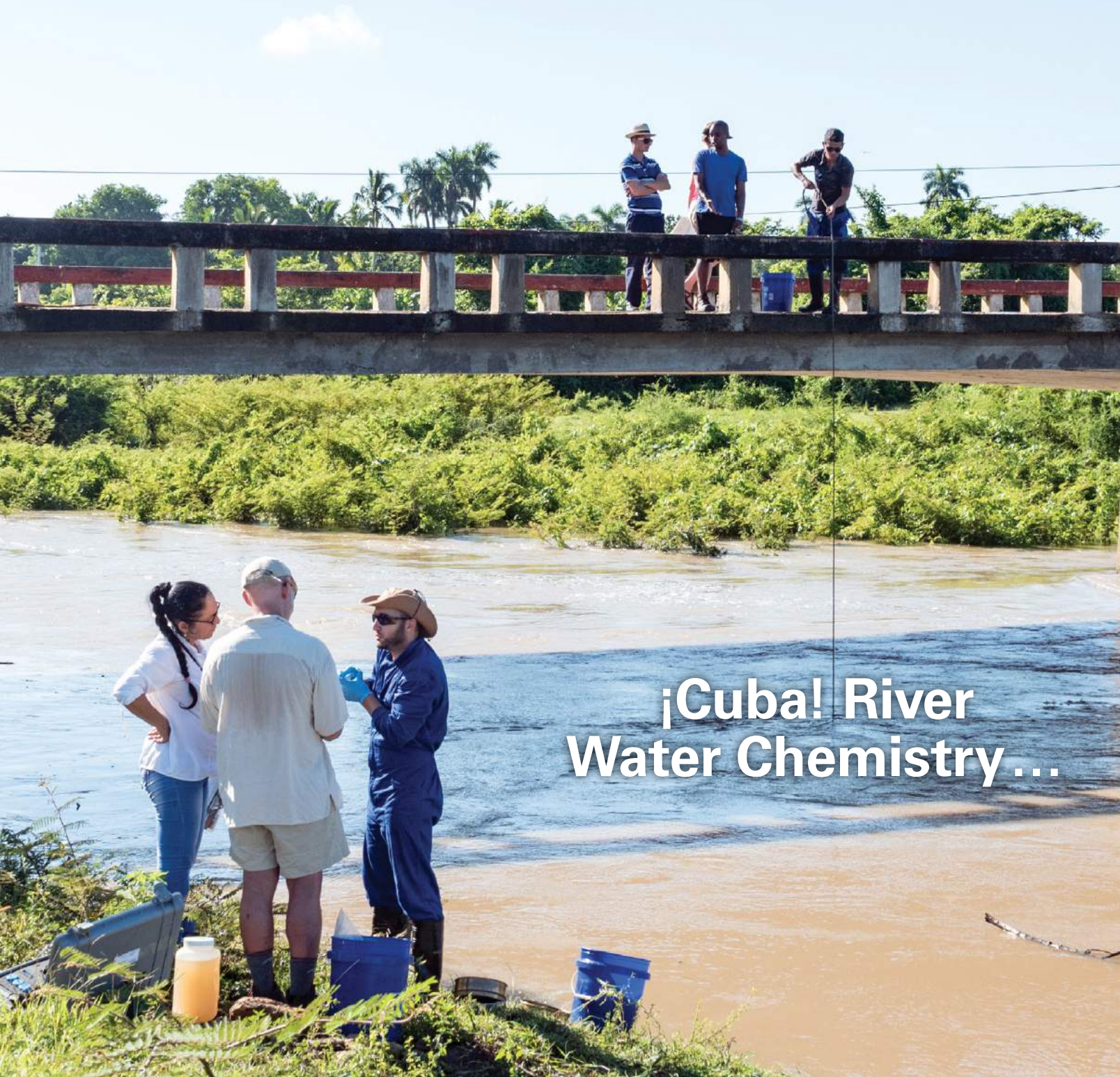


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¡Cuba! River
Water Chemistry...

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SCIENCE

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Paul Bierman et al.

Cover: The Cuban–U.S. team works to collect water and sediment from Rio Congojas at high flow (40 m³/s) after heavy thunderstorms the evening before. The water had high *E. coli* and turbidity but low conductivity and dissolved oxygen. Photo by Joshua Brown, University of Vermont. See related article, p. 4–10.



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¡Cuba! River Water Chemistry Reveals Rapid Chemical Weathering, the Echo of Uplift, and the Promise of More Sustainable Agriculture

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ABSTRACT

For the first time in more than half a century, a joint Cuban/American science team has worked together to quantify the impacts of chemical weathering and sustainable agriculture on river water quality in Cuba—the largest and most populous Caribbean island. Such data are critical as the world strives to meet sustainable development goals and for understanding rates of landscape change in the tropics, an understudied region. To characterize the landscape, we collected and analyzed water samples from 25 rivers in central Cuba where upstream land use varies from forested to agricultural.

Cuban river waters bear the fingerprint of the diverse rock types underlying the island, and many carry exceptionally high dissolved loads. Chemical denudation rates are mostly among the top 25% globally and are similar to those measured in other Caribbean islands. High rates of solute export and the distinct composition of the waters in specific basins suggest flow paths that bring river source waters into contact with fresh, weatherable rock—unusual in a warm, wet, tropical climate where weathering should extend deep below the surface. Tectonically driven uplift likely maintains the supply of weatherable material, leading to channel incision and, thus, to the exposure of bedrock in many river channels.

Despite centuries of agriculture, the impact on these rivers' biogeochemistry is limited. Although river water in many central Cuban rivers has high levels of *E. coli* bacteria, likely sourced from livestock,

concentrations of dissolved nitrogen are far lower than other areas where intensive agriculture is practiced, such as the Mississippi River Basin. This suggests the benefits of Cuba's shift to conservation agriculture after 1990 and provides a model for more sustainable agriculture worldwide.

INTRODUCTION

The Republic of Cuba (Fig. 1) has more than 11 million inhabitants, but there has been little collaboration between U.S. and Cuban scientists for more than half a century although only 160 km separates the two countries (Feder, 2018). River biogeochemistry data, which are sparse in tropical regions, are needed to guide sustainable development in Cuba and, by example, in other tropical and island nations.

Here, we present and interpret extensive new data characterizing river waters in

central Cuba, the result of a bi-national, collaborative field campaign. Biogeochemical analyses allow us to address fundamental geologic questions, such as the pace of chemical weathering in the tropics, as well as applied environmental questions related to the quality of river water and human impacts on a landscape where small-scale, sustainable farming has replaced substantial swaths of industrial agriculture (The Guardian, 2017).

BACKGROUND AND METHODS

Cuba's wet, warm tropical landscape is dominated by mountains (up to 1917 m above sea level [asl] in the east, 500–700 m asl elsewhere) running parallel to the north and south coasts (Fig. 1). Mainly forested uplands descend into farmed rolling plains and mangrove-lined, low-lying coastal estuaries. The climate is summer-wet and

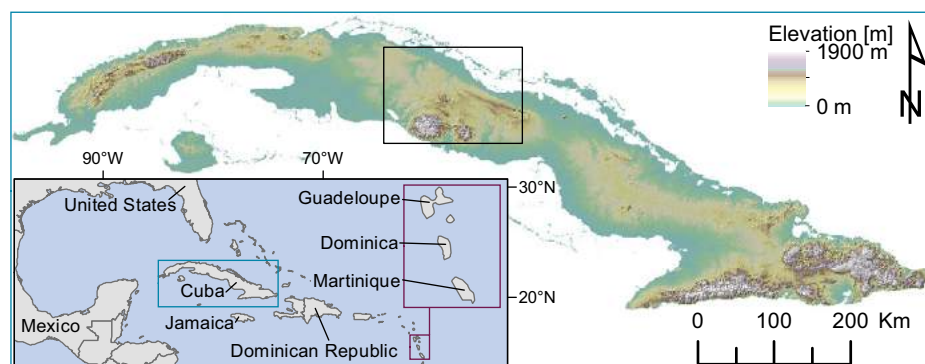


Figure 1. Cuba with elevation as color ramp. Black outline is area mapped in Figure 3. Inset shows location of Cuba in relation to North America.

winter-dry with precipitation delivered both by trade-wind showers and by larger tropical storms.

The diverse geology of Cuba reflects its tectonic setting at the boundary of the North America and Caribbean plates. Central Cuban basement lithologies include accreted igneous rocks, sediments (clastic, carbonate, and evaporite) formed along passive margins, obducted ophiolite, and island arc rocks (Iturralde-Vinent et al., 2016). This basement is unconformably overlain by slightly deformed, younger marine and terrestrial sedimentary rocks (Iturralde-Vinent, 1994). Where river water has interacted with these diverse rocks, surface water chemistries should reflect the composition of underlying rock units.

Agriculture has been practiced in Cuba for centuries. Indigenous people cultivated cassava, yucca, and maize (Coscolluela, 1946). Spanish colonization from 1492 brought slaves, large-scale sugar agriculture, and cattle farming (Zepeda, 2003). Following Cuba's independence from Spain in 1898, sugar production in Cuba quadrupled under U.S. influence (Whitbeck, 1922). When Cuba allied with the Soviet Union in 1959, industrialization of the sugar industry to increase yields and exports became a central goal (Pérez-López, 1989). By the 1980s, Cuba boasted the most mechanized agricultural sector in Latin America (Febles-González et al., 2011); however, the collapse of the Soviet Union in 1991 catalyzed Cuban adoption of reduced tillage, organic soil amendments, the use of cover crops, and the replacement of fuel-hungry tractors with domesticated draft animals, including horses and oxen (Gersper et al., 1993).

Surface water biogeochemical monitoring in central Cuba has focused mainly on reservoirs. In central Cuba, water chemistry data (1986–2005) from four reservoirs, representing two river systems and four basins with varied geology (Betancourt et al., 2012) showed that the primary control on major ion concentration is rock weathering upstream; there was no statistically significant difference in water chemistry between dry and rainy seasons in three of the four basins.

In August 2018 (the wet season), we collected water samples from 25 river basins in central Cuba. We selected these sites to encompass a range of land uses, underlying upstream rock types, discharges, and basin

sizes, while avoiding rivers that had major dams (Figs. 2 and 3N). See the GSA Data Repository¹ for detailed methods. Our analysis assumes that the concentration of cations and anions we measured are representative of annual average values (Godsey et al., 2009).

RESULTS

River water samples from central Cuba contain high concentrations of dissolved material (Figs. 3 and 4). Conductivity and total dissolved load were high (130–1380 $\mu\text{S}/\text{cm}$ and 117 to over 780 mg/L, respectively, Tables S1 and S2 [see footnote 1]); stream water, except that sampled from forested catchments, was turbid. Sample pH was near neutral to slightly alkaline with high values of bicarbonate alkalinity (65–400 mg/L). As, Ba, Cr, Mn, Ni, Sr, and U were present in some or all of the Cuban river waters we analyzed, in all cases at levels below drinking water standards (Table S3 [see footnote 1]). Dissolved oxygen measured in the field ranged from 59% to 145% (average 97%). Using basin-specific precipitation (Fig. 3), along with run-off estimates (Beck et al., 2015, 2017) and total dissolved solids (TDS) from each Cuban water sample, we estimate chemical weathering rates between 42 and 302 t $\text{km}^{-2} \text{y}^{-1}$ with a mean of $161 \pm 66 \text{ t km}^{-2} \text{y}^{-1}$.

Dissolved organic carbon (DOC) was highly variable, ranging from <1 mg/L to 9 mg/L (Table S4 [see footnote 1]). Total dissolved nitrogen (TDN) ranged from <0.1–1.5 mg/L (mean = 0.76 mg/L); on average 60% was present as nitrate (range 24%–93%). Nitrate values measured in the field and then in the lab several weeks later are well correlated. Nitrite was present in all samples, averaging 1.2 mg/L (0.37 mg/L of N). DOC/TDN ratios also vary widely, from 1.3 to 14.8. Anion concentrations decreased in the order $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-} > \text{NO}_3^- > \text{HPO}_4^{2-} > \text{NO}_2^- > \text{Br}^- > \text{F}^-$.

The anion orthophosphate (as P) was measured both in the field (0.1–0.8 mg/L) and lab (0.4–0.5 mg/L); field and lab analyses were positively correlated. Cations decreased on average in the order $\text{Ca} > \text{Na} > \text{Mg} > \text{Si} > \text{K}$.

E. coli bacteria were found in all samples, and most samples (20/24) contained enough bacteria to be deemed unsafe for recreational use according to World Health Organization criteria (Most Probable Number (MPN) > 127/100 ml). Genetic microbial source trac-

ing in two samples with MPN/100ml >1000 (CU-107 and 110) did not identify any human-sourced bacteria; rather, the bacteria in sample CU-110 were identified as being of unguilate origin, and no specific source could be determined for bacteria in CU-107.

There are numerous correlations between anions and cations in our river water samples (Table S5 [see footnote 1]). Na and Cl are positively correlated ($p < 0.01$) as well as Na and HCO_3^- , F, SO_4^{2-} , NO_2^- , K, Ca, Br, Ti, As, Rb, Sr, Ba, and U ($p < 0.05$, all positive, Fig. 4). These elements are also correlated to one another positively and significantly. In addition, Mg is positively correlated to SiO_2 , V, Cr, and Ni ($p < 0.05$). NO_2^- is positively correlated with conductivity.

Four of the 25 samples (CU-120, -121, -122, and -132), all collected in the northwestern part of the field area, are geochemically distinct (Figs. 3, 4, and 5). These samples have the highest or nearly highest Cl, SO_4^{2-} , Br, NO_2^- , and Na concentrations, field conductivity, and TDS (Fig. 4, red symbols) in the sample set. These are four of only five samples to contain low but measurable As (1.0–1.4 ppb). They plot in a distinct zone of the Piper diagram (Fig. 5) and also have higher Rb, Sr, Ba, and U concentrations (1.8–4.3 ppb) than other Cuban river water samples. Three of the four samples contain >115 mg/L Ca and high concentrations of Na, Cl, and SO_4^{2-} . These four samples were collected near one another and drain the same bedrock map unit (post-Eocene marine sediment). One (CU-122) drains mostly wetland while the others drain dominantly agricultural catchments.

DISCUSSION/INTERPRETATION

Bedrock Controls Central Cuban River Water Chemistry

In central Cuba, river water composition and TDS covary with rock types (Figs. 3 and 4D) suggesting a close connection between river water chemistry and underlying rock units. For example, high concentrations of Ca, Mg, and alkalinity in most samples are consistent with the mapped presence of carbonate rocks in most sampled drainage basins (Fig. 3). Distinct anion, cation, and trace metal compositions of rivers draining four (CU-120, -121, -122, -132) watersheds in the NW quadrant of our field area and underlain by marine sediments (French and Schenk, 2004) suggest dissolution of evap-

¹GSA Data Repository item 2020097, data tables and extended methods, is available online at <https://www.geosociety.org/datarepository/2020>.

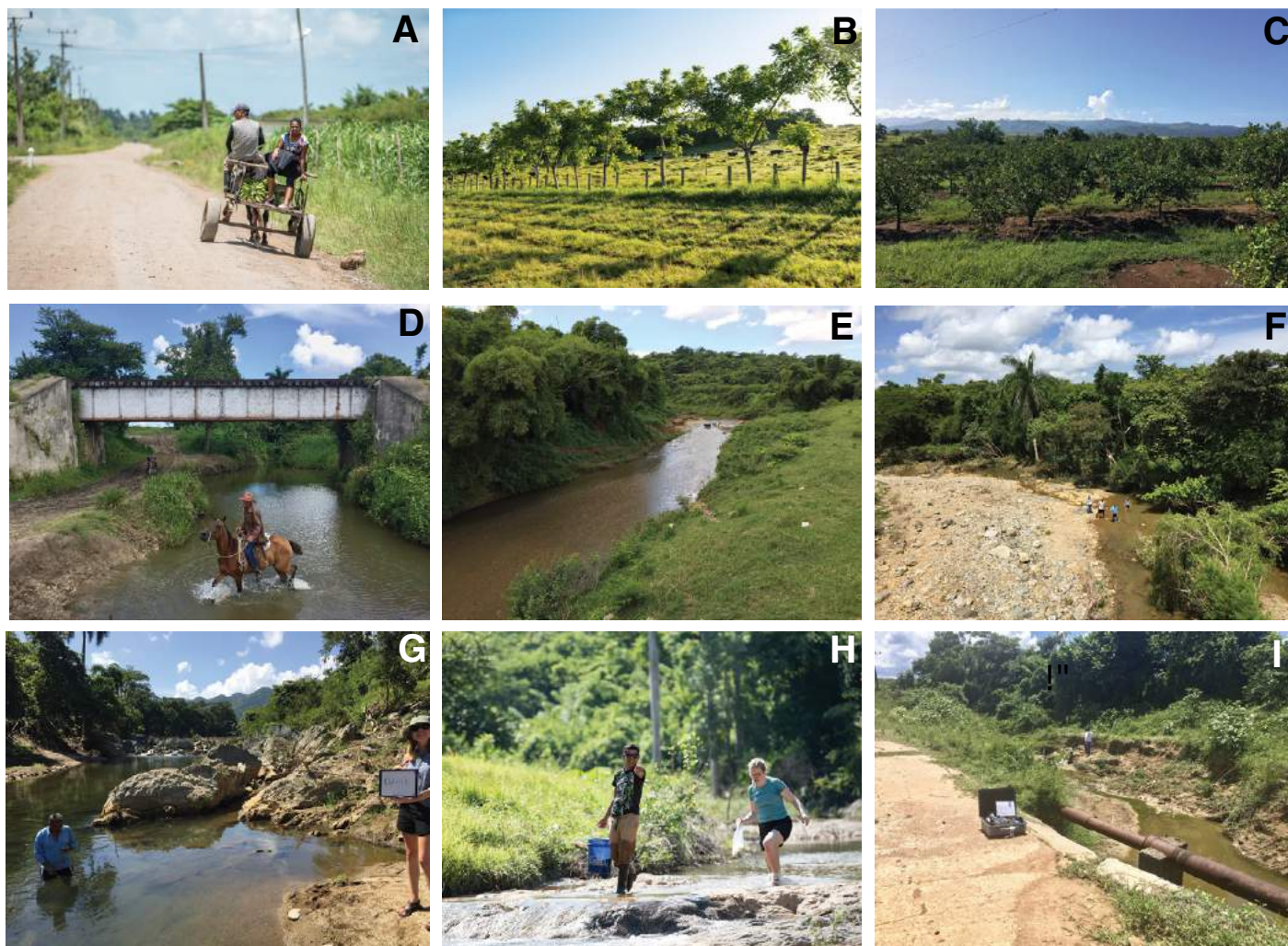


Figure 2. Common Cuban landscapes and example sample sites. (A) Sugarcane and dirt roads are common on the island. (B) Cattle grazing on cleared fields. (C) Citrus groves on slopes in southern field area. (D) Horses were frequently in rivers, CU-132. (E) Plane-bed sand and gravel channel with cows in the river, CU-101. (F) Large point bar flooded during Hurricane Alberto showing dynamic range of river flows over time, CU-114. (G) Boulder/bedrock channel during conductivity measurement, CU-115. (H) Bedrock channel, CU-114. (I) Low flow sample site in incised channel, CU-122. Locations identified by letter in Figure 3N.

orite deposits including those that contain nitrite (Figs. 3, 4, and 5).

The relationship between water chemistry and bedrock type in central Cuba suggests the presence of fresh, weatherable mineral surfaces along flow paths carrying subsurface flow to Cuban rivers. This inference is supported by comparison of Cuban river water chemistry with that from Martinique, Guadeloupe, and Dominica (Rad et al., 2013). The latter three islands are underlain primarily by andesite, and their surface water contains more Si and K and less Ca and Mg than Cuban rivers (Fig. 6A). The higher concentration of most other anions and cations in Cuban waters as compared to waters from volcanic Caribbean islands reflects the influence of readily soluble carbonate and evaporite rocks in Cuba. Although average TDS for waters from

Cuba exceeds that on other, e.g., volcanic, Caribbean islands (Fig. 6A), chemical denudation rates estimated from central Cuban river water samples are similar to other Caribbean islands (Fig. 6B) because mean annual precipitation and thus runoff in Cuba is lower. All Caribbean chemical denudation rates are high when compared to global data (Larsen et al., 2014).

Field observations of incised, bedrock-floored river channels and the chemical data that mandate extensive water/rock interaction similar to that on tectonically active, volcanic Caribbean islands suggest ongoing bedrock uplift in central Cuba rather than tectonic stability and the development of a deep tropical weathering mantle. Raised marine terraces along southern and eastern Cuba (Muhs et al., 2017) are consistent with such uplift, which, along

with tectonically induced rock fracturing, is likely responsible for the continued supply of fresh, easily weatherable rock, and thus high chemical weathering rates.

Human Activities and Water Quality

High TDS in central Cuban river water as a result of bedrock chemical weathering is not hazardous but could limit some uses. About 20% of samples we collected have TDS and Na levels above the taste threshold. High TDS samples may cause CaCO₃ scaling on pipes, household cooking implements, and industrial equipment; scaling could be a health benefit if lead remains in the water distribution system. High levels of DOC (up to 9 mg/L) in central Cuban river water suggest a potential risk of trihalomethane formation during chlorination (Engelage et al., 2009), which is the most

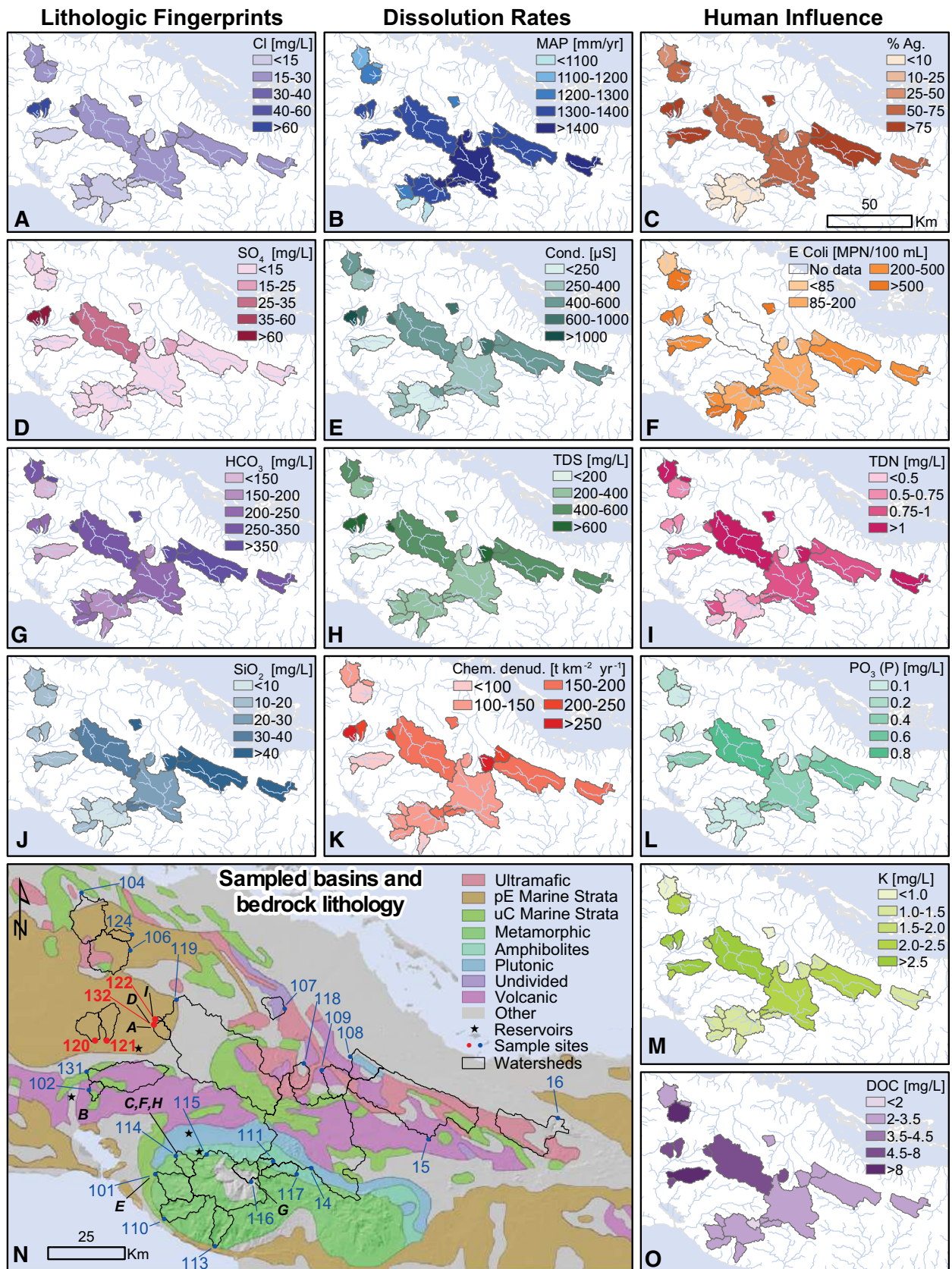


Figure 3. Results of river water biogeochemical analyses plotted for 25 sampled basins. (A) Chloride. (B) Mean annual precipitation. (C) Percent agricultural land use. (D) Sulfate. (E) Conductivity. (F) *E. coli*. (G) Bicarbonate. (H) Total dissolved solids. (I) Total dissolved nitrogen. (J) Silica. (K) Chemical denudation rate. (L) Orthophosphate as phosphorus. (M) Potassium. (N) Sampled basins overlain on generalized geological map (French and Schenk, 2004). Letters show location of photos in Figure 2. Four basins (CU-120, -121, -122, and -132 labeled with red text and points) have distinct water chemistry. Dots represent sample sites. Stars shows reservoir water samples (Betancourt et al., 2012). (O) Dissolved organic carbon.

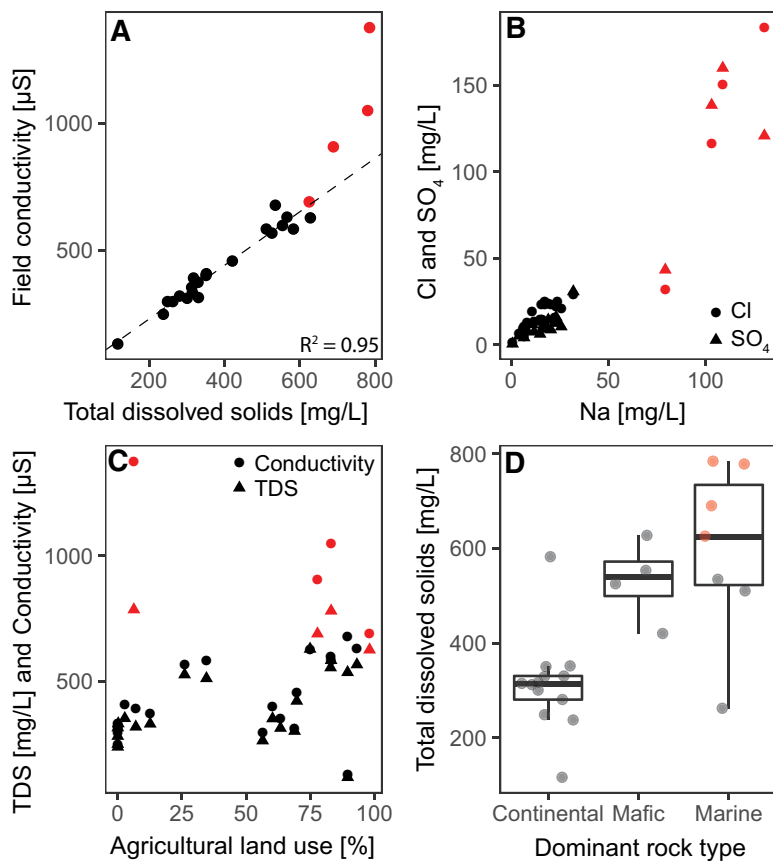


Figure 4. Rock type influences river water chemistry. Red symbols indicate basins with distinct water chemistry highlighted in Figures 3 and 5. (A) Total dissolved solids (TDS) and field conductivity are well correlated. (B) Positive correlation of Na with SO₄ and Cl suggests evaporite source of these solutes. (C) No correlation between percent basin area used for agriculture and total dissolved solids or conductivity. (D) Basins underlain by marine and mafic rocks have higher river water TDS.

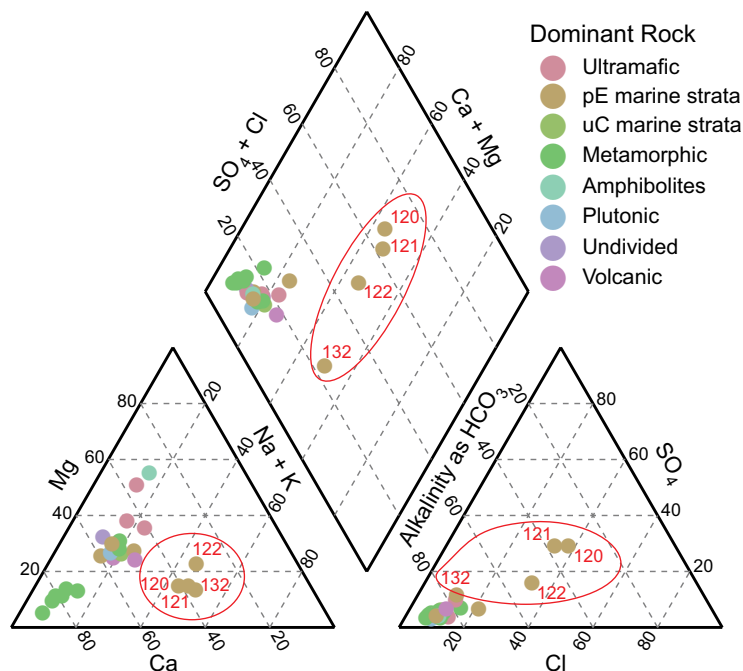


Figure 5. Piper diagram of all data color-coded by mapped lithology (Fig. 3) (French and Schenk, 2004). Numbered samples are those with distinct water chemistry influenced by evaporite rocks.

frequently used water treatment technique in Cuba (Cueto and De Leon, 2010).

Bacterial contamination of river water in central Cuba is consistent with the nearly ubiquitous presence of livestock on the landscape, perhaps because animals have in part replaced fossil-fuel-powered transportation and farm equipment (Fig. 3). We do not know the source of the detected *E. coli*; however, the ungulate match in one of two samples we tested is consistent with numerous cows we observed walking in and around rivers as well as extensive pastures near and upstream of many sampling sites.

High levels of *E. coli* are found in rivers around the world. Data from other Caribbean islands, including Martinique, Trinidad, and Puerto Rico, show similarly high *E. coli* levels in river, spring, and coastal waters (Bachoon et al., 2010; Pommepuy et al., 2000; Wampler and Sisson, 2011). *E. coli* levels above health advisory levels are routinely measured in Vermont river water, a similarly agricultural state with more than a quarter million cows, only half the stocking density per area of Cuba (Riera, 1994). Although pigs and chickens were common in central Cuba, we did not see them near rivers, which may explain why tests for fecal matter from these animals were negative as were those for human fecal bacteria.

Central Cuban river waters provide evidence that agriculture need not overload rivers, and thus reservoirs and coastal zones, with nutrients. N and P are present in Cuban river waters, but at lower concentrations than in the United States, where agriculture is intensive and fertilizer use is heavy (Fig. 6). Total dissolved nitrogen in central Cuban river water is <50% of the Mississippi River average and <25% of peak Mississippi River concentrations (Fig. 6C). Cuban waters have only slightly more TDN than less agricultural Caribbean volcanic islands (Rad et al., 2013).

The history of fertilizer use over time is telling (Fig. 6D). Cuban fertilizer use peaked in 1978 and then declined, whereas fertilizer use in the United States rose after 1961 and has remained high, more than twice the area-normalized value as Cuba. Sustainable agricultural initiatives, implemented in Cuba after the end of Soviet assistance, have resulted in less fertilizer use and better river water quality (Fig. 6). The result is far less downstream transport and loading of nutrients into coastal waters, nutrients that can have a profound and negative effect, including the presence of anoxic, marine dead zones (Obenour et al., 2013).

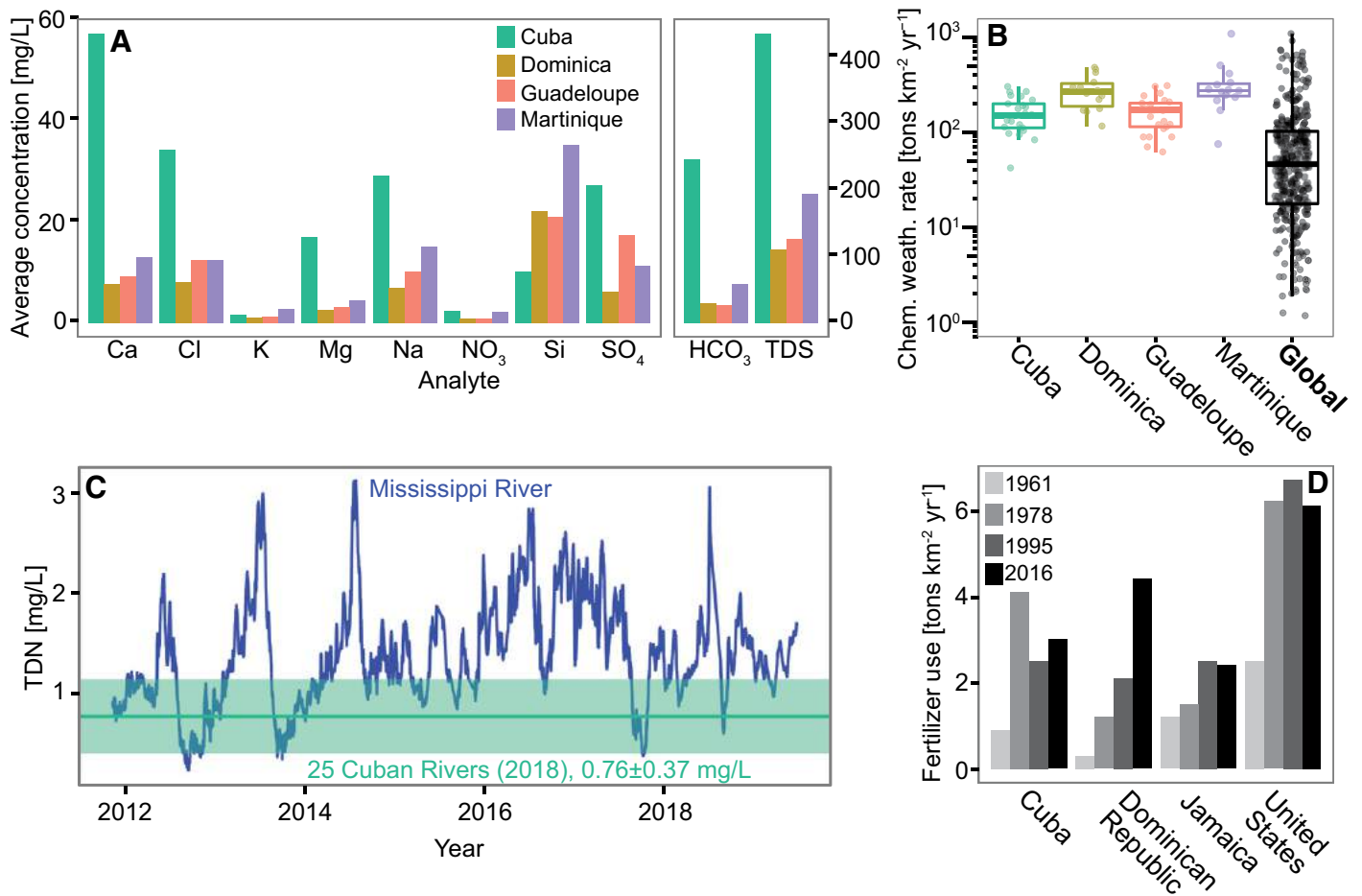


Figure 6. Cuban river water data in context. (A) Cuban waters contain greater dissolved concentrations for most elements or ions than other Caribbean islands (Rad et al., 2013). (B) Chemical weathering rates (cations, anions, and Si) in rivers sampled in central Cuba, Dominica, Guadeloupe, and Martinique (Rad et al., 2013) are high and similar (cf. global from Larsen et al. [2014]; $n = 299$). Note log scale. Median is middle line, the 25th and 75th percentiles are the edges, and whiskers extend to include all samples within 1.5 times the range of the box. (C) Total dissolved nitrogen (TDN) for Mississippi River at Baton Rouge (water.usgs.gov) compared to central Cuban rivers (this paper). (D) Cuban fertilizer use (P, K, N) normalized by arable land area is stable and less than other nations. Data from <https://data.worldbank.org/indicator/>, Rawlins et al. (1998), and <https://www.epa.gov/roe/>.

IMPLICATIONS

Our data provide a comprehensive snapshot of the chemistry of water moving through rivers in central Cuba. From these data, we calculate high rates of rock weathering and landscape-scale denudation and thus infer the presence of flow paths through fresh rock or regolith supplying water to rivers we sampled—perhaps in response to tectonic uplift. Cuba's transition toward sustainable agriculture (and its reduced use of fertilizer per acre of crop land) results in much lower river-water nutrient concentrations in central Cuban rivers than in the Mississippi River—a model for other agricultural economies. Additional management strategies to reduce manure and sediment loads to rivers (such as fencing to keep cattle off river banks) could further and rapidly improve central Cuban river water quality. Reducing sediment and manure loads will have economic benefits, because rivers eventually discharge into the coastal zone

where suspended sediment, and bacteria from agricultural activity, impact water quality and clarity on coral reefs and beaches frequented by tourists (Rawlins et al., 1998), a source of income to Cuba (Duffy and Kline, 2018).

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MANUSCRIPT RECEIVED 17 JULY 2019
 REVISED MANUSCRIPT RECEIVED 17 DEC. 2019
 MANUSCRIPT ACCEPTED 20 DEC. 2019

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Give us your best shots!

2021 GSA CALENDAR PHOTO SEARCH

Each year, we enjoy seeing how you connect with the natural world through your camera lens. If you have a remarkable or noteworthy geologic image that's sure to wow us, enter the 2021 GSA Calendar Photo Search. Send up to three of your best images in landscape orientation, using the following categories as a guide:

ICONIC LANDSCAPES

Striking or notable geologic landscapes and features.

ABSTRACT IMAGES

The patterns of geology at any scale, photomicrographs to satellite images.

GEOLOGIC PROCESSES PAST AND PRESENT

Process or feature resulting from a specific process. For example: An erupting volcano or volcanic rocks that represent ancient eruptions.

HOW TO ENTER

Email the following to editing@geosociety.org with the subject line "Calendar Submission":

- Your name, email, and mailing address.
- A caption describing the image(s), plus a photo credit, including a one-sentence bio. Feel free to include information on how you captured the image.
- Up to three images in landscape orientation, in .jpg format, and no larger than 1 MB each (if your image is chosen, we'll ask for a high-resolution file).
- Name your file using your initial and last/family name (e.g., FBascom_image1.jpg).

Deadline: 19 March 2020

Go to <https://www.geosociety.org/GSA/Publications/GSA/Pubs/Photos.aspx> for more information.

If you have some amazing shots in a vertical orientation, please send them to gsatoday@geosociety.org for consideration for publication in *GSA Today*.





25–28 October
GSA 2020
Montréal, Québec, Canada

IMPORTANT DATES

Late March: Space request system opens (non-technical, social, and business-meeting room requests)

Early May: Housing opens

1 April: Abstracts submission form opens

Early June: Registration opens; travel grant applications open

8 June: Meeting room request deadline—fees increase after this date

4 Aug.: Abstracts submission deadline

Early Aug.: Student volunteer program opens

21 Sept.: Early registration deadline and GSA Sections travel grants deadline

28 Sept.: Registration and student volunteer cancellation deadline

30 Sept.: Housing deadline for discounted hotel rates



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© Caroline Buche.

Meeting Location

Registration, technical programs, poster sessions, exhibits, and field trip departures will be at the Palais des congrès de Montréal (Palais), 1001 Place Jean-Paul-Riopelle, Montréal, Québec, H2Z 1M2.

Hotel Information

The GSA Housing Bureau will open for reservations in early May. The DoubleTree by Hilton Montréal will serve as GSA headquarters, and the Le Westin Montréal is the co-headquarters hotel. Both hotels are a five-minute walk from the Palais des congrès de Montréal (Palais). The GSA block includes nine hotels offering rates from C\$255 to C\$159 single occupancy (per night, plus tax). All other hotels are within a half a mile of the Palais.

Protect yourself: As the number of online hotel bookings continues to increase, so does the rate of booking scams. According to the American Hotel & Lodging Association, fraudulent websites

con 2.5 million North Americans out of US\$220 million every year. Only use a trusted source to make your hotel reservation, and beware of anyone contacting you directly via email, phone, or fax. If you have any questions, please contact the GSA meetings department at meetings@geosociety.org. We will post information to our website regarding hotel reservations in early May.

Don't Forget Your Passport

Passports will be required for entry into Canada. In addition, passports should be valid for at least six months on the date of application for a visa. Participants are invited to consult the website of the visa office to determine whether they will need a visa: <https://www.cic.gc.ca/english/visit/visas.asp>. As a general rule, the validity of a Canadian visa cannot go beyond the validity of the passport. Also, the passport must have at least two blank pages.

<https://www.geosociety.org/annualmeeting>

SCIENCE EDITOR

OPENINGS
2021
FOR

GSA is soliciting applications for three science co-editors for the journal *Geology*. The **four-year terms begin 1 January 2021**. Duties include: ensuring stringent peer review and expeditious processing of manuscripts; making final acceptance or rejection decisions after considering reviewer recommendations; and, along with your co-editors, setting the editorial tone of *Geology* and maintaining excellent content through publication of a diverse range of papers. *Geology* editors should expect to handle 200–250 manuscripts each year, with ~35 active manuscripts on any given day.

3 POSITIONS AVAILABLE

GEOLOGY Research interests that complement those of the continuing editors include, but are not limited to: geochemistry, geomorphology, petrology, tectonics, tectonophysics, structural geology, seismology, volcanology, Earth surface processes, planetary geology, Quaternary studies, hydrogeology, and economic geology.

GEOLOGY

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

TO APPLY

Submit the following to Jeanette Hammann, jhammann@geosociety.org:

- ▶ A **letter** detailing how your experience (including editorial experience) qualifies you for a science editor position, and
- ▶ A **curriculum vitae**

The GSA Publications Committee will review applications at its spring 2020 meeting. The Committee won't consider incomplete applications.

Editors work out of their current locations at work or at home. The positions are considered voluntary, but GSA provides an annual stipend and funds for office expenses. **DEADLINE:** First consideration will be given to nominations or applications received by **15 March 2020**.

A SUCCESSFUL EDITOR WILL HAVE:

- ▶ a broad interest and experience in geosciences, including familiarity with new trends;
- ▶ experience as an editor or associate editor for a geoscience journal (experience with a GSA publication is preferred but not required);
- ▶ international recognition and familiarity with many geoscientists and their work;
- ▶ a progressive attitude and a willingness to take risks and encourage innovation;
- ▶ ability to make timely decisions; and
- ▶ a sense of perspective and humor.

GSA/ExxonMobil Field Awards



GSA/ExxonMobil Bighorn Basin Field Award

Who should apply? Undergraduate and graduate students and faculty

Deadline: 27 March

Camp dates: 19–26 July 2020

This award offers 20 undergraduate and graduate students and five faculty members a high-quality educational experience in the spectacular Bighorn Basin of north-central Wyoming, USA. This one-week field seminar is free to accepted participants, and all transportation, meals, and living expenses are covered.

Supported by



GSA/ExxonMobil Field Camp Excellence Award

Who should apply? Anyone, but the award must be used toward field camp operations

Deadline: 27 March

This US\$10,000 award is given to a geology field camp that clearly focuses on the fundamentals of geologic mapping and field methods. It is based on safety awareness, diversity, and technical excellence. One field camp instructor/director will receive the award to assist with his or her summer field season.

To apply, go to <https://www.geosociety.org/field-experiences>. Students and recent graduates must submit an online application form, two letters of recommendation, and a cover letter.

Questions? Contact Jennifer Nocerino at jnocerino@geosociety.org or +1-303-357-1036.

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Check the GeoCareers website for upcoming webinars and view recordings of past webinars on petroleum, minerals, and environmental consulting at <https://www.geosociety.org/webinars>.

GSA J. David Lowell Field Camp Scholarships

The importance of field schools to practicing geologists is unquestionable, yet the opportunities to experience field geology are dwindling. J. David Lowell Field Camp Scholarships give undergraduate students the opportunity to experience the wonder of the geosciences and learn something new about the world. These scholarships will provide US\$2,000 to undergraduate students so they can attend the summer field camp of their choice. Awards will be based on diversity, economic/financial need, and merit.

Students must submit an online application form, two letters of recommendation, and a cover letter by 27 March. Go to <https://www.geosociety.org/field-experiences> to apply. Questions? Contact Jennifer Nocerino, jnocerino@geosociety.org, +1-303-357-1036.

Supported by



GSA FOUNDATION



"I am very thankful for the support of GSA, which helped make it possible for me to partake in this educational adventure. My skills in geologic mapping and interpretation were brought to a new level, and I leave with many fond memories I will enjoy for years to come."

—Cody Keith, 2019 GSA Field Camp Scholar Award Winner



2020 Undergraduate Student Research Grants

Take advantage of this opportunity: Five of GSA's geographic Sections offer undergraduate research grants. Deadlines vary by Section, ranging from 1 March to 1 April.

<https://www.geosociety.org/undergradgrants>

Paleozoic Stratigraphy and Resources of the Michigan Basin

Edited by G. Michael Grammer,
William B. Harrison III, and David A. Barnes




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This volume provides significant new insights into the Michigan Basin to both academic and applied geoscientists. It includes papers that discuss various aspects of the sedimentology and stratigraphy of key units within the basin, as well as papers that analyze the diverse distribution of natural resources present in this basin.

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On To the Future Travel Awards

- 75% of applicants awarded grants
- Average award: US\$516

Join more than 600 students from diverse backgrounds who have received travel grants to attend their first GSA Annual Meeting & Exposition, this year in Montréal, Québec, Canada, 25–28 October.

Awardees are paired with a mentor and have opportunities to interact with GSA leadership. GSA encourages low-income, underrepresented, first-generation, non-traditional, women, veterans, LGBTQ+, and students with disabilities to apply. **Application deadline:** 29 May.

<https://www.geosociety.org/OTF>



Expanding Representation in the Geosciences (ERG) Scholarships

Undergraduate students from groups who are underrepresented in the geosciences are encouraged to apply or be nominated for this scholarship. Up to six awards include a US\$1,500 scholarship, GSA student membership, and full meeting registration for the 2020 Annual Meeting & Exposition. Qualified applicants must be U.S. citizens studying at an accredited university or college in one of GSA's geographic sections (including Canada and Mexico). **Application/nomination deadline:** 15 May.

<https://www.geosociety.org/erg>

In Memoriam

The Society notes with regret the deaths of the following members (notifications received between 1 Aug. 2019 and 1 Jan. 2020). Memorials to deceased members are published open access at www.geosociety.org/memorials. Visit that page for links to information on how to honor someone with a memorial.

Sarah Andrews

Sebastopol, California, USA
Date of death: 24 July 2019

Albert W. Bally

Houston, Texas, USA
Date of death: 1 Aug. 2019

Clifford A. Balster

Billings, Montana, USA
Date of death: 12 Jan. 2019

Jackson M. Barton Jr.

Dainfern, Sandton, South Africa
Date of death: 21 Jan. 2019

Edward Scudder Belt

Amherst, Massachusetts, USA
Date of death: 23 Mar. 2019

James E. Brooks

Dallas, Texas, USA
Date of death: 13 Sept. 2019

F. William Cambray

Okemos, Michigan, USA
Date of death: 2 June 2019

Robert G. Corbett

Normal, Illinois, USA
Date of death: 27 July 2019

Howard R. Dixon

Bettendorf, Iowa, USA
Date of death: 1 Aug. 2019

James Robert Dodd

Albuquerque, New Mexico, USA
Date of death: 15 Sept. 2019

Frank D. Eckelmann Sr.

Brevard, North Carolina, USA
Date of death: 7 Dec. 2019

Ralph H. Espach Jr.

Loveland, Colorado, USA
Date of death: 10 May 2019

Warren A. Evenson

Cross Lanes, West Virginia, USA
Date of death: 10 July 2019

Henry Frankel

Prairie Village, Kansas, USA
Date of death: 2 Nov. 2019

Erik H. Hauri

Washington, D.C.
Date of death: 5 Sept. 2018

Dennis Lee Hipple

Miami, Florida, USA
Date of death: 22 Nov. 2019

Charles W. Holmes

Tallahassee, Florida, USA
Notified 12 Sept. 2019

Marvin E. Kauffman

Pearland, Texas, USA
Date of death: 15 Aug. 2019

Thomas C. Klekamp

Mandeville, Louisiana, USA
Date of death: 4 Oct. 2018

Ralph L. Langenheim Jr.

Urbana, Illinois, USA
Date of death: 3 Aug. 2019

Alvis L. Lisenbee

Rapid City, South Dakota, USA
Date of death: 16 Nov. 2018

Lawrence R. Matson

Accord, New York, USA
Date of death: 2 Nov. 2019

Alexander R. McBirney

Eugene, Oregon, USA
Notified 12 Sept. 2019

Andrew H. Merritt

Gainesville, Florida, USA
Date of death: 2 Nov. 2019

William R. Moore

Lake Jackson, Texas, USA
Date of death: 1 July 2019

Kurt L. Othberg

Walla Walla, Washington, USA
Notified 24 Sept. 2019

Zell E. Peterman

Lakewood, Colorado, USA
Date of death: 21 July 2019

William C. Peters

Tucson, Arizona, USA
Date of death: 5 Feb. 2019

Jack A. Redden

Rapid City, South Dakota, USA
Date of death: 20 May 2019

Robert H. Rutford

Lincoln, Nebraska, USA
Date of death: 1 Dec. 2019

Dale R. Simpson

Winchester, Virginia, USA
Date of death: 18 Oct. 2019

Brian J. Skinner

New Haven, Connecticut, USA
Date of death: 21 Aug. 2019

Mary-Camilla Wallis

Santa Barbara, California, USA
Date of death: 6 Dec. 2018

Willard Lynn Watney

Baldwin City, Kansas, USA
Date of death: 9 July 2019

William J. Wayne

Lincoln, Nebraska, USA
Date of death: 5 Nov. 2019

John L. Wray

Colorado Springs, Colorado, USA
Date of death: 7 July 2019

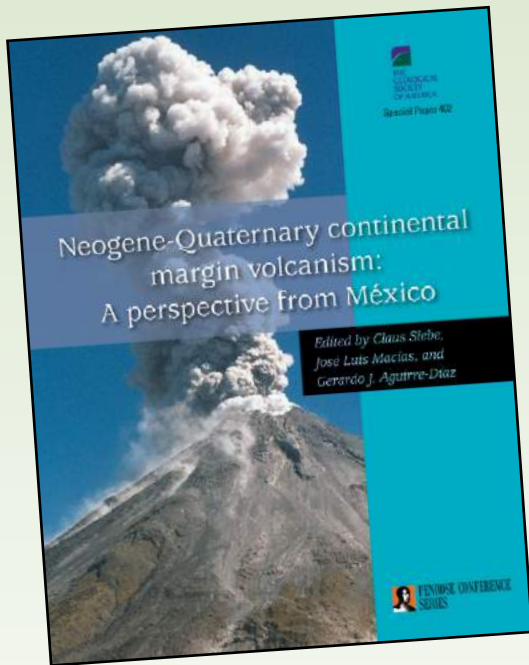
Lynn A. Yehle

Lakewood, Colorado, USA
Notified 23 Oct. 2019

- SPOTLIGHT ON MEXICO -

Guides and Research on This Seismically Active Region and Its Geology

VOLCANOLOGY



A PENROSE CONFERENCE VOLUME

Neogene-Quaternary Continental Margin Volcanism: A Perspective from México

Edited by Claus Siebe, José Luis Macías, and Gerardo J. Aguirre-Díaz

SPE402, 329 p., ISBN 0813724023 | **\$10.00**

This volume represents the culmination of a Penrose Conference held in January 2004 at the foot of Popocatepetl volcano in central México. At the conference, specialists discussed petrological and geochemical issues, eruption dynamics, hazard studies, and other topics relating to arc volcanoes in great detail. This volume includes the most recent advances in our knowledge of the subduction-related Trans-Mexican Volcanic Belt. This area is densely populated and includes some of the potentially most dangerous volcanoes in the world.

FIELD GUIDE RELATED TO SPECIAL PAPER 402

Volcanic Hazards in the Mexico City Metropolitan Area from Eruptions at Popocatepetl, Nevado de Toluca, and Jocotitlán Stratovolcanoes and Monogenetic Scoria Cones in the Sierra Chichinautzin Volcanic Field

By Claus Siebe and José Luis Macías

FLDPEN01P, 77 p. | **\$9.99**

Tephrochronological studies carried out in the area surrounding Mexico City have yielded a wealth of radiocarbon ages from eruptions at Popocatepetl, Nevado de Toluca, and Jocotitlán stratovolcanoes and monogenetic scoria cones in the Sierra Chichinautzin Volcanic Field. These dates allow us to constrain the frequency and types of eruptions that have affected this area during the course of the past 25,000 yr.

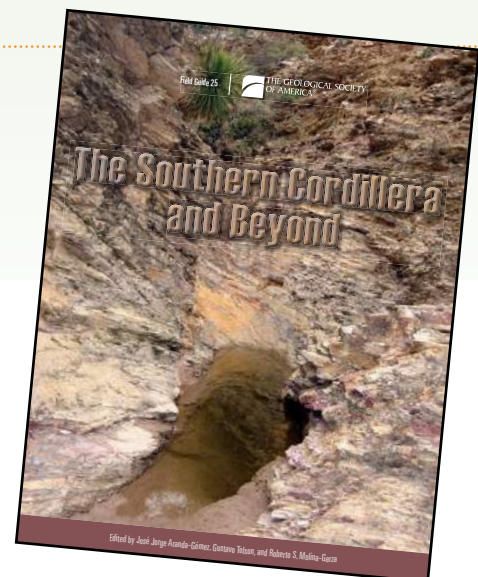
A FIELD GUIDE VOLUME

The Southern Cordillera and Beyond

Edited by José Jorge Aranda-Gómez, Gustavo Tolson, and Roberto S. Molina-Garza

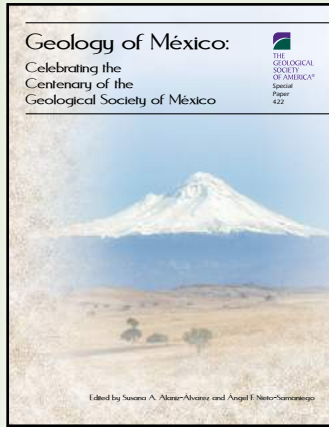
FLD025, 193 p., ISBN 9780813700250 | **\$10.00**

Prepared in conjunction with the 2012 GSA Cordilleran Section Meeting, Querétaro, Mexico, this volume's eight guides showcase three aspects of the geology of the southern end of the North America cordillera: Mid-Tertiary and Quaternary volcanology, environmental geology, and Mesozoic tectonics. This volume explores the Cenozoic stratigraphy of Sierra de Guanajuato, an important Mexican mining district, and addresses the accretion of the Guerrero terrane and its possible role in the Late Cretaceous–Early Tertiary orogeny.



<https://rock.geosociety.org/store/>

TECTONICS

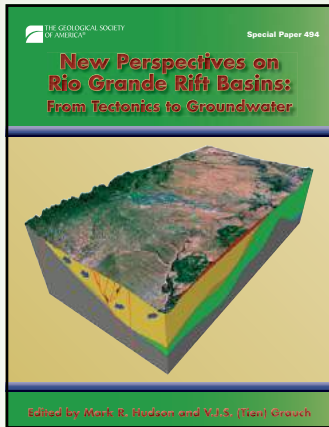


Geology of México: Celebrating the Centenary of the Geological Society of México

Edited by Susana A. Alaniz-Álvarez and Ángel F. Nieto-Samaniego

SPE422P, 458 p., ISBN 9780813724225 | **\$9.99**

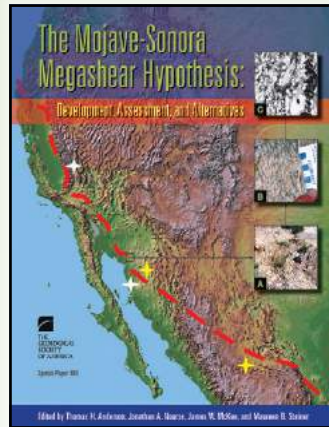
This volume focuses on three subjects: reviews of some of the geological provinces, major faults that constitute tectonic borders, and ore deposits. Papers are of general or regional character but provide a deep treatment of the themes and bring together useful information for researchers, students, technicians, and others interested in México.



New Perspectives on Rio Grande Rift Basins: From Tectonics to Groundwater

Edited by Mark R. Hudson and V.J.S. (Ten) Grauch

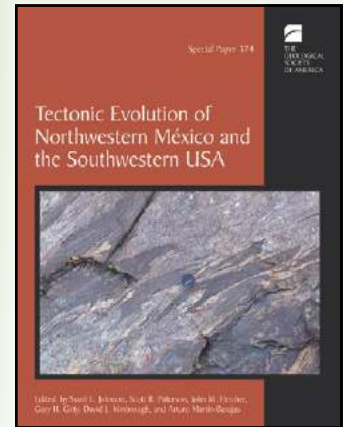
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The Mojave-Sonora Megashear Hypothesis: Development, Assessment, and Alternatives

Edited by Thomas H. Anderson, Jonathan A. Nourse, James W. McKee, and Maureen B. Steiner

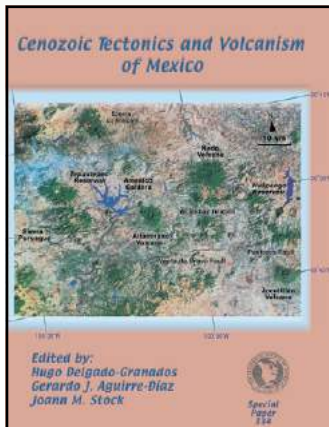
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Tectonic Evolution of Northwestern México and the Southwestern USA

Edited by Scott E. Johnson, Scott R. Paterson, John M. Fletcher, Gary H. Girty, David L. Kimbrough, and Arturo Martín-Barajas

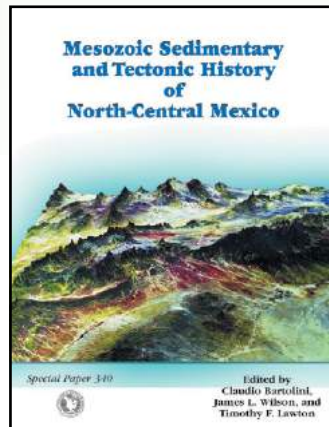
SPE374P, 478 p., ISBN 0813723744 | **\$9.99**



Cenozoic Tectonics and Volcanism of México

Edited by Hugo Delgado-Granados, Gerardo J. Aguirre-Díaz, and Joann M. Stock

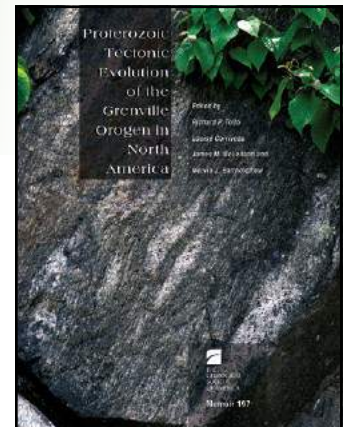
SPE334P, 275 p., ISBN 0813723345 | **\$9.99**



Mesozoic Sedimentary and Tectonic History of North-Central Mexico

Edited by Claudio Bartolini, James Lee Wilson, and Timothy F. Lawton

SPE340P, 380 p., ISBN 081372340X | **\$9.99**



Proterozoic Tectonic Evolution of the Grenville Orogen in North America

Edited by Richard P. Tollo, James McLelland, Louise Corriveau, and Mervin J. Bartholomew

MWR197P, 830 p., ISBN 0813711975 | **\$9.99**

2020 GSA Section Meetings



South-Central

9–10 March
Fort Worth Convention Center
Fort Worth, Texas, USA
Chairs: Omar Harvey, omar.harvey@tcu.edu;
Arne Winguth, awinguth@uta.edu
www.geosociety.org/sc-mtg

Fort Worth Stockyards. Photo by Visit Fort Worth.



Joint Southeastern–Northeastern

20–22 March
Hyatt Regency Reston
Reston, Virginia, USA
Chairs: Arthur Merschat, amerschat@usgs.gov;
Patrick Burkhart, patrick.burkhart@sru.edu
www.geosociety.org/se-mtg

Great Falls Park. Photo by Visit Fairfax.



Rocky Mountain

4–5 May
Utah Valley Convention Center
Provo, Utah, USA
Chair: Daniel Horns, hornsda@uvu.edu
www.geosociety.org/rm-mtg

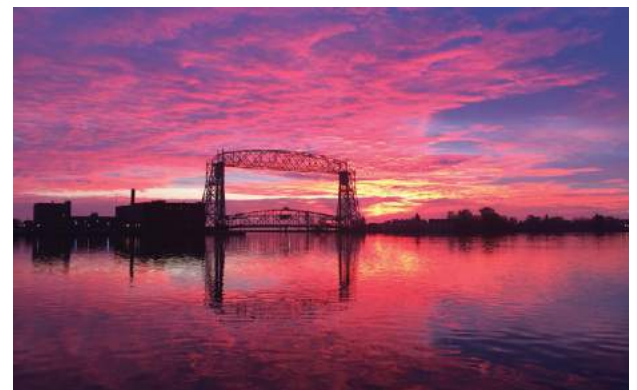
Mount Timpanogos. Photo by Hike395 via Wikimedia Commons.



Cordilleran

12–14 May
The Westin Pasadena
Pasadena, California, USA
Chair: Doug Yule, doug.yule@csun.edu
www.geosociety.org/cd-mtg

City Hall. Photo by Pasadena Convention & Visitors Bureau.



North-Central

18–19 May
Duluth Entertainment Convention Center
Duluth, Minnesota, USA
Chair: Karen Gran, kgran@d.umn.edu
www.geosociety.org/nc-mtg

Aerial Lift Bridge at sunrise. Photo by Visit Duluth.

GeoCareers Programs at the 2020 Section Meetings

Career Workshops

Geoscience Career Workshop Part 1: Career Planning and Networking

Your job-hunting process should begin with career planning, not when you apply for jobs. This workshop will help you begin this process. This section is highly recommended for freshmen, sophomores, and juniors. The earlier you start your career planning the better.

Geoscience Career Workshop Part 2: Geoscience Career Exploration

What do geologists in various sectors earn? What do they do? What are the pros and cons of working in academia, government,

and industry? Workshop presenters and professionals in the field will address these issues.

Geoscience Career Workshop Part 3: Cover Letters, Résumés, and CVs

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

Mentor Programs for GSA Student Members

GSA student members: Enjoy a free lunch while meeting with geoscience mentors working in applied sectors. The popularity of these programs means that space is limited, so plan to arrive early, because lunch is first-come, first-served. For further information, contact Jennifer Nocerino at jnocerino@geosociety.org.

South-Central Section: Fort Worth, Texas, USA
Shlemon Mentor Luncheon: Monday, 9 March
Mann Mentors in Applied Hydrology Luncheon: Tuesday, 10 March

Joint Meeting: Southeastern and Northeastern Sections:
Reston, Virginia, USA
Shlemon Mentor Luncheon: Friday, 20 March
Mann Mentors in Applied Hydrology Luncheon: Saturday, 21 March

Rocky Mountain Section: Provo, Utah, USA
Shlemon Mentor Luncheon: Monday, 4 May
Mann Mentors in Applied Hydrology Luncheon: Tuesday, 5 May

Cordilleran Section: Pasadena, California, USA
Shlemon Mentor Luncheon: Tuesday, 12 May
Mann Mentors in Applied Hydrology Luncheon: Wednesday, 13 May

North-Central Section: Duluth, Minnesota, USA
Shlemon Mentor Luncheon: Monday, 18 May
Mann Mentors in Applied Hydrology Luncheon: Tuesday, 19 May



CALL FOR NOMINATIONS

GSA Scientific Division Awards



GEOARCHAEOLOGY DIVISION

Claude C. Albritton, Jr., Award

Nominations due 15 Mar.

Submit nominations to gsa.agd@gmail.com

<https://community.geosociety.org/geoarchdivision/awards/student/albritton>

Richard Hay Student Paper/Poster Award

Nominations due 30 Aug.

Submit nominations to gsa.agd@gmail.com

<https://community.geosociety.org/geoarchdivision/awards/student/hay>

GEOSCIENCE EDUCATION DIVISION

Biggs Award for Excellence in Earth Science Teaching

Nominations due 15 Mar.

Submit nominations online

<https://community.geosociety.org/gedivision/awards/biggsaward>

HISTORY AND PHILOSOPHY OF GEOLOGY DIVISION

History and Philosophy of Geology Student Award

Nominations due 15 June

Submit nominations to Michael Smith at smithms@uncw.edu

<https://community.geosociety.org/histphildiv/awards/student>

LIMNOGEOLOGY DIVISION

Israel C. Russell Award

Nominations due 15 Mar.

Submit nominations to David Finkelstein at finkelstein@hws.edu

<https://community.geosociety.org/limnogeologydivision/awards/russell>

Kerry Kelts Research Award

Nominations due 30 June

Submit nominations to David Finkelstein at finkelstein@hws.edu

<https://community.geosociety.org/limnogeologydivision/awards/kerrykelts>

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

MGPV Distinguished Geologic Career Award

Nominations due 31 Mar.

Submit nominations to J. Alex Speer at jaspeer@minsocam.org

<https://community.geosociety.org/mgpvdivision/awards/dgca>

MGPV Early Career Award

Nominations due 31 Mar.

Submit nominations to J. Alex Speer at jaspeer@minsocam.org

<https://community.geosociety.org/mgpvdivision/awards/earlycareer>

PLANETARY GEOLOGY DIVISION

Eugene M. Shoemaker Impact Cratering Award

Nominations due 19 Aug.

Submit nominations online

<https://community.geosociety.org/pgd/awards/shoemaker>

Ronald Greeley Award for Distinguished Service

Nominations due 30 June

Submit nominations to the Division management board at

<https://community.geosociety.org/pgd/aboutus/officers>

<https://community.geosociety.org/pgd/awards/greeley>

QUATERNARY GEOLOGY & GEOMORPHOLOGY DIVISION

Farouk El-Baz Award for Desert Research

Nominations due 1 Apr.

Submit nominations to the first vice-chair

<https://community.geosociety.org/qggdivision/awards/el-baz>

Distinguished Career Award

Nominations due 1 Apr.

Submit nominations to Sarah Lewis at sarah.lewis@oregonstate.edu

<https://community.geosociety.org/qggdivision/awards/distinguished-career>

SEDIMENTARY GEOLOGY DIVISION

Sedimentary Geology Division *and* Structural Geology & Tectonics Division Joint Award

Stephen E. Laubach Structural Diagenesis Research Award

Nominations due 15 May

Submit nominations to Timothy Byrne at timothy.byrne@uconn.edu

<https://community.geosociety.org/sedimentarygeologydiv/awards/laubach>



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The Edwards Aquifer: The Past, Present, and Future of a Vital Water Resource

Edited by John M. Sharp Jr., Ronald T. Green, and Geary M. Schindel

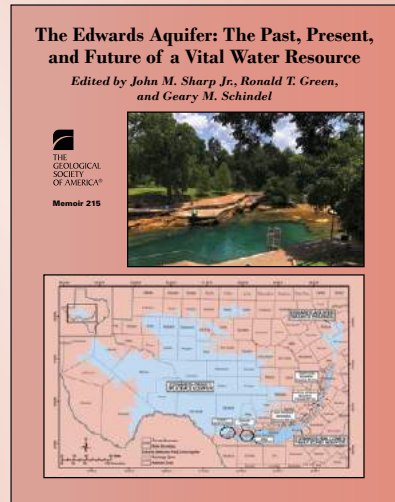


The Edwards aquifer system is one of the great karstic aquifer systems of the world. It supplies water for more than 2 million people and for agricultural, municipal, industrial, and recreational uses. The Edwards (Balcones Fault Zone) Aquifer in the San Antonio, Texas, area was the first to be designated a sole source aquifer by the Environmental Protection Agency in 1975. The Edwards Aquifer also hosts unique groundwater, cave, and spring ecosystems. This 27-chapter memoir reviews the current state of knowledge, current and emerging challenges to wise use of the aquifer system, and some of the technologies that must be adopted to address these challenges.

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Memoir 215

Elections: GSA Officers and Councilors

GSA's success depends on you—its members—and the work of the officers serving on GSA's Executive Committee and Council.

GSA elections begin 5 March. Ballots must be submitted electronically or postmarked by 4 April. During this voting period,

a member-only secure electronic ballot will be active on the GSA website, and biographical information on the nominees will be online for review. Paper versions of the ballot will also be available.

Vote on these nominees and shape GSA's future.



J. Douglas Walker

PRESIDENT

(July 2020–June 2021)

J. Douglas Walker

University of Kansas
Lawrence, Kansas, USA

We congratulate our incoming president, J. Douglas Walker, voted into office by GSA members in 2019.

2020 OFFICER AND COUNCIL NOMINEES

PRESIDENT-ELECT/ PRESIDENT

(July 2020–June 2022)

Barbara (Barb) L. Dutrow
Louisiana State University
Baton Rouge, Louisiana, USA

TREASURER (continuing)
(July 2020–June 2021)

Richard C. Berg
Illinois State Geological
Survey
Champaign, Illinois, USA

COUNCILOR POSITION 1 (July 2020–June 2024)

Susan G. Stover
Kansas Geological Survey
Topeka, Kansas, USA

Pinar O. Yilmaz
ExxonMobil Exploration
Company
Spring, Texas, USA

COUNCILOR POSITION 2 (July 2020–June 2024)

Madeline E. Schreiber
Professor, Virginia Tech
Blacksburg, Virginia, USA

Dave Szymanski
Bentley University
Waltham, Massachusetts, USA

COUNCILOR POSITION 3 (July 2020–June 2024)

Abhijit Mukherjee
Indian Institute of Technology
(IIT)–Kharagpur
West Bengal, India

Manfred R. Strecker
Universität Potsdam
Potsdam-Golm, Germany

Call for Committee Service

If you are looking for the opportunity to work toward a common goal, network, and make a difference, then we invite you to volunteer (or nominate a fellow GSA member) to serve on a Society committee or as a GSA representative to another organization. Learn more and access the nomination form at [https://](https://rock.geosociety.org/Nominations/CS.aspx)

rock.geosociety.org/Nominations/CS.aspx. Open positions and qualification information is online at <https://rock.geosociety.org/forms/viewopenpositions.asp>. GSA headquarters contact: Dominique Olvera, P.O. Box 9140, Boulder, CO 80301-9140, USA; +1-303-357-1060; dolvera@geosociety.org.

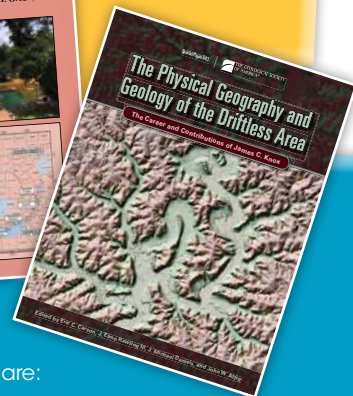
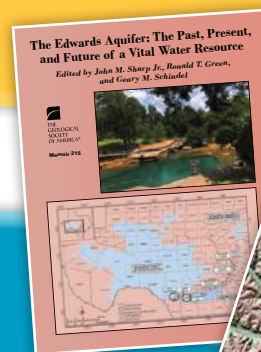
Nomination deadline: 15 June. Terms begin 1 July 2021 unless stated otherwise.

COMMITTEE NAME	NO. OF VACANCIES	POSITION TITLE & SPECIAL REQUIREMENTS	TERM (YEARS)
Academic and Applied Geoscience Relations Committee	1	Member-at-Large: Industry	3
Annual Program Committee	3	Members-at-Large	4
		Member-at-Large: Student	2
Arthur L. Day Medal Award Committee	2	Members-at-Large	3
Council Officers	5	President-Elect	3
		Treasurer	1
		Councilor	4
Diversity in the Geosciences Committee	3	Members-at-Large	3
Education Committee	4	Members-at-Large	4
		Two-Year College Faculty Representatives	4
		Pre-College Educator (K-12) Representatives	4
		Graduate Student Representatives	2
Geology and Public Policy Committee	2	Members-at-Large	3
GSA International	2	Members-at-Large	4
Joint Technical Program Committee (terms begin Dec. 2020)	2	Members-at-Large: Marine/Coastal Geology	2
Membership and Fellowship Committee	1	Member-at-Large: Industry	3
Nominations Committee	1	Member-at-Large: Industry	3
North American Commission on Stratigraphic Nomenclature	1	GSA Representative	3
Penrose Medal Award Committee	2	Members-at-Large	3
Penrose Conferences and Thompson Field Forums Committee	2	Members-at-Large: Early Career Scientists	3
Professional Development Committee	1	Member-at-Large	3
Publications Committee	1	Member-at-Large	4
Research Grants Committee	15	Members-at-Large (various specialties)	3
Young Scientist Award (Donath Medal) Committee	1	Member-at-Large	3

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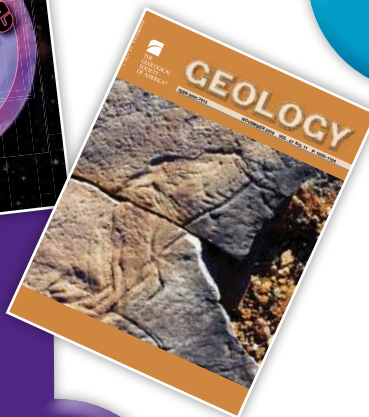
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	2019	5-YEAR	
Geology	5.006	5.406	geology.msubmit.net
GSA Bulletin	3.970	4.708	gsabulletin.msubmit.net
Geosphere	2.847	2.989	geosphere.msubmit.net
E&EG	0.844	0.76	www.editorialmanager.com/eeg

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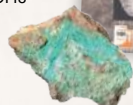
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Ads (or cancellations) must reach the GSA advertising office no later than the first of the month, one month prior to the issue in which they are to be published. (Note: Combined March/April issue releases on March schedule.) Print ads will also appear on the Geoscience Job Board to coincide with the month of print issue. **Contact:** advertising@geosociety.org, +1-800-472-1988 ext. 1053, or +1-303-357-1053. Email correspondence should include complete contact information (including phone and mailing address). Rates are in U.S. dollars.

Classification	Per Line for 1st month	Per line each add'l month (same ad)
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Fellowship Opportunities	\$9.40	\$9.35
Opportunities for Students		
First 25 lines	FREE	\$5.00
Additional lines	\$5.00	\$5.00

POSITIONS OPEN

Tier I Canada Research Chair in Metallogeny, Laurentian University

The Harquail School of Earth Sciences (HES) and Mineral Exploration Research Centre (MERC) at Laurentian University invite applications for a Tier I Canada Research Chair in Metallogeny that integrates ore system research with broad scale tectonic processes. The Chair will enhance research and teaching in the field of ore deposit geology and tectonics, and advance the position of Laurentian University as a centre of excellence in Mineral Deposits and Precambrian Geology. The Chair will be one of the scientific leaders of Metal Earth, a Canadian \$104 million R&D program led by Laurentian University and funded through the Canada First Research Excellence Fund.

We seek an innovative individual with an outstanding record of research and publication, who will provide leadership for national and international collaborative research and become a focus for integration of research initiatives involving HES/MERC. The Chair will be expected to contribute to our BSc, MSc, and Ph.D. programs. The successful applicant will have access to a wide range of facilities, including recently updated LA-ICP-MS facility (Teledyne Cetac Analyte G2 Excimer Laser, Thermo Neptune Plus high-resolution MC-ICP-MS, and iCap TQ triple-quadrupole ICP-MS with dedicated full-time Ph.D. technician). Additional information about the School, MERC and Metal Earth can be found at hes.laurentian.ca, merc.laurentian.ca, and merc.laurentian.ca/research/metal-earth.

A Ph.D. degree in a related field is required at the time of appointment. Applications, including a statement of teaching philosophy, evidence of teaching, an overview of research interests, and a curriculum vitae should be sent as PDF files to vpap@laurentian.ca. Applicants should arrange to have three letters of reference directly sent to the email address above. Review of complete applications will begin immediately but applications will be accepted until the position is filled. Questions concerning the position may be directed to Dr. Doug Tinkham at dthinkham@laurentian.ca. The full advertisement for this position can be downloaded at <https://hes.laurentian.ca/news-standard/careers-tier-i-canada-research-chair-metallogeny>.

Laurentian University is an inclusive and welcoming community and encourages applications from

members of equity-seeking communities including women, racialized and Indigenous persons, persons with disabilities, and persons of all sexual orientations and gender identities/expressions. Laurentian University's bilingualism policy (Section 7.3.b) provides a provision regarding the language requirement for persons self-identifying as First Nations, Métis or Inuit, and the University has a policy of passive bilingualism (English/French) as a condition of tenure. Information can be found at <https://laurentian.ca/bilingualism>. LU faculty members are part of the Laurentian University Faculty Association (LUFA). Candidates are advised to consult the Collective Agreement at www.lufapul.ca/. Laurentian University is committed to providing an inclusive and barrier free experience to applicants with accessibility needs. Requests for accommodation can be made at any stage during the recruitment process. Please contact the Office of the Vice-President, Academic and Provost for more information. All qualified persons are encouraged to apply; however, in accordance with Canadian immigration requirements, Canadian citizens and permanent residents of Canada will be given priority.

3-Year Faculty Position in Sedimentary Geology, Pomona College

The Geology Department at Pomona College, the founding member of the Claremont Colleges, invites applications for a 3-year, non-tenure-track position beginning July 1 2020 to teach courses and assist with senior thesis supervision.

We seek a candidate eager to interact with talented undergraduates in a liberal arts college environment where teaching and research are emphasized. Annual teaching responsibilities are expected to include Sedimentology and Earth History, each with a lab, plus Introductory Geology and one other non-lab course determined through discussion between the candidate and department.

Pomona College and the Geology Department support equal access to higher education. Fifty-two percent of our current cohort of first-year students (class of 2023) self-identify as domestic students of color, 11% are international, and 19% are first-generation college students. The successful candidate will have the opportunity to teach and mentor exceptional students of diverse backgrounds—utilizing pedagogical practices that are rigorous, inclusive, and which promote academic equity.

Applicants should e-mail to GeoFacSearch@pomona.edu a dossier including (1) a letter of interest, (2) curriculum vitae, (3) a brief statement of teaching philosophy, (4) a summary of research plans, and (5) undergraduate and graduate transcripts. Applicants should arrange to have two letters of reference sent directly to the search e-mail address. Hard copies of materials may also be mailed to Geology Faculty Search, c/o Lori Keala, Geology Department, 185 E. Sixth Street, Claremont, CA 91711.

Web address: <https://www.pomona.edu/academics/departments/geology>; refer questions to Dr. Eric Grosfils (e-mail: egrosfils@pomona.edu; 909-621-8673). Review of completed applications will begin by April 1st 2020 and will continue until the position is filled.

OPPORTUNITIES FOR STUDENTS

Lithium Americas Summer 2020 Exploration Internship.

Lithium Americas Corporation is hiring paid student interns for the summer of 2020. Successful applicants will work with the geological exploration team to identify sedimentary lithium deposits in the United States and develop detailed models of their origins. Internship responsibilities will include: (1) extensive field geological mapping; (2) sample collection, preparation, and geochemical analysis; (3) GIS desktop mapping; (4) synthesis of field and geochemical data; and (5) writing of reports. During mapping campaigns, interns will be performing field work in hot, arid conditions and often camping in the evenings. A monthly stipend of \$2,500 will be provided.

Applicants must have a bachelor's degree in earth science and be working towards (or recently finished) a graduate degree in economic geology, sedimentary geology, volcanology, petrology, geochemistry, structural geology, or a related discipline. Experience with field mapping and GIS systems is required.

Interested applicants should fill out the Summer 2020 Exploration Internship Application Form on the Lithium Americas website, <https://www.lithiumamericas.com/contact/careers/>. Please fill out all portions of the application form, and include PDF versions of your cover letter and CV. Email the application form, cover letter, and CV as a single PDF document to hr@lithiumamericas.com. Applications close on 13 March 2020.

For additional information or inquiries, please contact Lithium Americas' Lead Global Exploration Geologist, Tom Benson (tom.benson@lithiumamericas.com).

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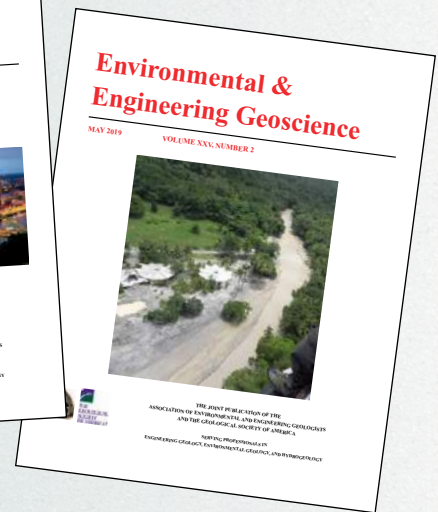
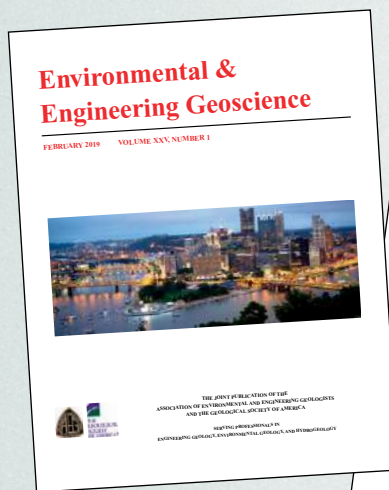
— Recent GSA advertiser

CALL FOR EDITOR

ENVIRONMENTAL & ENGINEERING GEOSCIENCE

GSA is soliciting applications and nominations for a science co-editor for *Environmental & Engineering Geoscience (E&EG)* with a term of 4 years beginning January 2021. Duties include: ensuring stringent peer review and expeditious processing of manuscripts; making final acceptance or rejection decisions after considering reviewer recommendations; and, along with your co-editor, setting the editorial tone of the journal. *E&EG* editors also solicit submissions to the journal through interacting with colleagues at meetings and through organizing special issues.

Research interests that complement those of the continuing editor include hydrogeology, low-T geochemistry, geomorphology, and/or environmental geophysics.

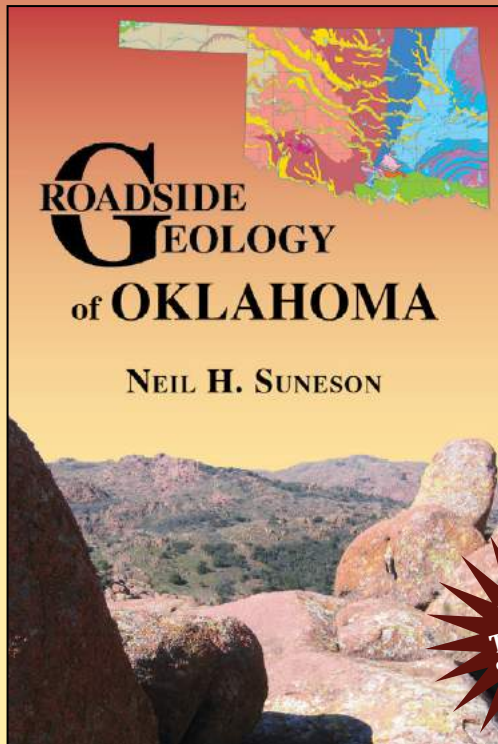


To Apply: Submit a letter detailing how your experience (including editorial experience) qualifies you for this position, and a curriculum vitae to Jeanette Hammann, jhammann@geosociety.org. The GSA Publications Committee will review applications at its spring 2020 meeting. GSA encourages applications from all qualified persons and is committed to diversity.

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

DEADLINE: First consideration will be given to nominations or applications received by 15 March 2020.

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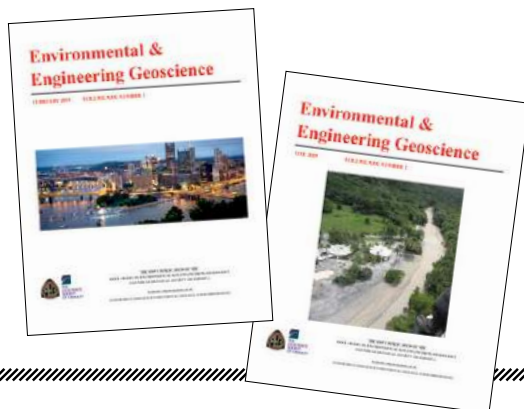


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Submit Your Research to *Environmental & Engineering Geoscience*

Environmental & Engineering Geoscience, a quarterly journal jointly published by the Association of Environmental & Engineering Geologists (AEG) and GSA, has a new manuscript submission platform at <https://www.editorialmanager.com/eeg>.



Coming up for the journal in 2020 are two special issues.

“Naturally Occurring Asbestos” (NOA) memorializes the findings and state-of-the-art practices described by many of the presenters at the NOA Symposium held as part of the combined XIII Congress of the International Association for Engineering Geology and the Environment (IAEG) and the AEG Annual Meeting in September 2018 in San Francisco, California. The guest editors of this special edition are R. Mark Bailey and Sarah Kalika.

The second *Environmental & Engineering Geoscience* special issue, “Springs,” grew out of presentations at recent GSA Annual Meetings. The guest editor of this special issue is Abraham Springer.



Corporations and Geologists in Industry: An Important Role with GSA

GSA and the GSA Foundation have long partnered with corporations in both support and programmatic involvement. While contributed funds are vital to the existence of many programs, so is the hands-on, engaged participation of companies and their employees.

We appreciate that our partners are highly committed to the next generation of geoscience talent. Chesapeake Energy Corporation is one of those—supporting programs through both funding and interaction with GSA students through committed employees who volunteer their time and share their experience directly. During GSA's 2018 Annual Meeting & Exhibition in Indianapolis, Indiana, USA, Chesapeake was present not only as an exhibitor and sponsor of the GeoCareers program, but also with employees actively engaged in the meeting overall, attending posters, technical sessions, and events. JP Dube, geoscience manager, found great benefit in all the ways that the company was involved: "I think that sometimes petroleum geoscientists forget that GSA is their society too. By encouraging and supporting attendance to the GSA Annual Meeting and Exposition, Chesapeake has been able to take advantage of a strong technical program rooted in fundamentals, network with partners and stakeholders in geoscience, and supplement our college recruiting efforts with an improved level of quality and diversity."

JP believed their involvement to be so beneficial that he accepted an invitation from GSA's then-president Robbie Gries to chair an ad hoc committee for the 2019 GeoCareers program. With a strong focus on engaging companies more deeply with GSA, JP and other representatives from various industry sectors, academia, and student

membership worked collaboratively leading up to the 2019 Annual Meeting in Phoenix, Arizona, USA, to incorporate career webinars and onsite components into a well-rounded program for students and early career attendees. Six representatives from Chesapeake attended the meeting as part of GeoCareers, including a human resources representative with whom students found great advantage in talking. We are pleased that JP will continue in his role as GeoCareers committee chair for 2020; we value his enthusiasm and support for the program rooted in his first-hand experience. In each year of participation, Chesapeake reviewed more than 100 graduate students at GSA and interviewed about 20 people. Four out of 24 total interns over the past two years (summer hires for 2019 and 2020) have come from GSA, and of those four, three represented students from schools new to the company. One of their 2019 interns from GSA is returning for a second internship this coming summer.

This partnership represents a depth and breadth of collaboration between GSA and corporations that reaches far beyond a one-time financial contribution to a program. We value the support of our partners and the devoted time of their employees to GSA students and efforts. Together, we can maximize the collective ability to foster current and future leaders in the geoscience community. We strive to engage business and industry as a positive force to advance science, stewardship, and service, joining with corporations to have a meaningful impact. If you want to learn how you or your employer can join these efforts, please contact Debbie Marcinkowski at +1-303-357-1047 or dmarcinkowski@geosociety.org.





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3 Li 6.941 Lithium	4 Be 9.012182 Beryllium											5 B 10.811 Boron	6 C 12.0107 Carbon	7 N 14.0067 Nitrogen	8 O 15.9994 Oxygen	9 F 18.9984032 Fluorine	10 Ne 20.1797 Neon
11 Na 22.98976928 Sodium	12 Mg 24.305 Magnesium											13 Al 26.9815386 Aluminum	14 Si 28.0855 Silicon	15 P 30.973762 Phosphorus	16 S 32.065 Sulfur	17 Cl 35.453 Chlorine	18 Ar 39.948 Argon
19 K 39.0983 Potassium	20 Ca 40.078 Calcium	21 Sc 44.955912 Scandium	22 Ti 47.867 Titanium	23 V 50.9415 Vanadium	24 Cr 51.9961 Chromium	25 Mn 54.938045 Manganese	26 Fe 55.845 Iron	27 Co 58.933195 Cobalt	28 Ni 58.6934 Nickel	29 Cu 63.546 Copper	30 Zn 65.38 Zinc	31 Ga 69.723 Gallium	32 Ge 72.64 Germanium	33 As 74.9216 Arsenic	34 Se 78.96 Selenium	35 Br 79.904 Bromine	36 Kr 83.798 Krypton
37 Rb 85.4678 Rubidium	38 Sr 87.62 Strontium	39 Y 88.90585 Yttrium	40 Zr 91.224 Zirconium	41 Nb 92.90638 Niobium	42 Mo 95.96 Molybdenum	43 Tc (98.9) Technetium	44 Ru 101.07 Ruthenium	45 Rh 102.90550 Rhodium	46 Pd 106.42 Palladium	47 Ag 107.8682 Silver	48 Cd 112.411 Cadmium	49 In 114.818 Indium	50 Sn 118.71 Tin	51 Sb 121.76 Antimony	52 Te 127.6 Tellurium	53 I 126.90447 Iodine	54 Xe 131.29 Xenon
55 Cs 132.9054 Cesium	56 Ba 137.327 Barium	57 La 138.90547 Lanthanum	58 Ce 140.12 Cerium	59 Pr 140.90766 Praseodymium	60 Nd 144.242 Neodymium	61 Pm (145) Promethium	62 Sm 150.36 Samarium	63 Eu 151.964 Europium	64 Gd 157.25 Gadolinium	65 Tb 158.92535 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.93032 Holmium	68 Er 167.259 Erbium	69 Tm 168.93421 Thulium	70 Yb 173.054 Ytterbium	71 Lu 174.967 Lutetium	
87 Fr (223) Francium	88 Ra (226) Radium	89 Ac (227) Actinium	104 Rf (261) Rutherfordium	105 Db (262) Dubnium	106 Sg (266) Seaborgium	107 Bh (264) Bohrium	108 Hs (277) Hassium	109 Mt (276) Meitnerium	110 Ds (281) Darmstadtium	111 Rg (280) Roentgenium	112 Cn (285) Copernicium	113 Nh (284) Nihonium	114 Fl (289) Flerovium	115 Mc (288) Moscovium	116 Lv (293) Livermorium	117 Ts (294) Tennessine	118 Og (294) Oganesson

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