down the Ohio River on a keel boat named *Philanthropist*, later referred to as the "Boatload of Knowledge" (Straw and Doss, 2008). Even though the experimental society in New Harmony dissolved by 1828, the community became a beacon for scientific investigations on the frontier. Specifically, geological work endured for more than 50 years in New Harmony, serving as the headquarters for numerous state and federal geological surveys conducted by David Dale Owen and those whom he trained as geologists.

EDUCATION

David Dale Owen was born on 24 June 1807 in Lanarkshire, Scotland, to Anne Caroline Dale and Robert Owen. He was the third youngest of eight children in his family, with six of his siblings surviving infancy: Robert Dale, William, Anne Caroline, Jane Dale, Richard Dale, and Mary. In childhood, Owen was privately tutored at his family's Braxfield House prior to his three years of education under the tutelage of Philipp Emanuel von Fellenberg's school at Hofwyl, Switzerland. While attending the Swiss school, he received instruction in chemistry, geology, and natural history. Owen, along with his brother Richard, returned to Scotland in 1826 to continue their education in the natural sciences under Andrew Ure at the Andersonian Institute at Glasgow (Hendrickson, 1943).

In 1827, Owen, along with his brothers Robert Dale and Richard, sailed to America with their father, Robert Owen, arriving in New York City in January 1828. While in New Harmony, Owen interacted with several competent artists who focused on scientific illustration, such as Virginia Poullard DuPalais, Charles Alexandre Lesueur, and Lucy Sistaire Say. To continue refining his artistic talents, Owen spent a year in New York City in 1830 with his brother, Robert, improving upon his drawing and painting. Through these experiences, Owen became an accomplished artist who drew sketches and drafted illustrations that were reproduced as lithographs or engravings with his publications.

In 1831, Owen traveled to England and studied chemistry and geology at the University of London. Upon his return to the United States in 1833, he began remodeling the Harmonist Shoemaker's Shop in New Harmony to be used as a geological workshop with a lecture hall, laboratory, storage room, and museum. By the early 1830s, New Harmony had gained global notoriety through its association with Charles Alexandre Lesueur, William Maclure, Robert Owen, and Thomas Say.

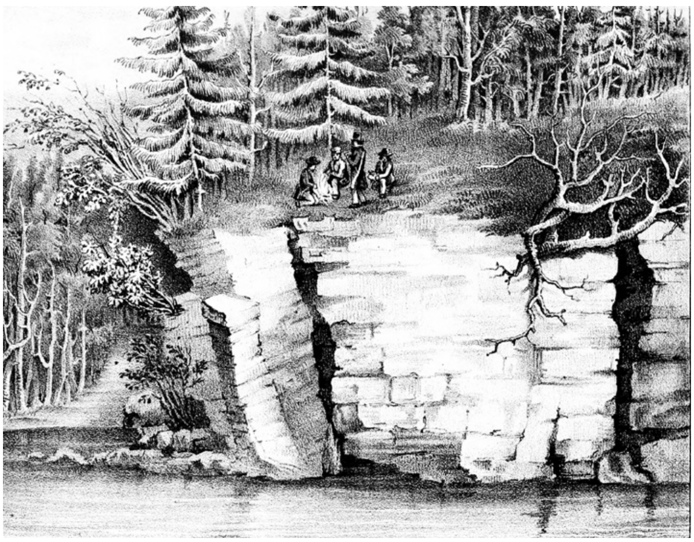
Beginning in 1835, Owen studied anatomy, chemistry, and osteology at the Ohio Medical College in Cincinnati, earning a medical degree in 1836. He also continued to improve upon his sketching, especially in regards to anatomy. Although he never established a medical practice, he used these skills to describe and illustrate fossils, reconstruct vertebrate skeletons, and conduct geological investigations.

EARLY CAREER

Owen acquired his first professional experience as a geologist at age 29 by assisting Gerard Troost with a geological survey of Tennessee. Through this work, Owen gained valuable experience in conducting geological surveys, understanding the significance of fossils in determining the age of sedimentary rocks, and documenting the extent and grade of mineralogical and coal resources. He also conducted chemical analyses on mineral, ore, and rock samples to determine their elemental composition.

Afterward, Owen returned to New Harmony, and in March 1837, the Indiana General Assembly commissioned him to conduct a geological survey of Indiana. During the first year, Owen focused on the building stone and coal and chemical analyses, distribution, and physical properties of minerals and rocks. In March 1838, Owen was reappointed as geologist for Indiana and continued to gain valuable field experiences. From his previous work in 1837, he proposed the further study of ironstones, extent and access to coal resources, the occurrence and quality of brine wells used for salt production, and the origin of native copper in Indiana. Through this work, Owen emphasized the practical application of geology to the discovery and evaluation of natural resources.

At 32 years of age, Owen was appointed as a U.S. geologist by Congress in July 1839 to conduct a survey of Iowa, Wisconsin, and northern Illinois. He assembled a team to discharge the survey, calling upon the assistance of John Locke and Ebenezer Phillips. The geological report summarizing his work was published as U.S. House Executive Document No. 239 on 2 April 1840. A follow-up report that included 25 plates of hand-drawn illustrations and maps was published as Senate Executive Document No. 407 on 11 July 1844. This latter report showcased Owen's artistic talents of sketching landscapes and fossils, as well as establishing a systematic way to summarize a geological survey.



Cliff Limestone (aka Galena Limestone, Ordovician) along the Upper Iowa River, sketched by David Dale Owen and included as a lithograph (Plate V) with Senate Executive Document No. 407, published in 1844.

The federal geological survey conducted by Owen quickly gained fame, and the town of New Harmony was visited by several famous geologists of the time. In the spring of 1841, James Hall joined Owen on a float trip down the Ohio River to collect fossils from Louisville to New Harmony. A few years later, in 1846, Charles and Mary Lyell were guests at the Owen home for several days in New Harmony (Hendrickson, 1943). While visiting, Lyell spent time examining fossil and mineral specimens in Owen's cabinets, along with participating in several field trips to examine Pleistocene loess deposits and sedimentary rocks of the Late Pennsylvanian Bond Formation near New Harmony.

In 1846, his eldest brother and U.S. Congressman Robert Dale Owen requested assistance from David Dale Owen on the design and recommendations of suitable building materials for constructing the new home of the Smithsonian Institution. Owen proposed the distinctive red-brown Seneca Creek Sandstone as the building material for the Smithsonian, which came to fruition with the completion of the Smithsonian castle in 1855.

LEGACY

In 1847, Owen was once again appointed by the U.S. Congress to expand his geological investigation of the mineral lands of Illinois, Iowa, and Wisconsin to include Minnesota and parts of Nebraska. He assembled a team of geologists to conduct this work under his supervision, including John Evans, Fielding B. Meek, Joseph G. Norwood, Richard Owen, Benjamin Shumard, Charles Whittlesey, and Amos H. Worthen. For this work, Owen trained and educated most of these geologists in New Harmony, who later led state and federal surveys of their own.

In 1852, the report generated by Owen standardized the format for federal geologic reports, including the narrative, maps, plates, and illustrations. This report also used several new reproduction techniques, including metal-ruled on steel and Daguerreotypes to illustrate fossils. Ultimately, this work provided a foundation for the forthcoming railroad surveys of the western United States in the 1860s and 1870s and the establishment of the U.S. Geological Survey in 1879.

After his role as U.S. geologist ended in 1854, Owen assumed the role of state geologist of Kentucky from 1854 to 1857; state geologist of Arkansas from 1857 to 1859; and returned as Indiana state geologist from 1859 to 1860. In October 1860, Owen was diagnosed with acute rheumatism and was confined to his sleeping chamber. Instead of resting, Owen continued toward completion of his second geological report of Arkansas. To accomplish this task, he dictated to two persons from his bedside. His colleagues claimed that he worked himself to death by 53 years of age, passing away on 13 November 1860 (Hendrickson, 1943).

Owen was buried next to Thomas Say in the Maclure vault near his home and laboratory in New Harmony. In the 1890s, his remains were moved to Maple Hill Cemetery and marked with a large granite monument with the appropriate epithet "David Dale Owen, Geologist." Undoubtedly, his geologic studies were paramount to the westward expansion of the United States in the early to middle nineteenth century, and his legacy of geological surveys was continued by his numerous contemporaries and apprentices.

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Communicating about the Geosciences during a Pandemic

***Becca Dzombak,** science writer; Ph.D., Earth & Environmental Sciences*

When COVID-19 shut down offices back in March of 2020, I was gearing up for my final year of graduate school and weighing my options about what to do next. The pandemic threw a wrench into all my plans. As I packed up my desk and turned off the lights in the lab, I had no idea what the next year would bring.

Four months later, I was elated to hear that I had been selected as the Science Communication Fellow for the Geological Society of America. As a geology graduate student, I had already received GSA grants that sent me to collect ancient soils and modern biological soil crusts in the southwestern U.S., and half of my pint glasses sport logos from years of attending GSA meetings. Over the previous year or so, I had dipped a toe into science writing, feeling pulled to connect my research world with the public. Now, as the Science Communication Fellow, I had an opportunity to work on the media side of geology.

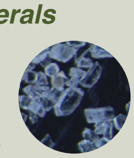
Bringing two of my passions—communications and geology—together in this fellowship has been such a gratifying and foundational experience. Because I was still a graduate student, I balanced my time between finishing my research and diving into the world of science writing. In choosing what to cover in a press release, I'd pore over lists of abstracts, highlighting a few I thought would be newsworthy—which would I want to read about in the news? Working with Justin Samuel and Christa Stratton to hone those instincts and find compelling angles was like putting together a puzzle: satisfying for the final pieces to fall into place and see how it all came together.

I reveled in exploring topics outside the narrow niche of my dissertation research. In ten months, I covered everything from microplastics in karst and the risks of per-/polyfluoroalkyl substances to hidden magma bodies and why we get earthquakes. Speaking with that range of geologists was enjoyable, and I felt like I came away from each interview having learned something new. Interviewing early-career geoscientists who were eager to share their work was particularly rewarding, as I found their energy and excitement about their science to be contagious.

The GSA 2020 Connects Online meeting provided an opportunity for me to highlight issues around diversity, equity, and inclusion in the geosciences, in addition to covering some of the excellent research presented there and working with the previous Fellows. I contributed two reported blog pieces, one on Indigenous perspectives in geoscience education and one on queer inclusivity in geology, both of which were extremely rewarding to write. The geosciences remain (in many ways) one of the least diverse fields, but I have been gratified to see important conversations around inclusion and accessibility continue over the past year.

I was also able to highlight diverse, early-career voices in geosciences by helping GSA research-grant recipients craft their own science stories. I worked with the GSA research grants team to solicit interested awardees, then met with them one-on-one to discuss their research and find compelling narratives. As many of us have become accustomed to collaborating remotely, the back-and-forth process of editing was smooth. I found myself looking forward to those meetings and editing sessions more and more as I got to know the authors. A few of these have been posted to GSA's *Speaking of Geoscience* blog so far, and keep your eyes peeled for a few more in the months to come!

Serving as the 2020–2021 Science Communication Fellow has given me the room to grow as a science writer during a challenging year—both because of the pandemic and because the last year in a Ph.D. is always tough. I am coming away from this experience with more skills and confidence than I had one year ago, and I cannot recommend the fellowship highly enough for anyone who cares about the public face geology shows the world.



Earth to Economy: Accelerating Innovation for Climate-Change Solutions

Kasey White, *Director for Geoscience Policy, Geological Society of America (GSA);* ***Doug Walker,*** *GSA Past President;* ***Barbara Dutrow,*** *GSA President;* ***Mark Little,*** *GSA President-Elect*

With a grant from the National Science Foundation (NSF), the Geological Society of America (GSA) gathered input from the geoscience community to identify bold and creative ideas for translating scientific research to solutions for climate-change problems that can be implemented within a two- to three-year timeframe. Ideas focused on four specific questions.

GSA used multiple social media platforms to solicit feedback from its broad membership during the two-week comment period. A website was created to submit text and video answers to questions designed to elicit requested information. GSA also conducted targeted outreach to ensure the project received responses from students, early career professionals, groups underrepresented in the geosciences, people from multiple subdisciplines, and other stakeholders who might not be GSA members. Additionally, online brainstorming sessions provided opportunities for interaction and idea development.

GSA is grateful to its members and the broader community for their thoughtful responses. These responses illustrate the fundamental role of geoscience in understanding climate change and its impacts, sourcing needed materials for solutions, and designing effective mitigation, geoengineering, and adaptation measures. Geoscience will be critical to understanding the changing conditions that affect communities, such as water resources, agriculture, and extreme events, and developing mitigation measures, such as low-carbon energy sources and carbon capture and storage. Equitable partnerships and engagement with communities, particularly those most vulnerable to climate impacts, are needed. These efforts must be prioritized, valued, and funded, which requires a change in the culture and funding structure to be effective. Summaries of the answers to each question follow. GSA's full report to the NSF is online at **https://www.geosociety.org/GSA/Science_Policy/GSA/Policy/climate-solutions.aspx** with reports of other societies that conducted similar outreach.

Q1: What do you view as the most transformative climate-change challenge(s) that can be addressed with actionable solutions in a two- to three-year timeframe?

The responses to this question were extensive and covered a large range of topics. The responses focus on ways to adapt to climate, promote low/no-carbon energy and storage, reduce the carbon footprint of transportation and infrastructure, and expand research on carbon sequestration and geoengineering.

Q2: How would you reach that climate-change goal? What stakeholders, technology, and/or partnerships are needed to effect change?

Ideas offered here may take longer than three years to implement, but all must be started today to have any hope of implementing in the future. Responses concentrated on ways to involve the communities of stakeholders and researchers whose work impacts the solutions for climate change, promote behavioral and political solutions for climate change, and invest in targeted cutting-edge research.

Q3: How do we effectively communicate the critical role of geoscience to the public and decision makers in providing solutions, tools, utilities, and technologies to help address identified challenges in climate change?

A primary missed avenue to working on solving climate change is the knowledge base of the public and public officials. Responses here are aimed at much-improved communication and education, including using professional communicators and compelling graphics. Although we all live the reality of climate change, no consistent and crystal-clear message is being communicated.

Q4: How can we effectively embed a culture of innovation, entrepreneurialism, and translational research in the geosciences? What resources, training, pedagogical change, etc., are needed to drive forward that change?

The responses to this question were generally aimed at better communication and education of the public and students on climate-change and engineering solutions and making scholarly products more readily available and accessible. They also addressed the nature of incentives afforded to researchers and actions that the NSF can take in the short-term to create and foster research in climate change solutions as well as translational research.

We take this opportunity to recognize that no one scientific discipline has all the solutions or the expertise to innovate and change. We also know that non-scientists have tremendous knowledge and critical context to contribute. We at GSA are already working with other organizations and societies to share and collaborate, as are our members and leaders. We welcome further discussions with the broad NSF community and representatives of the sciences and the public to work together on the climate-change solutions needed for a robust world.

STUDENT AND EARLY CAREER PROFESSIONAL UPDATE

Unlocking the Mysteries of Museum Careers

Carmi Milagros Thompson

Museums are places of wonder and inspire audiences of all ages. Despite being important centers of education and information, museum careers are aspects of museums that are not well-discussed. As a kid, I grew up near the National Museum of Natural History in Washington, D.C. While I was fortunate enough to visit often, thanks to free admission and accessibility via public transportation, I never considered that a career in a museum could be possible for me. It was not until graduation following my senior year of undergraduate studies that I began to realize that museums could be a viable career path. It is in that vein that I hope to share some of my early career knowledge and insight that I have gained along the way.

Museum careers are competitive. Many folks are often applying for the same job slot. However, this is true for many industries and many disciplines of study, so do not let this dissuade you from trying your best to find a career path in a museum setting. In fact, the skills learned in a museum job can serve well in whatever kind of career that you end up pursuing. Additionally, museums are full of many unique and unusual positions that can fulfill your professional interests.

In giving this bit of career advice, I have to offer a few disclaimers. My interests in museums lean toward paleontology/natural history—but there are many kinds of museums, from art to botany to trains to all dimensions of history. Thus, I am going to provide a natural-history focus of the museum discipline, specifically as it pertains to U.S.-based natural history museums. Nonetheless, it is my hope that some of this information can be useful to people just getting started or curious about exploring this career path.

A museum career can take you many places. On the top is a local field site and on the bottom is late afternoon during fieldwork in Nebraska.

GETTING STARTED

1. The easiest way to get started is to look for a place or lab in which to volunteer. Short-term internships can be a good option. However, this is not useful, or even possible, for everyone. It can block people from accessing potential careers, if, like me, they are not able to take on unpaid work.
2. Proofread your application. If you have the time, have others proofread your application—even just five minutes can lead to a much stronger submission.
3. Show up! Be respectful of both your time and your supervisor's time, both for in-person and virtual museum experiences.
4. Develop "soft" skills (managing conflict, scheduling personnel, interpersonal communication) —building these skills as a trainee is invaluable for when you may take on a supervisory role.
5. Be flexible—think of different ways to obtain the experience that you want.
6. There are many ways to work in a museum, including as a science writer or outreach coordinator. Look at the staff pages of large museums like the National Museum of Natural History, the American Museum of Natural History, and the California Academy of Sciences to get more ideas.
7. Explore resources related to natural history museums, like the Society for the Preservation of Natural History Collections (SPNHC), Association for Materials and Methods in Paleontology (AMMP), Integrated Digitized Biocollections (iDigBio), and more. Listservs like nhcoll and paleonet are also good places to explore different facets of museum careers and see examples of job postings.
8. Ask for help from trusted individuals (advisor, mentor, sponsor)—often being able to voice your ideas and career dreams can help these individuals help you.
9. Think outside the box—one of my favorite science communicators/museum professionals is Emily Graslie of Brain Scoop fame. There can be many ways to arrive at careers that are interesting and fulfilling, so keep your options, and career pathway, flexible.

GETTING THE JOB

1. Plan to prepare several documents as part of your application portfolio, such as an updated CV, cover letter, and statement of purpose. Teaching, diversity, and museum statements are often required as well.
2. The interview process often begins with phone, video, or other virtual interview formats. Sometimes the process includes an in-person visit.
3. An interview often lasts half an hour to an hour. They may provide questions in advance. Be prepared to come with a few questions of your own.
4. When offered a position, look at all dimensions that it offers for you, professionally and personally. It is often good to discuss this with mentors and supervisors before formally accepting a position.

While it can be a difficult process, engaging in museum careers can be rewarding and worthwhile. These tips should be able to demystify some of the more opaque aspects of both finding opportunities in museums and starting a career in the field of natural history. Best of luck in your exploration!

Carmi Milagros Thompson is currently in graduate school and employed as a research assistant in the Department of Natural History at the Florida Museum of Natural History. Thompson has previously worked as an invertebrate paleontology collection manager at the Florida Museum of Natural History and as a research intern at the National Museum of Natural History.

This is one of the several million specimens that I cared for in my time as a staff member at the Florida Museum of Natural History.

THE GEOLOGICAL SOCIETY OF AMERICA®

GEOLOGY AND HEALTH DIVISION

Connecting the Geological and Biomedical Sciences: GSA's Geology and Health Scientific Division

Malcolm Siegel, Chair, GSA Geology and Health Scientific Division
Nelson Eby, First Vice-Chair, GSA Geology and Health Scientific Division
Laura Ruhl, Second Vice-Chair, GSA Geology and Health Scientific Division
Jean Morrison, GSA Geology and Health Scientific Division
Reto Gieré, Member-at-Large, GSA Geology and Health Scientific Division
Ann Ojeda, GSA Geology and Health Communications Chair

GSA's Geology and Health scientific Division was established in 2005 and has maintained a membership of about 200 professionals and students. Medical geology has been defined as, "The impacts of geologic materials and geologic processes on animal and human health" (Selinus et al., 2005). It holistically integrates information drawn from the geological and medical sciences and aims at connecting the presence of environmental contaminants to human health effects. Medical geology attempts to bridge the "cultural" differences between the way that geoscientists and medical specialists view risks posed by geologic materials and processes and, thus, can lead to more effective risk communication and risk management.

Although the term "medical geology" was not officially adopted until 1997, publications containing references to this relationship date back to the third century BCE. Early reports from China discuss lung problems related to rock crushing and symptoms of occupational lead poisoning. The relationship between goiter due to severe iodine deficiency was probably recognized by medical practitioners in the Inca state of Peru. Hippocrates noted that under certain circumstances, water coming from soil that produces thermal waters, such as those containing iron, copper, silver, and other elements, was "bad for every purpose." It has been suggested that a contributing factor to the fall of the Roman Empire in 476 CE may have been the excessive use of lead in pottery, water pipes, and other sources.

Medical geology has a long tradition in northern Europe. Historically, farmers in Norway have been aware of the unusually frequent occurrence of osteomalacia, a bone disease among domestic animals in certain districts where bedrock soils are very poor in the mineral apatite, causing phosphorus deficiency in the vegetation, which could be remedied by adding phosphorus fertilizer to the soil or crushed bone to the animal feed.

Modern medical geology has developed in Europe, Asia, Africa, and the United States. Conferences focusing on the relationship between geochemistry and health were held in the United States and Germany in the 1960s and 1970s, and collaboration among scientists from various parts of the world led to establishment of the Society for Environmental Geochemistry and Health (SEGH) and the journal *Environmental Geochemistry and Health* in 1985. The field has grown to include the development of formal courses at academic institutions and short courses at international conventions. In addition, over the past 20 years, several medical geology books have been published describing the health impacts of various geogenic materials (e.g., specific elements, minerals, organic compounds, volcanic ash, and dust) as well as tools and techniques used in medical geology. A survey of several hundred articles in Google Scholar and PubMed using the key words "geology and health" and "medical geology" published since 2006 revealed more than 300 articles in 166 different journal outlets.

The Geology and Health Division sponsors technical sessions and Symposia at GSA annual and Section Meetings, and a second medical geology short course will be offered at GSA Connects 2021. The Division also sponsors student research grants and several awards, including the Meritorious Service, the Distinguished Career, the Best Publication, and Student Poster. We collaborate with other international organizations with similar interests, including the International Medical Geology Association, the American Geophysical Union Geohealth Section, and the International Society for Exposure Science.

Over the past few decades, medical geology has encompassed several tools and subdisciplines. Many of the early studies of the relationships between soil or water geochemistry and disease were descriptive or used the tools of environmental epidemiology. Later studies used the tools of chemical extraction, surface spectroscopy, and chemical reaction modeling to understand the fate of geogenic materials ingested or inhaled in biological fluids. In the decade ahead, incorporation of concepts and methods in exposure science could be fruitful. These include studies within the framework of the exposome, the use of -omics technologies, and geographic information systems. There is much more to be learned about the health impacts of coal combustion; the gastro/pulmonary geochemistry of lead, arsenic, uranium, and synthetic chemicals; and the environmental transport of geogenic and anthropogenic contaminants. We hope the future holds a greater emphasis on building stronger connections between the broader public-health community, environmental engineering, public policy, and climate-change science.

BOOKMARK THE GEOSCIENCE JOB BOARD

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

POSITIONS OPEN

Assistant Professor in Structural Geology, New Mexico Institute of Mining and Technology

The New Mexico Institute of Mining and Technology (NMT) invites applications for a tenure-track, assistant professor position in structural geology. We seek candidates with a strong track record of field-based research directed at the investigation of fundamental tectonic processes. Specific interests may include (but are not limited to) one or more of the following topics: active tectonics and hazards, remote sensing, seismogenic fault zone processes, ductile shear zone kinematics and petrology, thermochronology, surficial dating, thermo-kinematic or hazards modeling, and field method development. The successful candidate will be expected to develop a cutting-edge, externally funded research program and teach three classes per year.

Applicants should submit: (1) a cover letter, (2) curriculum vitae, (3) statement of research interests, (4) statement of teaching interests, (5) statement indicating how you would contribute to NMT's commitment to diversity, multiculturalism, and community, (6) one representative publication, and (7) names of three references, in a single pdf to Rosa.Jaramillo@nmt.edu and mark.person@nmt.edu. Inquiries should be directed to structural geology search committee chair, Mark Person (mark.person@nmt.edu). Review of application materials will begin on September 15, 2021. The search will remain open until the position is filled. New Mexico Tech, a Hispanic serving institution, is an equal opportunity/affirmative action employer.

Assistant Professor Position in Geophysics, New Mexico Institute of Mining and Technology

The Earth and Environmental Science Department at New Mexico Institute of Mining and Technology (NMT) invites applications for a tenure-track, assistant professor in geophysics. We seek candidates whose interests would complement the Department's strengths in understanding the Earth using geophysical techniques; applicants with interests in any field of observational, experimental, or computational geophysics are welcome. The successful candidate will be expected to develop a vigorous, independent, and externally funded research program supporting M.S. and Ph.D. students and teach three courses per year.

New Mexico Tech, located in the central Rio Grande valley community of Socorro, specializes in science and engineering education and research, and has an enrollment of approximately 2000 undergraduate and graduate students. The Earth and Environmental Science Department (www.nmt.edu/academics/ees) has undergraduate programs in Earth Science and Environmental Science, and M.S. and Ph.D. programs in Geophysics, Geology, Geochemistry, Geobiology, and Hydrology. The Department consists of 15 faculty and approximately 100 undergraduate and graduate students. Additional on-campus geoscience expertise includes the New Mexico Bureau of Geology and Mineral Resources (geoinfo.nmt.edu), Petroleum Recovery Research Center (www.prrc.nmt.edu), and IRIS-PASSCAL (www.passcal.nmt.edu).

Applicants should submit: (1) a cover letter, (2) curriculum vitae, (3) statement of research interests (2 pages), (4) statement of teaching interests (2 pages), (5) statement indicating how you would contribute to NMT's commitment to diversity, multiculturalism, and community (1 page), (6) one representative publication, and (7) names of three references, in a single pdf sent to nmtjobapps@npe.nmt.edu and glenn.spinelli@nmt.edu. Applicants must have a doctoral degree in Earth sciences or a related field. Inquiries should be directed to the geophysics search committee chair, Glenn Spinelli (glenn.spinelli@nmt.edu). Review of application material will begin on September 15, 2021. The search will remain open until the position is filled. New Mexico Tech, a Hispanic Serving Institution, is an equal opportunity/affirmative action employer.

Structural Geologist, Stephen F. Austin State University

The Department of Geology at Stephen F. Austin State University invites applications for a tenure-track position at the assistant (or associate) professor level. Applicants must have a doctoral degree in geology or a related field with emphasis on structural geology, a strong commitment to excellence in teaching and a willingness to direct Master of Science geology students in research. Preference will be given to candidates with teaching and/or research experience in structural geology and field camp. Teaching responsibilities will include introductory courses, structural geology, field methods, summer field camp (co-taught), upper-level undergraduate and graduate courses in the applicant's specialty, and occasional weekend field-trip courses. The successful candidate will serve as director of the summer field camp. Other expectations include research, university service and continuing professional development.

To apply and submit required documents, please visit: http://careers.sfasu.edu/postings/7044

Review of applications will begin on September 1, 2021 and will continue until the position is filled. SFA is an equal opportunity employer. This is a security-sensitive position and will be subject to a criminal history check.

GSA FOUNDATION Update

A Familiar Face in a New Role Leading the Foundation

"Between climbing routes at Little Stony Man Cliffs in Shenandoah, I picked up an unusual rock. A group of students suddenly swarmed the area, and since I heard their professor talking about the 570-million-year-old greenstone lava flows, I asked if they could tell me about this rock. When I learned they had just attended the Southeastern Section Meeting of GSA, I knew the job I had flown to Boulder, Colorado, to interview for the week prior was meant to be," says the GSA Foundation's Debbie Marcinkowski.

As an experienced fundraiser who has also seen some of Earth's great geologic wonders while climbing, volunteering, and working around the world, joining the GSA Foundation (GSAF) nine years ago was the perfect fit for Debbie. Long under the spell of alluring mountain ranges, her appreciation for geology grows with her years at GSAF: whether hearing about your work and experiences at the Foundation booth, writing the stories of student grant recipients, or learning about geoscience career paths through discussions with industry partners, her work is rich and rewarding.

In April, GSAF's Board of Trustees announced Debbie's promotion to the newly created position of executive director. Her initial role in corporate partnerships was a shared position between GSAF and GSA. With a master's degree in nonprofit management, she brought experience in funding, communications, and partner relations for global health, environmental conservation, and arts/education organizations. Strategic planning, collaboration to maximize funding opportunities, and relationship development with a wide range of people were key to her previous roles. Her work has always been in funding: from sponsors, campaigns, and advertising at a renowned arts center in the Washington, D.C., area to global partnerships for a Geneva-based organization that brought together developing country and donor governments, the World Health Organization, the World Bank, private philanthropists, and corporate donors. One of her most interesting research and writing projects was a proposal to the Crown Prince of Abu Dhabi that helped secure US$33M matched by another US$33M from the Gates Foundation to fund vaccines for children across Afghanistan.

Debbie's energy for fundraising—mixed in with some adventure—drives her individual as well as professional endeavors. She was a founding climbing team member and expedition leader for a nonprofit raising funds for cancer studies at a leading research university. Ascending the headwall of a peak in the Andes, curiosity about the strong odor of sulfur rising from the active volcano's snow-capped crater gave her the final push to summit—and even greater marvel of the underlying geology. Her experience in strategy- and awareness-building earned her a spot on a Himalayan expedition through the Everest region funded by National Geographic, with two of their explorers studying glacial lake outburst flood hazards, while creating a plan to reach the international mountaineering and adventure travel industries

Marcinkowski at the 5897 m (19,348 ft) summit of Cotopaxi, Ecuador, one of the world's highest active volcanoes and few equatorial glaciers.

gsa-foundation.org

regarding environmental stewardship. Debbie's passion for conveying compelling messages that inspired funds to help build orphanages in Tibet (and far-from-standard funding practices to get the cash into the region) now helps communicate the significant impact of donations that encourage students to pursue the geosciences.

During the challenging past year, Debbie was inspired by the Foundation's committed donors who leapt to assist student members, while maintaining their regular support of GSA programs. She is thrilled to continue working with you in her expanded role, with a vision for GSAF to make a leap, as you did, in its support of GSA's priorities. As the world around us shifts, so do philanthropic movements. "Much of mountaineering is about a positive mindset; the same applies to effective funding work that is gratifying to donors and organizations alike. We will continue to seek creative avenues to encourage and provide funding while communicating how vital your support is—both to those who will fill future roles in the geosciences and to our professional members in their ongoing scientific discovery, communication, and application of geoscience knowledge."

THE GEOLOGICAL SOCIETY OF AMERICA®

2022 GSA SECTION MEETINGS

SOUTH-CENTRAL SECTION

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

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

JOINT CORDILLERAN–ROCKY MOUNTAIN SECTION

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

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

NORTHEASTERN SECTION

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

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

JOINT NORTH-CENTRAL–SOUTHEASTERN SECTION

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

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

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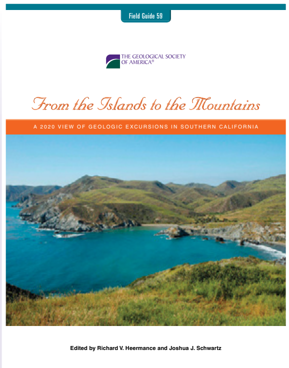

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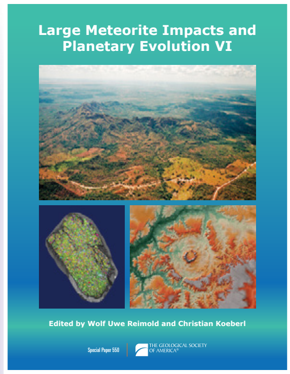

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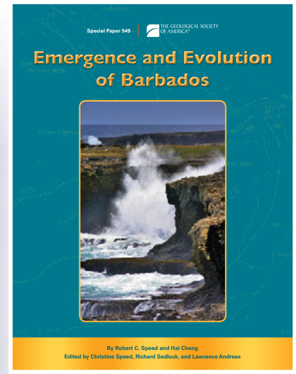

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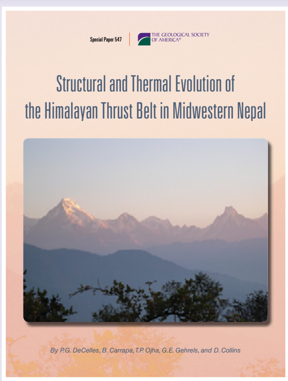

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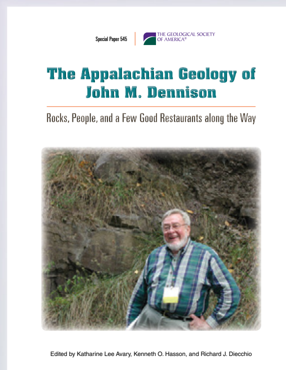

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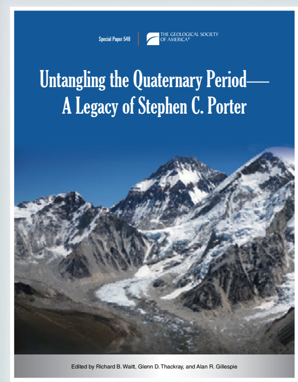

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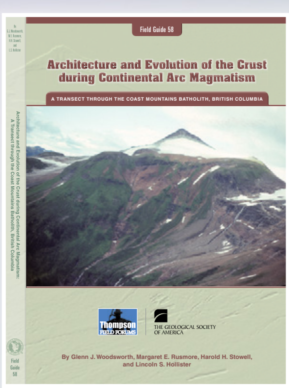

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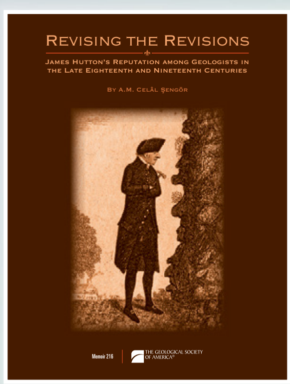

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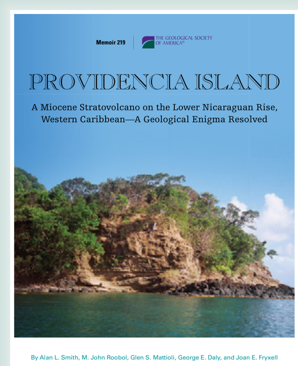

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