

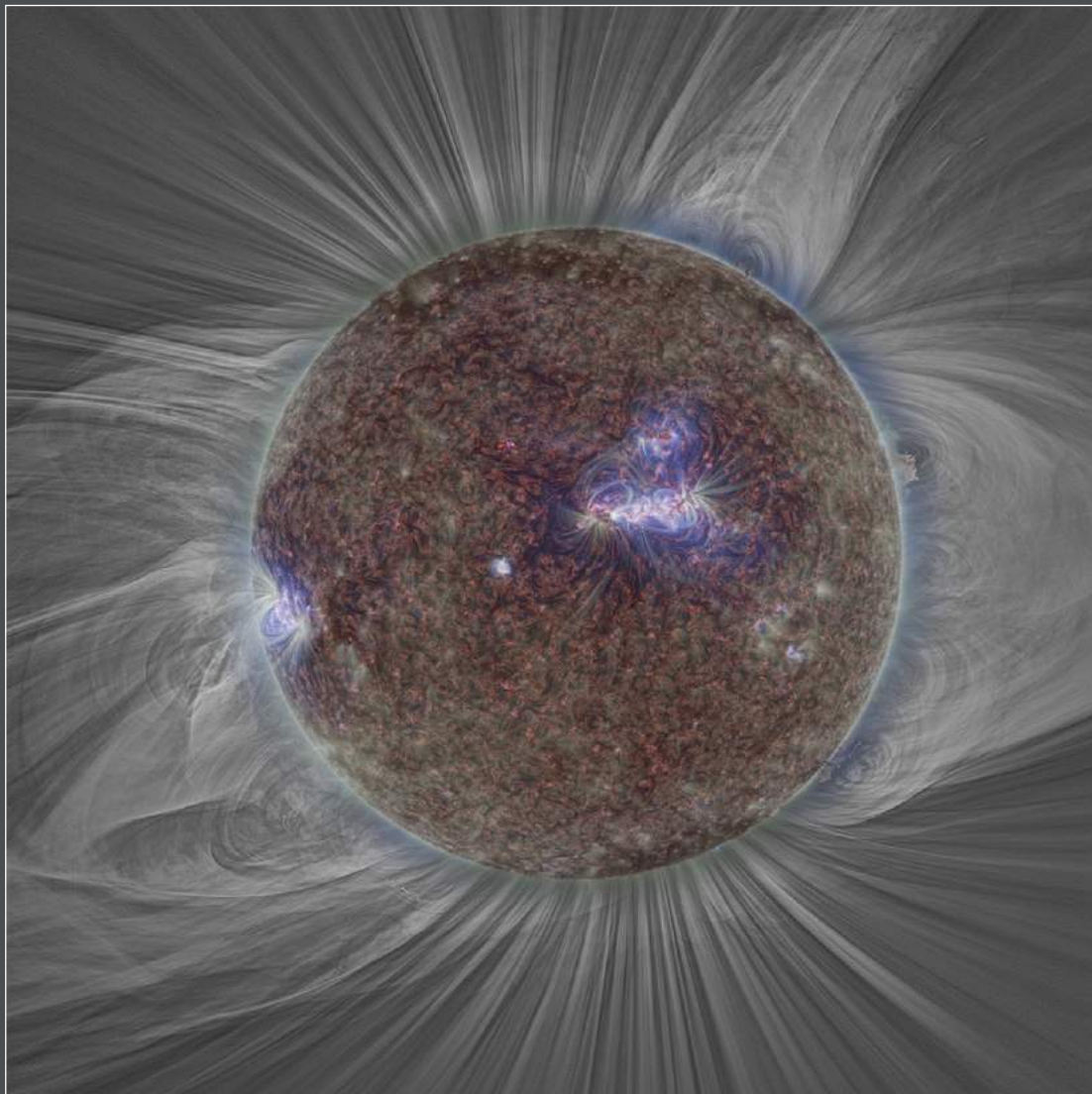
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The Faint Young Sun Problem Revisited



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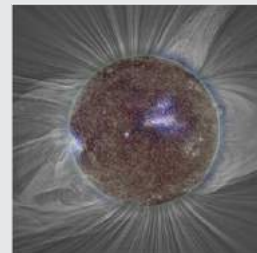
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SCIENCE

4 The Faint Young Sun Problem Revisited Jon Spencer

Cover: Composite of two images, one of the solar corona as seen during the total solar eclipse of 21 Aug. 2017, the other of the solar disk at ultraviolet frequencies as imaged by the Solar Dynamics Observatory satellite. Streamers from polar regions are areas where solar wind flows outward along magnetic field lines. At lower solar latitudes, arcing magnetic-field lines are associated with sunspots and other surface activity that can yield explosive coronal mass ejections. Both solar wind and mass ejections carry away mass and angular momentum. This type of solar activity was much greater during the Sun's fast-spinning youth. Image provided by Miloslav Druckmüller, Institute of Mathematics, Faculty of Mechanical Engineering, Brno University of Technology, Czech Republic. See related article, p. 4–10.



- 12 **2020 Graduate Student Research Grants**
- 12 **J. David Lowell Field Camp Scholarships**
- 12 **Travel Awards to the 2020 Northeastern-Southeastern Joint Section Meeting**
- 13 **GSA GeoCorps™ America Program**
- 13 **National Park Service Geoscientists-in-the-Parks (GIP) Opportunities**
- 14 **Why GSA Membership Is Important to Me**
- 15 **2020 Section Meetings Calendar**
- 16 **Preliminary Announcement and Call for Papers: GSA North-Central Section Meeting**
- 20 **Second Announcement: GSA South-Central Section Meeting**
- 24 **Second Announcement: Joint Meeting: Southeastern Section and Northeastern Section**
- 30 **Call for Applications: 2020–2021 GSA-USGS Congressional Science Fellow**
- 31 **Geoscience Jobs & Opportunities**
- 37 **GSA Foundation Update**
- 39 **Call for Proposals: GSA 2020 Annual Meeting & Exposition**



The Faint Young Sun Problem Revisited

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ABSTRACT

Earth and Mars should have been frozen worlds in their early history because of lower solar luminosity but were not, which challenges our understanding of early atmospheres and surface conditions and/or our understanding of solar evolution. This is known as the “faint young Sun problem.” One resolution to the problem is that the Sun was more massive and luminous in its youth before blowing off mass. Astrophysical studies of stellar evolution and behavior, however, including recent analysis of Kepler space-telescope data, indicate that mass loss is both insufficient and occurs too early to allow for a more luminous Sun after ca. 4 Ga. Alternatively, greenhouse gases were surprisingly effective at warming young Earth and Mars. High concentrations of CO₂ with the possible addition of biogenic CH₄ are likely dominant factors promoting open-water conditions on Archean Earth. Evidence of precipitation and flowing water on young Mars, including river valleys thousands of kilometers long, is more problematic. Recent studies indicate that 3–4 Ga river valleys and delta deposits in crater lakes could have been produced in <~10⁷ years. Highly transient warm periods during times of favorable orbital parameters possibly led to brief melting under otherwise icy conditions. Seasonal melting and runoff would be more likely with ~1%–10% atmospheric H₂ and CH₄, perhaps derived from serpentinization of olivine in the martian crust and released from frozen ground by impacts and volcanism, and/or derived directly from volcanic outgassing. The recently recognized effectiveness of hydrogen and methane at absorbing infrared radiation in a thick CO₂-dominated atmosphere, in a process known as “collision-induced absorption,” is probably essential to the solution to the faint young Sun problem for Mars.

INTRODUCTION

The basic concepts involved in stellar-energy generation were known by the 1950s and include the insight that stellar luminosity gradually increases over time because of increasing density in stellar cores resulting directly from thermonuclear fusion (e.g., Burbidge et al., 1957) (Fig. 1). Solar luminosity at birth was calculated to be ~70% of modern luminosity. The idea that Earth should have geologic evidence of its presumably frozen youth was gradually determined to be inconsistent with growing evidence for liquid water at the surface of Archean Earth. The problem was first addressed by Sagan and Mullen (1972), who proposed that atmospheric ammonia was crucial to early warming. More recent robotic exploration of Mars similarly indicates surprisingly warm and wet conditions during its early geologic history. The discrepancy between low solar-energy production and warm early Earth and Mars is

known as the “faint young Sun problem” (Ulrich, 1975; Feulner, 2012). This article is a brief review of solar evolution and the faint young Sun problem for Earth and Mars that highlights recent developments.

STELLAR ENERGY PRODUCTION

Stars form by gravitational contraction of clouds of interstellar gas dominated by hydrogen. During contraction and adiabatic heating, increasing stellar energy production by nuclear fusion of hydrogen into helium eventually terminates gravitational contraction (e.g., Haxton et al., 2013). Over millions of years, helium produced by fusion of hydrogen accumulates in the cores of stars and increases core density, causing gravitational contraction and adiabatic heating which, in turn, raise fusion rates and energy generation. This process occurs gradually and continuously, resulting in increasing core temperature and total luminosity (Fig. 1) (Bahcall et al., 2001). The Sun began with ~71% hydrogen

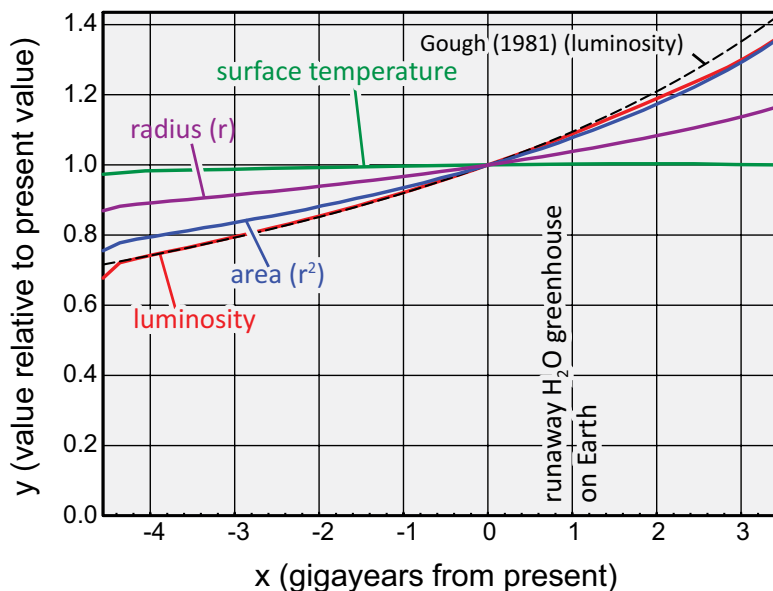
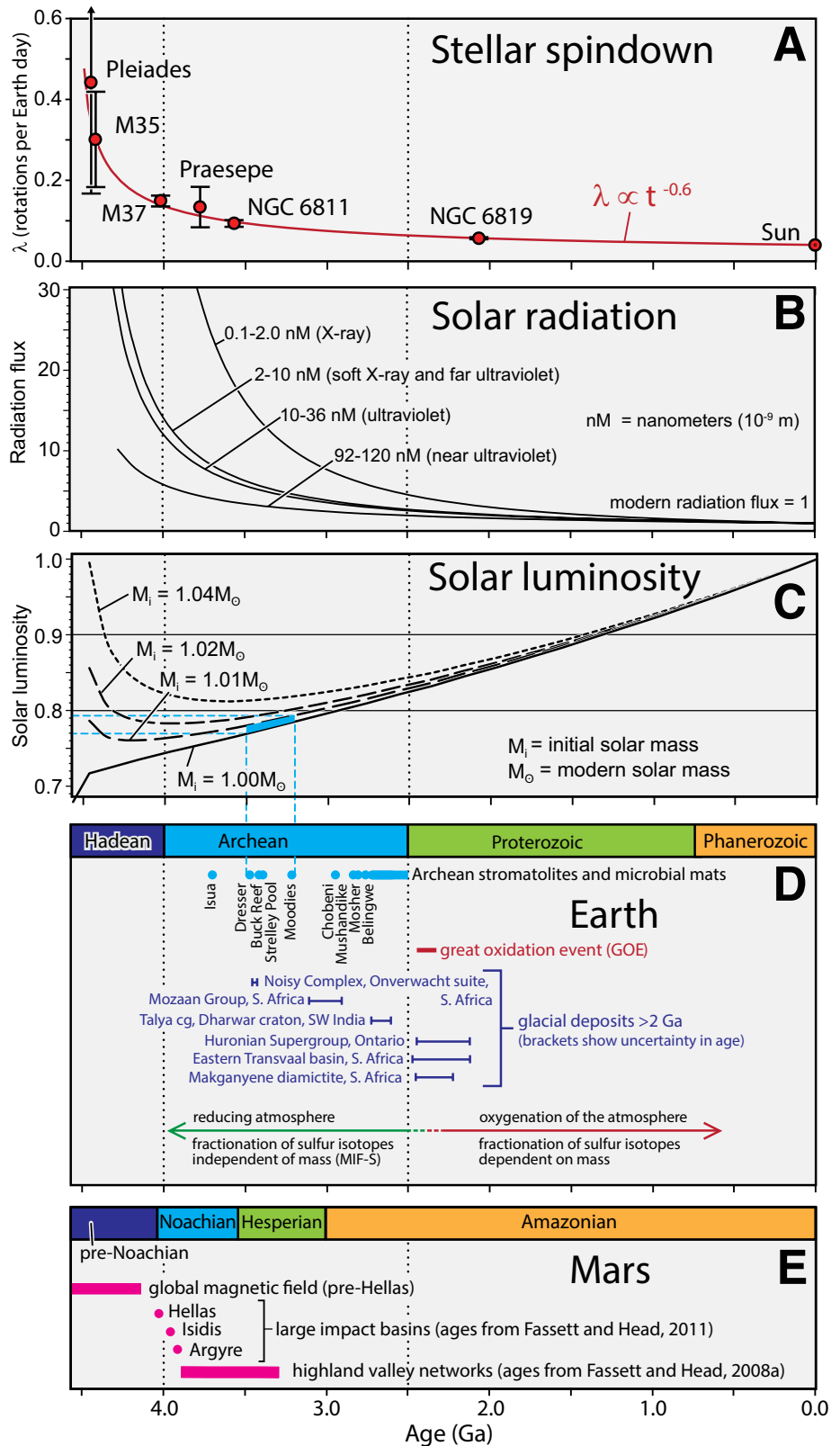


Figure 1. Evolution of solar properties (from Bahcall et al., 2001). A simple approximation of solar-luminosity evolution (Equation 1 of Gough, 1981) is also shown.

Figure 2. Known or hypothetical evolution of the Sun, Earth, and Mars. (A) Star clusters, each containing stars of similar age, are plotted against rotation rate (Rebull et al., 2016, 2017; Meibom et al., 2009, 2011, 2015; Hartman et al., 2009). These are plotted as proxies for solar evolution, so cluster age on the horizontal axis is plotted as distance from the left edge of the graph rather than the right edge. Curve showing approximate spindown rate is from Ayres (1997; t = time since cluster birth). (B) Ultraviolet and X-ray radiation fluxes inferred for the Sun over time based on measured fluxes from nearby stars with approximate solar mass but different ages (modified from Figure 8 of Ribas et al., 2005). Current radiation flux = 1. (C) Evolution of solar luminosity for initial solar mass equal to, or slightly greater than, modern solar mass. The rate of mass loss is shown as proportional to the rate of spindown of solar type stars as shown in (A). Current luminosity = 1.0. Blue area at 3.2–3.5 Ga represents calculated luminosity (~77%–79% of modern) at the time of deposition of four stromatolite and microbial mat fossil units in northwest Australia and South Africa. (D) Some events in Earth history that reflect climate and atmospheric composition, including ages and names of Archean stromatolite and microbial mat deposits older than ca. 2.7 Ga and ages and names of glacial deposits older than ca. 2.0 Ga. Archean glacial deposits from Young et al. (1998; Mozaan), Ojakangas et al. (2014; Talya), and de Wit and Furnes (2016; Noisy) (cg—conglomerate). (E) Some events in Mars history. Pre-Noachian magnetization of the martian crust ended before formation of the Hellas impact basin. Noachian to early Hesperian highland valley networks formed after the large impact basins.



in its core and now has ~34%. The core will continue to contract, while the convecting outer layer will expand due to greater energy output from the core.

A BRIGHT YOUNG SUN?

Difficulties in identifying the causes of warm climates on young Earth and Mars provoked consideration of a more massive and therefore more luminous young Sun. Specifically, if the Sun was 4%–5% more massive at its birth, before blowing off mass as solar wind and coronal mass ejections, it could have provided elevated luminosity to warm the young planets to approximately modern temperatures (Fig. 2C) (Whitmire et al., 1995; Sackmann and Boothroyd, 2003). This is plausible because stellar luminosity is very sensitive to stellar mass. For a roughly solar-mass star, absolute luminosity scales to almost the fifth power of solar mass, while the greater gravitational attraction of a more massive star reduces orbital radius proportional to mass. These factors together result in insolation at Earth and Mars that scales to almost the seventh power of solar mass such that a 1% greater solar mass would result in ~7% greater insolation for orbiting planets

(1.01 raised to the 6.75 power ≈ 1.07 ; Minton and Malhotra, 2007).

The angular momentum of spinning stars is gradually carried away by stellar winds. This is effective because rotating

stellar magnetic fields sweep through stellar winds and accelerate the winds circumferentially, thereby flinging the winds away and transferring angular momentum from the star to the wind.

Loss of angular momentum is more effective when stars spin faster, because magnetic fields are generally stronger and sweep through stellar winds faster, and because coronal mass ejections are more common (e.g., Gallet and Bouvier, 2015).

Studies of star populations in clusters in which all the stars have similar age indicate that most stellar spindown, and by inference mass loss, occurs during the first few hundred million years of a star's life (Fig. 2A) (Skumanich, 1972; Ayres, 1997). This interpretation was strengthened by recent studies using data from the Kepler planet-finder satellite mission (active 2009–2018). The Kepler telescope was designed to detect changes in stellar luminosity resulting from passage of planets in front of stars but also identified luminosity variations due to transit of starspots on stellar surfaces. This allowed determination of rotation periods for thousands of stars and accurate representation of stellar spindown rates (Fig. 2A) (Meibom et al., 2011, 2015; Rebull et al., 2017). It appears from these studies that, if the Sun did have greater mass during its youth, it would have lost most of that additional mass during rapid spindown before deposition of Archean algal stromatolites on Earth and Noachian river-channel incision and lake-delta deposition on Mars (Figs. 2C–2E).

SOLAR RADIATION OVER TIME

Short-wavelength solar radiation was stronger during the Sun's youth, which further complicates warming scenarios because some greenhouse gases such as methane are readily photolyzed (broken down) by such radiation or by free radicals produced by photolysis of other gases (Catling and Kasting, 2017). Six nearby stars similar in mass to the Sun, but with a range of ages, were identified by Ribas et al. (2005) and used to estimate radiation characteristics of the Sun over time (Fig. 2B). Short-wavelength radiation, especially far ultraviolet and X-ray, is significantly more intense for younger stars because their faster rotation rate increases the accumulation of magnetic-field energy in stellar envelopes, which in turn results in greater short-wavelength radiation from stellar surfaces and coronae.

EARTH

Solar luminosity is calculated to have been ~77%–79% of its current value at 3.2–3.5 Ga, when at least four different

rock units were deposited during open-water, probably sunlit conditions (Figs. 2C and 2D). If Earth absorbed and retained solar energy with modern effectiveness, water at ancient Earth's surface would have been largely if not entirely frozen during this time, except where heated by magmatic and hydrothermal activity or beneath hundreds to thousands of meters of ice. Geologic evidence of ancient warm conditions is outlined below, followed by possible explanations for effective surface warming with a faint young Sun.

Archean strata deposited in shallow water with evidence of sunlit conditions indicate surface temperatures above freezing. These rock units include calcareous and siliceous strata interpreted as fossil microbial mats and mound-forming algal stromatolites that harbored, or were produced by, photosynthetic bacteria (e.g., Grotzinger and Knoll, 1999; Noffke, 2008; Tice et al., 2011). One of the oldest examples of aquatic microbial life is the 3.42 Ga Buck Reef Chert in South Africa, which contains carbonaceous layers, filaments, and grains deposited within fine-grained, wave-agitated, siliceous sediments (Tice and Lowe, 2004) (Fig. 2D). The 3.35–3.43 Ga Strelley Pool Formation in the Pilbara Supergroup of northwestern Australia (Wacey et al., 2010) contains abundant evidence of microbial biofilms that precipitated carbonate and/or trapped fine detrital grains to form laminated stromatolites (Allwood et al., 2009; Wacey, 2010; Duda et al., 2016). Multiple associated sedimentary features in the Strelley Pool Formation, including rare desiccation cracks, indicate deposition in shallow-water, tidally affected, marine environments (e.g., Allwood et al., 2006). Fossil microbial mats and stromatolites resemble much younger and modern microbial mats, photosynthetic stromatolites, and cyanobacterial mounds (Suosaari et al., 2016).

The abundance of sedimentary and fossil indicators of liquid water at Earth's surface during the Archean indicates the effectiveness of warming mechanisms that are still not well understood. CO₂ and N₂ were likely the dominant atmospheric gases (Kasting, 2014; Catling and Kasting, 2017). The absence of significant O₂ in Earth's Archean atmosphere is indicated by unoxidized detrital sulfides and uraninite in Archean fluvial sediments (Rasmussen and Buick, 1999; Burrton et

al., 2018) and by sulfur isotopes in sedimentary rocks that were fractionated independent of mass by ultraviolet photolysis of SO₂ in an anoxic atmosphere (Farquhar and Wing, 2003; Claire et al., 2014; Dauphas and Schauble, 2016). CH₄ and H₂ are potential greenhouse gases but would be slowly oxidized in such an atmosphere due to various reactions involving H₂O and CO₂ that are triggered by ultraviolet radiation, a process that would be more effective with more intense short-wavelength radiation in the Archean (Pavlov et al., 2001; Catling and Kasting, 2017). Methane could have been an important greenhouse gas, however, if methane-generating bacteria were abundant and if bacterial growth was not inhibited by cooling due to sunlight-shielding organic haze produced by photochemical reactions involving CH₄ and CO₂ (Domagal-Goldman et al., 2008). Effective warming by reducing greenhouse gases is suggested by the coincidence of earliest Proterozoic glaciations with the great oxidation event ("GOE") of Earth's atmosphere (Holland, 2006) (Fig. 2D). The GOE would have destroyed atmospheric CH₄ and H₂, thereby causing the temperature drop (Pavlov et al., 2000; Haqq-Misra et al., 2008).

Three-dimensional climate models of Archean Earth's atmosphere have been used to evaluate the effectiveness of several atmospheric variables that are important for a warm climate, including CO₂, CH₄, and H₂ concentration, absolute pressure, and abundance of cloud-condensation nuclei. Warm, open-water conditions not unlike modern conditions were calculated for a 1-bar atmosphere with 1% CO₂ and 0.2% CH₄ at 2.5 Ga (Charnay et al., 2013); 1.2% CO₂ and 0.1% CH₄ at 3.5 Ga (Le Hir et al., 2014); and 0.1–0.36 bar CO₂ partial pressure with 1 bar N₂ at 3.8 Ga (Charnay et al., 2017). A variety of other factors influence global temperature, including sea-ice dynamics and the abundance of cloud-droplet condensation nuclei. Appropriate values of multiple variables appear to be capable of warming Archean Earth to approximately modern temperatures, but the relative significance of these factors in supporting warm conditions under a faint young Sun has not been clearly identified.

MARS

The heavily cratered Noachian highlands of equatorial and southern Mars,

which are the oldest exposed part of the martian crust, contain abundant evidence of erosion by water. Mars is freezing cold now and, with similar surface and atmospheric conditions, should have been even colder at 3–4 Ga. Some drainages are thousands of kilometers long and were fed by numerous tributaries that reached drainage divides in headwater regions (Howard et al., 2005; Hynek et al., 2010). Many rivers flowed into or through crater lakes, and some left delta deposits (Irwin et al., 2005; Fassett and Head, 2008b; Goudge et al., 2016). Calculations based on canyon width and depth indicate that canyons reflect $\sim 10^3$ – 10^7 years of erosion and were not incised by catastrophic outflows (Barnhart et al., 2009; Hoke et al., 2011; Rosenberg and Head, 2015). Precipitation, drainage incision, and crater-lake filling are inferred at ca. 3.3–3.9 Ga based on crater density in affected terrains (Fassett and Head, 2008a; Hoke and Hynek, 2009) (Fig. 2E).

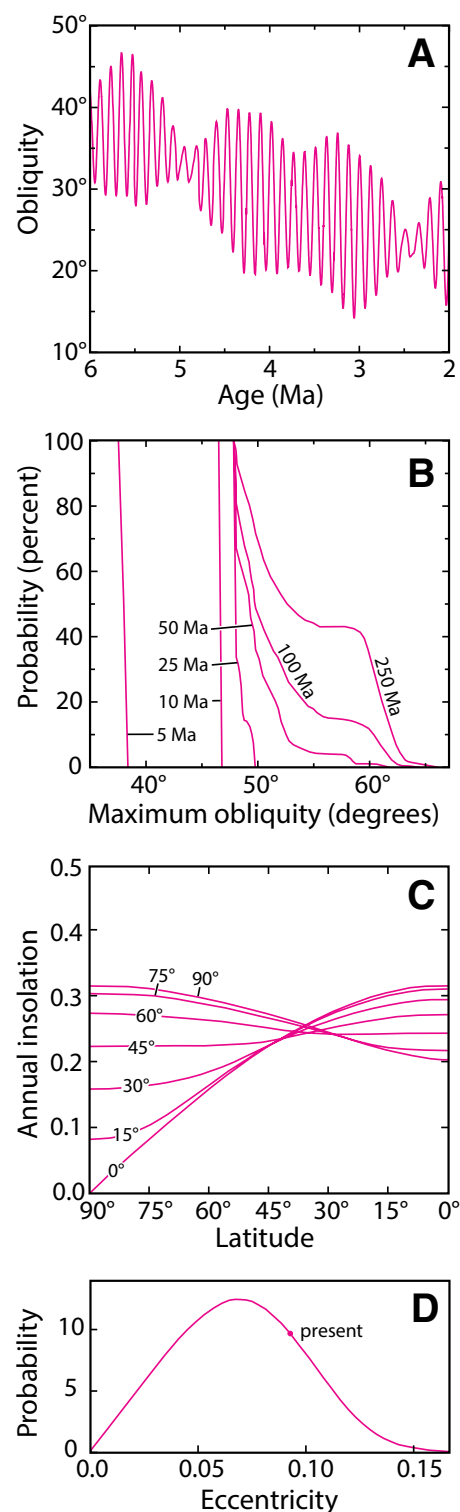
Several factors would have supported warmer Noachian environmental conditions, although maybe not enough for precipitation and flowing water. The pressure of the modern martian atmosphere, at 6–10 millibars, is $\sim 1\%$ that of Earth, but the ancient atmosphere was much thicker. The size and abundance of the smallest martian impact craters can be used to determine atmospheric pressure because the smallest meteorites are slowed or destroyed during passage through the atmosphere and so do not create impact craters. Size-frequency distributions for craters in fluvial deposits near Gale crater indicate that Noachian atmospheric pressure was in the range of ~ 1 – 2 bars during heavy Noachian bombardment (Kite et al., 2014). Atmospheric pressure greater than a few hundred millibars results in a vertical temperature profile that approximates an adiabatic gradient (Wordsworth, 2016). Under such conditions, surface temperatures are lower at higher elevation, with potential accumulation of snow and ice at high elevations. Even if the atmosphere was pure CO_2 , however, this would not be adequate to warm early Mars to the point of supporting running water, especially in highland regions (Kasting, 1991; Forget et al., 2012).

Orbital factors relevant to early Mars climate are the variable tilt of its spin axis relative to the normal to the orbital plane (the obliquity) and the variable eccentricity (ellipticity) of the orbit. Earth's

Figure 3. (A) Obliquity of Mars at 2–6 Ma as calculated by Touma and Wisdom (1993). Note that obliquity exceeded 40° at 5–6 Ma. (B) Probability of reaching high obliquities during the chaotic obliquity evolution of Mars over a range of time periods, with initial 25° obliquity (from Laskar et al., 2004). (C) Total annual insolation versus latitude for obliquity variation of 0° – 90° . Insolation units are relative to the solar constant at 1.52 AU (from Ward, 1974). (D) Normalized density function for chaotic eccentricity variation for Mars (from Figure 18d of Laskar et al., 2004). At present eccentricity, solar insolation at perihelion (orbital point closest to the Sun) is 45% greater than at aphelion.

obliquity is currently 23° , but because of stabilizing tidal forces associated with the Moon, obliquity varies over geologic time by $\pm 2^\circ$ (Laskar et al., 1993). Mars, with current obliquity of 25° , does not have a massive moon, and its obliquity is not similarly stabilized. Because of tidal forces exerted on Mars by the Sun and planets, obliquity varied chaotically over millions of years to $>60^\circ$ (Figs. 3A and 3B) (Touma and Wisdom, 1993; Laskar et al., 2004). At obliquities $>>45^\circ$, polar regions receive more sunlight than equatorial regions, potentially resulting in seasonal sublimation and evaporation at high latitudes and snow at low latitudes at times near summer solstices (Fig. 3C) (Ward, 1974; Jakosky and Carr, 1985; Wordsworth, 2016). High-latitude evaporation would be especially effective if the summer solstice coincided with greater proximity to the Sun during a period of high orbital eccentricity, which also varies chaotically (Fig. 3D).

Favorable obliquity and eccentricity, and a thick CO_2 atmosphere, may have been adequate for evaporation and sublimation of ice at low elevations and accumulation of snow and ice at high elevations, but warmer conditions are needed to melt snow and ice at high elevations and produce runoff to carve river valleys and fill lakes in the Noachian highlands (Forget et al., 2012). Global climate models indicate that 1%–10% hydrogen and methane in a thick CO_2 atmosphere could have elevated temperatures sufficiently to melt ice at high elevations (Wordsworth et al., 2017). These reduced gases are highly effective at absorbing infrared radiation that would otherwise leave the planet because of a process called “collision-induced absorption.” In this process, extremely brief ($\sim 10^{-13}$ s) electrostatic interactions between colliding gas molecules (CO_2 - H_2 and CO_2 - CH_4 in this case)



produce a weak bond in which the two gas molecules can absorb infrared radiation that would not be absorbed by the individual gas molecules. Collision-induced absorption with these gases can potentially produce an early Mars atmosphere warm enough to cause melting and

runoff from frozen martian highlands (Wordsworth et al., 2017).

Multispectral imaging, lander observations, and the content of meteorites derived from Mars indicate that olivine is common on Mars (e.g., McSween et al., 2006; Koeppen and Hamilton, 2008; Ody et al., 2013). Hydrous alteration (serpentinization) of olivine and pyroxene by groundwater should have been common if not pervasive early in martian history (Oze and Sharma, 2005, 2007). Serpentinization yields H_2 , which in turn reacts with CO_2 to produce CH_4 , as is seen in hydrothermal fluids associated with ultramafic rocks on Earth (Bradley and Summons, 2010). Cooling of the young martian crust in the presence of groundwater would result in formation of a near-surface cryosphere of frozen groundwater. Downward propagation of the boundary between frozen ground and deeper groundwater would trap dissolved methane in methane clathrate, which is water ice with ~6% methane trapped within the cage-like molecular structure of the clathrate ice (e.g., Kvenvolden, 1993; Prieto-Ballesteros et al., 2006). As a result of clathrate genesis, the early martian cryosphere could have become a global methane reservoir (Lasue et al., 2015). Furthermore, the cryosphere would become an impermeable cap for trapped gaseous H_2 and CH_4 , as on Earth (Kvenvolden, 1993).

Methane and hydrogen liberated to the atmosphere by cryosphere disruption and melting from magmatism, impacts, and perhaps outburst floods, would result in minor to perhaps significant transient planetary warming. Such warming might have been sufficient to cause snow and ice melting and runoff from Noachian highlands for perhaps tens to hundreds of thousands of years (Chassefière et al., 2016; Wordsworth et al., 2017), especially if it occurred during favorable orbital parameters (Palumbo et al., 2018). Such warming could melt more methane clathrate in a positive feedback cycle (Wordsworth et al., 2017). Finally, the 10^5 – 10^7 years needed for river valley incision was perhaps the cumulative result of numerous short-lived warming episodes, each triggered by a different geologic event over hundreds of millions of years. It remains uncertain, however, if all these factors are adequate for melting and river-valley incision on Mars.

CONCLUSIONS

1. Total solar-energy production is increasing gradually due to well-understood physics controlling rates of thermonuclear fusion in the solar core (Bahcall et al., 2001). A more massive and luminous young Sun is not supported by recent astrophysical studies.
2. Archean sedimentary rocks on Earth include many indicators of liquid water at Earth's surface, including sedimentary rocks containing evidence of microbial life that in turn indicate open water with sunlight. The warm Archean Earth resulted from high atmospheric concentrations of CO_2 , with possible additional warming from methane and hydrogen, lower cloud albedo, a low ratio of land to water at Earth's surface, and other factors. It is not clear which additional factors were dominant or if we are missing something fundamental.
3. Abundant evidence of martian river channels and crater lakes at ca. 3.3–3.9 Ga indicates warm conditions in otherwise icy highlands of equatorial and southern Mars. Although transient melting might occur under favorable orbital parameters, augmentation of such warming by a few percent atmospheric H_2 and CH_4 released from crustal or mantle reservoirs may be a viable solution to the faint young Sun problem for Mars.

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TOOLS FIELD

Geologist's Wish List



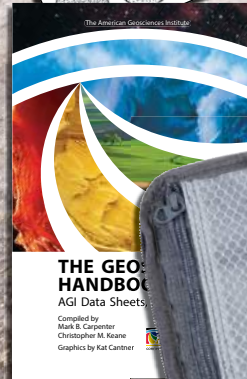
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Questions? Contact Jennifer Nocerino, jnocerino@geosociety.org.



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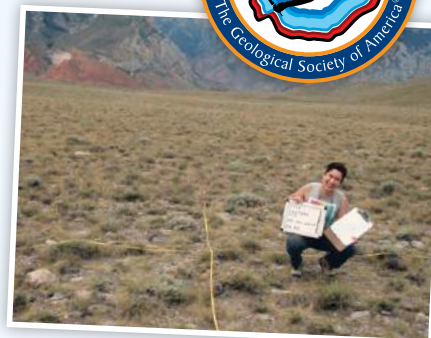
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Why GSA Membership Is Important to Me

GSA has afforded me many opportunities, including research funding, leadership experience, and the ability to network with outstanding professionals in my research areas.

I became a GSA member when I started graduate school and initially attended the conference to give presentations about my research. Everyone I met was extremely supportive and it was especially exciting for me to meet the geoscience education research community that is thriving within GSA. The ability to meet the faculty doing the type of research I wanted to pursue was very inspiring and motivated me to join the Geoscience Education Division board as a graduate student representative. This experience drew me further into the GSA community and has helped me overcome the incessant feelings of imposter syndrome as I now have faculty members from all over the country within my personal support network!

GSA has also been a place where the many geoscientists I have met from around the world regularly gather to share our science. It's very exciting to know that we are part of a much larger community, and it is gratifying to find the connections between our different disciplines as well as to see the value in each other's work.

Darryl Reano

Postdoctoral Associate
STEM Transformation Institute
Florida International University



“GSA has also been a place where the many geoscientists I have met from around the world regularly gather to share our science. It's very exciting to know that we are part of a much larger community.”

–Darryl Reano, GSA member since 2006



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2020 GSA Section Meetings



South-Central

9–10 March
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
Reston, Virginia, USA
Chairs: Arthur Merschat, amerschat@usgs.gov; Patrick Burkhardt, patrick.burkhardt@sru.edu
www.geosociety.org/se-mtg

Great Falls Park. Photo by Visit Fairfax.



Rocky Mountain

4–5 May
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
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, Minnesota, USA
Chair: Karen Gran, kgran@d.umn.edu
www.geosociety.org/nc-mtg

Aerial Lift Bridge at sunrise. Photo by Visit Duluth.

North-Central Section

54th Annual Meeting of the North-Central Section, GSA
Duluth, Minnesota, USA

18–19 May 2020

www.geosociety.org/nc-mtg



LOCATION

We are excited to bring the GSA 2020 North-Central Section Annual Meeting up north to Duluth, Minnesota, USA. Perched on the western tip of Lake Superior, Duluth offers unparalleled beauty and natural amenities. The meeting will be held at the Duluth Entertainment Convention Center (DECC), within walking distance of Canal Park and downtown Duluth. Geologic highlights range from the Precambrian Duluth Complex and Midcontinent Rift rocks to Lake Superior with its coastal dunes and seacliffs. Come north for a geologic adventure!

CALL FOR PAPERS

Abstracts deadline: 18 Feb.

Submit online at www.geosociety.org/nc-mtg

Abstract submission fee: US\$18 for students and US\$30 for all others. If you cannot submit an abstract online, please contact Heather Clark, +1-303-357-1018, hclark@geosociety.org.

TECHNICAL PROGRAM

- T1. **Insights into Processes of Proterozoic Crustal Growth, Modification, and Stabilization in the North-Central U.S. Continental Interior.** Daniel Holm, Kent State University, dholm@kent.edu; David Malone, Illinois State; John Craddock, Macalester.
- T2. **Intrusive Rocks of the Midcontinent Rift.** Joshua Feinberg, University of Minnesota Twin Cities, feinberg@umn.edu; Nicholas Swanson-Hysell, University of California Berkeley; Mark Severson, University of Minnesota Duluth Natural Resources Research Institute.
- T3. **Precambrian Geology of the Lake Superior Region.** Robert Lodge, University of Wisconsin–Eau Claire, lodgerw@uwec.edu; Mark Jirsa, Minnesota Geological Survey.
- T4. **Petrology, Mineralogy, and High-Temperature Geochemistry.** Fred Davis, University of Minnesota Duluth, fdavis@d.umn.edu.
- T5. **Novel Approaches to Studying Earth's Earliest Terrestrial Ecosystems: From Biogeochemistry to Astrobiology.** Erik Gulbranson, Gustavus Adolphus College, erikgulbranson@gustavus.edu; Rebecca Dzombak, University of Michigan; Nathan Sheldon, University of Michigan.
- T6. **Deciphering the Record of Lake Superior Iron Formations.** Athena Eyster, Massachusetts Institute of Technology, aeyster@mit.edu; Latisha Brengman, University of Minnesota Duluth; Chad Wittkop, Minnesota State University.
- T7. **Midcontinent Meteorite Impact Structures: Surficial and Subsurface Evidence of Deformation and Shock Metamorphism.** Ryan Clark, Iowa Geological Survey, ryan-j-clark@uiowa.edu; Kevin Ray Evans, Missouri State University.
- T8. **Structural Geology and Tectonics.** Melissa Lamb, University of St. Thomas, malamb@stthomas.edu.
- T9. **Paleontology of the Upper Midwest: Glimpses into Five Seashores.** John Westgaard, Science Museum of Minnesota, jwestgaard@smm.org; Kenneth C. Gass, independent researcher; Alex Hastings, Science Museum of Minnesota; Douglas Hanks, Science Museum of Minnesota and Minnesota Discovery Center.
- T10. **Pre-Wisconsin Episode Records in the Midcontinent.** *Cosponsored by GSA Quaternary Geology and Geomorphology Division.* Peter Jacobs, University of Wisconsin–Whitewater, jacobsp@uww.edu; Henry Loope, Indiana Geological and Water Survey; Jose Luis Antinao Rojas, Indiana Geological and Water Survey; Andrew Phillips, Illinois State Geological Survey.
- T11. **Glaciation and Deglaciation along the Southern Margin of the Laurentide Ice Sheet: Bringing Multiple Tools to Bear.** *Cosponsored by GSA Quaternary Geology and Geomorphology Division.* Jennifer McDonald, Minnesota Geological Survey, jmhorton@umn.edu; David Ullman, Northland College; Kenneth Lepper, North Dakota State University.
- T12. **All Things Aeolian.** *Cosponsored by GSA Quaternary Geology and Geomorphology Division.* Phillip Larson, Minnesota State University Mankato, phillip.larson@mnsu.edu; Randall Schaeztl, Michigan State University; Garry Running, University of Wisconsin–Eau Claire.
- T13. **Geoarchaeology: Exploring the Connections between Humanity and Geology.** Michele D. Stillinger, University of St. Thomas, mdstillinger@stthomas.edu.

- T14. **Magnetism from the Infinitesimal to the Planetesimal.** Michele D. Stillinger, University of St. Thomas, mdstillinger@stthomas.edu; Joshua M. Feinberg, University of Minnesota Institute for Rock Magnetism.
- T15. **Geophysical Studies in the Midcontinent of North America.** *Cosponsored by GSA Geophysics and Geodynamics Division.* Kevin Mickus, Missouri State University, kevinmickus@missouristate.edu.
- T16. **Subsurface Imaging within the Geosciences.** Harry Jol, University of Wisconsin–Eau Claire, jolhm@uwec.edu.
- T17. **Geochemical Cycling of Environmentally Relevant Elements.** Cara M. Santelli, University of Minnesota Department of Earth Sciences, BioTechnology Institute & MnDRIVE, santelli@umn.edu; Tingying Xu, University of Minnesota Department of Earth Sciences, BioTechnology Institute & MnDRIVE; Jacqueline Mejia, University of Minnesota Department of Earth Sciences, BioTechnology Institute & MnDRIVE.
- T18. **It's a Small (Microbial) World.** Elizabeth Swanner, Iowa State University, eswanner@iastate.edu; Jeff Havig, University of Minnesota Twin Cities; Cody Sheik, University of Minnesota Duluth.
- T19. **Applications of 3D Modeling Using Structure from Motion or Terrestrial Laser Scanning.** Stephanie S. Day, North Dakota State University, stephanie.day@ndsu.edu; Zachary Phillips, North Dakota State University.
- T20. **River Restoration Strategies in a Changing Climate.** *Cosponsored by GSA Quaternary Geology and Geomorphology Division.* Marty Melchior, Inter-Fluve, mmelchior@interfluve.com; Faith Fitzpatrick, U.S. Geological Survey.
- T21. **Flash Floods, Landslides, and Debris Flows in the Midcontinent.** *Cosponsored by GSA Quaternary Geology and Geomorphology Division.* Carrie E. Jennings, Freshwater Society, cjennings@freshwater.org; Karen Gran, University of Minnesota Duluth; Thomas Oommen, Michigan Technological University.
- T22. **Drainage Basin Evolution, Fluvial Geomorphology, and Fluvial Processes of the Great Plains, Great Lakes, and Upper Mississippi River Basin.** *Cosponsored by GSA Quaternary Geology and Geomorphology Division.* Phillip Larson, Minnesota State University Mankato, phillip.larson@mnsu.edu; Andrew Wickert, University of Minnesota; Douglas Faulkner, University of Wisconsin–Eau Claire.
- T23. **Cores to Drones: Understanding Shoreline Behavior, Processes, and Coastal Landscape Changes in the Great Lakes.** *Cosponsored by GSA Quaternary Geology and Geomorphology Division.* Erin P. Argyilan, Indiana University Northwest, eargyila@iun.edu; John Johnston, University of Waterloo; Todd A. Thompson, Indiana Geological Survey.
- T24. **Lakes as Sentinels of Environmental Change.** Byron A. Steinman, University of Minnesota Duluth, bsteinma@d.umn.edu; Kathryn M. Schreiner, University of Minnesota Duluth; Matthew Finkenbinder, Wilkes University.
- T25. **Land-Lake Connections: The Importance of Hydrologic Processes on Aquatic Ecosystems.** Christopher T. Filstrup, University of Minnesota Duluth, filstrup@d.umn.edu, John A. Downing, University of Minnesota Duluth.
- T26. **Groundwater Quality Degradation and Protection: Water Quality Assessment, Modeling and Uncertainty Analysis, and Water Supply Management.** *Cosponsored by Minnesota Ground Water Association.* Melinda L. Erickson, U.S. Geological Survey, merickso@usgs.gov; Katherine S. Pound, St. Cloud State University and Minnesota Ground Water Association; William W. Simpkins, Iowa State University.
- T27. **The Hydrogeology of Fracture and Karst Bedrock Aquifers.** E. Calvin Alexander Jr., University of Minnesota, alexa001@umn.edu; Anthony Runkel, Minnesota Geological Survey.
- T28. **Caves and Karst of the Midwest.** *Cosponsored by GSA Karst Division.* Erik Larson, Shawnee State University, elarson@shawnee.edu; Maurice Testa, University of Arkansas–Fort Smith.
- T29. **Addressing Habitat, Water, Ecosystem, and Sustainability Issues through Interdisciplinary Work.** *Cosponsored by GSA Geobiology and Geomicrobiology Division; GSA Hydrogeology Division; GSA Environmental and Engineering Geology Division; GSA Soils and Soil Processes Division.* Lisa Lamb, University of St. Thomas, malamb@stthomas.edu; Scott Clark, University of Wisconsin–Eau Claire; Richard Kiesling, U.S. Geological Survey; Eric Chapman, University of St. Thomas.
- T30. **Nutrient and Sediment Loading in Freshwater Systems: Sources, Fate, Transport, and Strategies for Mitigation.** Sarah Vitale, University of Wisconsin–Eau Claire, vitalesa@uwec.edu; Anna Baker, U.S. Geological Survey.
- T31. **Preventing, Responding to, and Understanding the Long-Term Behavior of Crude Oil and Petroleum in Terrestrial and Aquatic Environments.** Jared Trost, U.S. Geological Survey, jtrost@usgs.gov; Mark Toso, Minnesota Pollution Control Agency; Faith Fitzpatrick, U.S. Geological Survey.
- T32. **Unique Geology and Geoheritage of the Lake Superior Region.** Erika Vye, Michigan Technological University, ecvy@mtu.edu; William I. Rose, Michigan Technological University; Jim Miller; James M. DeGraff, Michigan Technological University.
- T33. **Highlighting Indigenous-Centered Geoscience Research and Education.** Wendy Smythe, University of Minnesota Duluth, wsmythe@d.umn.edu; Christie Poitra, Michigan

State University, Native American Institute; Judi Brown Clarke, Michigan State University, BEACON Center.

- T34. **Strategies to Address Barriers to Learning in Classroom, Lab, and/or Field.** Prajukti (Juk) Bhattacharyya, University of Wisconsin–Whitewater, bhatacj@uww.edu; Caitlin Callahan, Grand Valley State University.
- T35. **Encouraging New Scientists: What Works in STEM Recruitment and Retention.** *Cosponsored by GSA Geoscience Education Division; NAGT Geo2YC Division.* Joy Branlund, Southwestern Illinois College, joy.branlund@swic.edu; Sheldon Turner, Triton College.
- T36. **Teaching, Learning, and Research in Geoscience Education.** Kyle Gray, University of Northern Iowa, kyle.gray@uni.edu; Beth A. Johnson, University of Wisconsin–Oshkosh Fox Cities Campus.
- T37. **Undergraduate Research Poster Session.** *Cosponsored by Council on Undergraduate Research; GSA Geoscience Education Division.* Robert D. Shuster, University of Nebraska–Omaha, rshuster@unomaha.edu.

FIELD TRIPS

Registration opens in February. For additional information, please contact the field trip chair: Carrie Jennings, cjennings@freshwater.org.

Pre-Meeting

St. Louis River Sediment Remediation, Aquatic Habitat Restoration, and Harbor Tour. Ben Sheets, BSheets@barr.com, Barr Engineering.

Northern Minnesota Peatland and Soil Research Tour. Ed Nater, nater001@umn.edu; Kyungsoo Yoo, University of Minnesota; Stephen Sebestyen, U.S. Northern Forest Research Station.

The Sandstone Karst of Pine County, Minnesota. Calvin Alexander, University of Minnesota, alexa001@umn.edu; Greg Brick.

During the Meeting

Geology under the Surface: Lake Superior and the Research Vessel *Blue Heron*. Doug Ricketts, University of Minnesota Duluth, ricketts@d.umn.edu; Nigel Watrus, University of Minnesota Duluth.

Walking Tour of Minnesota Point. Harry Jol, jolhm@uwec.edu, University of Wisconsin–Eau Claire; Andy Breckenridge, University of Wisconsin–Superior.

Post-Meeting

Minnesota's Minerals, Mining, and the Environment of the Mesabi Iron Range. Megan Kelly, megan.j.kelly@state.mn.us; Heather Arends, MnDNR Lands and Minerals; Allyse Freeman,

Minnesota Discovery Center; John Westgaard, Science Museum of Minnesota.

Slope Stability, Extreme Floods, and Implications for Restoration in the Duluth Area. Emilie Richard, rich1726@d.umn.edu; Karen Gran, University of Minnesota Duluth; Faith Fitzpatrick, U.S. Geological Survey; Marty Melchoir, Inter-Fluve.

Geologic Setting of the 1850 Ma Sudbury Meteorite Impact Layer on the Gunflint Trail, Northeastern Minnesota. Mark Jirsa, Minnesota Geological Survey, jirsa001@umn.edu.

Duluth to Two Harbors—Transect through the Duluth Complex and Base of the North Shore Volcanic Group.

Jim Miller, emeritus, University of Minnesota Duluth, mille066@d.umn.edu; Terry Boerboom, Minnesota Geological Survey.

Sediments, Landforms, and Proglacial Lake History in Western St. Louis County, Minnesota.

Jennifer McDonald, University of Minnesota, jmhorton@umn.edu; Kaleb Wagner, Minnesota Geological Survey; Andy Breckenridge, University of Wisconsin–Superior.

SHORT COURSES

Registration opens in February. For additional information, please contact the short course chair: Josh Feinberg, feinberg@umn.edu.

Navigating the Path to Professional Licensure. Keith B. Rapp, AELSLAGID Geoscience Board Member, kbrapp@comcast.net.

3D Modeling Using Structure from Motion and Terrestrial Laser Scanning. Stephanie S. Day, North Dakota State University, stephanie.day@ndsu.edu; Zachary Phillips, North Dakota State University.

Programming IoT Monitoring Stations Built on the Arduino Framework with the EnviroDIY ModularSensor Library. Beth A. Fisher, Minnesota State University Mankato, beth.fisher@mnsu.edu; Anthony K. Aufdenkampe, LimnoTech.

Professional Ethics for Engineers and Geologists (2 PDH). Karl D. Everett, KEA Associates, karl_everett@q.com.

Ground-Penetrating Radar for the Geosciences. Harry Jol, University of Wisconsin–Eau Claire, jolhm@uwec.edu.

Workflow for Unmanned Aerial Systems. Scott M. Galetka, Bayfield County, sgaletka@bayfieldcounty.org; Martin Goettl, University of Wisconsin–Eau Claire.

REGISTRATION

Early registration deadline: 13 April

Cancellation deadline: 20 April

Registration opens in February. For further information or if you need special accommodations, please contact one of the general co-chairs: Karen Gran, kgran@d.umn.edu, or Harry Jol, jolhm@uwec.edu.

ACCOMMODATIONS

Hotel registration deadline: 27 April

A block of rooms has been reserved at the Canal Park Lodge (+1-218-279-6000), which is a few blocks from the Duluth Entertainment Convention Center (DECC), where the meeting will be held, for US\$119/room, and at the Holiday Inn & Suites (+1-218-722-1202) in downtown Duluth for US\$114/room. The Holiday Inn is connected to the DECC via the downtown skyway system. **Please call hotels directly and reference the group code of NCGSA20 when reserving a room.** Dormitory rooms are also available at the University of Minnesota Duluth and can be reserved online. Information and reservations are available at <https://forms.gle/95vF2LSh3kEszLVz9>. UMD is a 10-minute drive or 30-minute bus ride (DTA) from the DECC.

OPPORTUNITIES FOR STUDENTS AND EARLY CAREER PROFESSIONALS

Career Mentoring Luncheons

Ask your career-related questions and learn about non-academic pathways in the geosciences while networking with professionals at the Roy J. Shlemon and John Mann Mentor Luncheons. Students and early career professionals are welcome.

Career Workshop Series

This three-part series will feature career development planning, an exploration of geoscience job sectors, and information on best practices for crafting a résumé and cover letter. Non-technical skills and workforce statistics will be reviewed. The series will be led by workshop presenters and geoscientists. No registration is required, and everyone is welcome.

Learn more at www.geosociety.org/mentors/. Questions? Contact Jennifer Nocerino at jnocerino@geosociety.org.

Presentation Awards

Awards for the best graduate and undergraduate student posters and papers are supported by the *GSA North-Central Section and by the Great Lakes Section–SEPM (Society for Sedimentary Geology)*.

Lightning Talks

Students, please join us for an informal lightning-talk session during the Icebreaker Reception on Sunday night, 17 May. Lightning talks provide an opportunity to draw people to your poster or talk, or just to sharpen your presentation skills. Lightning talks must be three minutes (or less), and the three-minute limit will be enforced. Speakers may include up to two slides in their presentation, not including a title slide. The session is a great opportunity to meet other students and learn about their research. Anyone may attend, but speakers must be undergraduate or graduate students. Indicate your interest in giving a lightning talk when you register for the meeting. If you have questions, please contact Collin Roland at cjroland@wisc.edu.

PROFESSIONALS

Interested in sharing information about your applied geoscience or hydrology career with students? Being a mentor is a rewarding experience. To learn more about serving as a mentor at North-Central GSA, contact Jennifer Nocerino at jnocerino@geosociety.org.

The North-Central Section Meeting also offers an excellent opportunity to earn CEUs toward your continuing education requirements for your employer, K–12 school, or professional registration. Please check the meeting website after the meeting to download your CEU certificate.

LOCAL COMMITTEE

Chair: Karen Gran, kgran@d.umn.edu

Vice-Chair: Harry Jol, jolhm@uwec.edu

Technical Program Chair: Chad Wittkop, chad.wittkop@mnsu.edu

Field Trip Chair: Carrie Jennings, cjennings@freshwater.org

Sponsorship Chair: Howard Mooers, hmoosers@d.umn.edu

Exhibits Chair: Erik Brown, etbrown@d.umn.edu

Student Programs/Student Volunteer Chair: Prajukti (Juk) Bhattacharyya, bhattachj@uww.edu

Treasurer: Doug Ricketts, ricketts@d.umn.edu

Short Course Chair: Josh Feinberg, feinberg@umn.edu

South-Central Section

54th Annual Meeting of the South-Central Section, GSA
Fort Worth, Texas, USA

9–10 March 2020

www.geosociety.org/sc-mtg



Fort Worth Stockyards. Photo by Visit Fort Worth.

LOCATION

The meeting will be held at the Fort Worth Convention Center, 1201 Houston Street, Fort Worth, TX 76102, USA. Visitors can experience the city's vibrant western heritage in the Stockyards National Historic District—complete with the world's only year-round rodeo, authentic saloons, and the world's largest honky-tonk. The renowned Cultural District, less than four miles away, is a haven for art enthusiasts and home to five internationally recognized museums plus the emerging art-filled Foundry District. Premier shopping, dining, and live entertainment continue in downtown Fort Worth, with more upscale finds at the new Shops at Clearfork. The Trinity River also provides outdoor activities like canoe and kayak tours, stand-up paddling, and 70+ miles of uninterrupted trails.

REGISTRATION

Early registration deadline: 3 Feb.

Cancellation deadline: 10 Feb.

REGISTRATION FEES (all fees are in U.S. dollars)

	Early		Standard	
	Full Mtg.	One Day	Full Mtg.	One day
Professional Member	\$175	\$130	\$235	\$185
Professional Member 70+	\$110	\$80	\$160	\$120
Professional Nonmember	\$200	\$150	\$260	\$200
Early Career Professional Member	\$125	\$90	\$180	\$130
Student Member	\$60	\$45	\$120	\$75
Student Nonmember	\$90	\$60	\$150	\$80
K–12 Professional	\$75	\$45	\$110	\$60
Guest or Spouse	\$50	n/a	\$60	n/a
Field Trip/Short Course Only	\$45	n/a	\$60	n/a

CALL FOR PAPERS

Abstract deadline: 3 Dec.

For additional information, please contact the Technical Program Co-chairs, Xiangyang Xie, x.xie@tcu.edu, and Arne Winguth, awinguth@uta.edu.

TECHNICAL PROGRAM

Theme Sessions

- T1. **Open Versus Closed Systems in Diagenesis and Hydrothermal Alteration.** R. Douglas Elmore, University of Oklahoma, delmore@ou.edu; Matt Hamilton, University of Oklahoma, Matt.Hamilton@ou.edu; Katie Garrett, University of Oklahoma, katie-garrett@ou.edu. Oral only.
- T2. **Recent Progress in the Southern Oklahoma Aulacogen.** Matt Hamilton, University of Oklahoma, matt.hamilton@ou.edu; R. Douglas Elmore, University of Oklahoma, delmore@ou.edu; Jonathan D. Price, Midwestern State University, jonathan.price@msutexas.edu. Oral only.
- T3. **Unresolved Issues in Integrating Pennsylvanian Stratigraphy, Depositional Systems, and Tectonics in the Eastern Shelf of the Permian Basin.** William A. Ambrose, Bureau of Economic Geology, william.ambrose@beg.utexas.edu; Tucker F. Hentz, Bureau of Economic Geology, tucker.hentz@beg.utexas.edu. Oral only.
- T4. **Geophysical Methods and Application.** Jingyi Chen, The University of Tulsa, jingyi-chen@utulsa.edu; Priyank Jaiswal, Oklahoma State University, priyank.jaiswal@okstate.edu; Michael Behm, University of Oklahoma, michael.behm@ou.edu. Oral only.
- T5. **Recent Advances in Geoscience Research of Northeastern Mexico.** Juan Alonso Ramirez-Fernandez, Universidad Autónoma de Nuevo Leon, alonso_fct@hotmail.com, juan.ramirezf@uanl.mx; Fernando Velasco-Tapia, Universidad Autónoma de Nuevo Leon, fernando.velascotp@uanl.edu.mx; Uwe Jenchen, Universidad Autónoma de Nuevo Leon, uwe.jenchen@gmail.com. Oral and poster.
- T6. **Integrating Earth Observations and Geospatial Data for Monitoring and Assessing Natural and Anthropogenic Hazards in the South-Central United States (Posters).** Esayas Gebremichael, Texas Christian University, e.gebremichael@tcu.edu. Posters only.
- T7. **The Age of American Wastelands: Carboniferous-to-Jurassic Stratigraphy, Sedimentology, and Paleoenvironments of North America.** Neil Tabor, Southern Methodist

- University, ntabor@smu.edu; John Holbrook, Texas Christian University, john.holbrook@tcu.edu. Oral and poster.
- T8. **Permian of the South-Central U.S.: Land and Sea.** Lowell Waite, The University of Texas at Dallas, lowell.waite@utdallas.edu; Alicia Bonar, University of Oklahoma, alicia.bonar@ou.edu; Lily Pfeifer, University of Oklahoma, lspfeifer@ou.edu; Robert J. Stern, The University of Texas at Dallas, rjstern@utdallas.edu. Oral and poster.
- T9. **Geophysics and Remote Sensing Applications in Tectonics and Geomorphology.** *Cosponsored by GSA Geophysics and Geodynamics Division.* Andrew Katumwehe, Midwestern State University, andrew.katumwehe@msutexas.edu; Luel Emishaw, Oklahoma State University, leulseg@ostateemail.okstate.edu; Kevin Mickus, Missouri State University, kevinmickus@missouristate.edu. Oral only.
- T10. **Dynamics in Fluvial Process—Landform Relationships across Environmental Gradients.** Peyton E. Lisenby, Midwestern State University, peyton.lisenby@msutexas.edu; Michael C. Slattery, Texas Christian University, m.slattery@tcu.edu. Oral only.
- T11. **Mass Extinction in Earth History: New Insights from Paleobiological, Geochemical, and Modeling Studies of Mass Extinction Events.** Arne Winguth, The University of Texas at Arlington, awinguth@uta.edu. Oral only.
- T12. **Structural Evolution and Sedimentation along the Western Gulf of Mexico Margin.** Timothy Lawton, The University of Texas at Austin, tim.lawton@beg.utexas.edu; Elisa Fitz-Díaz, Universidad Nacional Autónoma de México, elisaf@geologia.unam.mx; Daniel F. Stockli, The University of Texas at Austin, stockli@jsg.utexas.edu. Oral and poster.
- T13. **Sandstone Provenance Study and Its Implications.** Xiangyang Xie, Texas Christian University, x.xie@tcu.edu; Majie Fan, The University of Texas at Arlington, mfan@uta.edu. Oral and poster.
- T14. **Topics in Ichnology: A Session on All Things Related to Trace Fossils.** Patrick Getty, Collin College, pgetty@collin.edu; Stephen Hasiotis, University of Kansas, hasiotis@ku.edu. Oral only.
- T15. **Orogenesis and Global Change.** Guangsheng Zhuang, Louisiana State University, gzhuang@lsu.edu. Oral and poster.
- T16. **The Role of Geochronology in Constraining the Development of Earth's Lithosphere: Focus on the U.S. South-Central Region, Mexico, and Beyond.** Elizabeth Catlos, The University of Texas at Austin, ejcatlos@jsg.utexas.edu; Rita Economos, Southern Methodist University, reconomos@smu.edu; J. Douglas Walker, University of Kansas, jdwalker@ku.edu. Oral only.
- T17. **Anthropogenic Seismicity in the Central U.S.** Heather DeShon, Southern Methodist University, hdeshon@smu.edu; Maria Beatrice Magnani, Southern Methodist University, mmagnani@smu.edu; Robert T. Gregory, Southern Methodist University, bgregory@smu.edu. Oral and poster.
- T18. **Sedimentology, Geochemistry, Chemostratigraphy, and Geomechanics of Mudrock Systems.** Helge Alsleben, Texas Christian University, h.alsleben@tcu.edu. Oral and poster.
- T19. **Little Minerals, Big Implications.** Nova Mahaffey, The University of Texas at Dallas, nxm154030@utdallas.edu; Leah N. Thompson, The University of Texas at Dallas, sip:lnt160230@utdallas.edu; Bob Finkelman, The University of Texas at Dallas, bobf@utdallas.edu. Oral only.
- T20. **Low-Temperature Geochemistry and Biogeochemical Cycles (Posters).** Todd Longbottom, Texas Christian University, todd.longbottom@tcu.edu; Sharmila Giri, Case Western Reserve University, s.giri@rsmas.miami.edu. Posters only.
- T21. **Shelf-to-Basin Transition: Carboniferous Sedimentation in Southern Midcontinent.** Walter L. Manger, University of Arkansas at Fayetteville, wmanger@uark.edu; Xiangyang Xie, Texas Christian University, x.xie@tcu.edu; Shaun Prines, Texas Christian University, s.t.prines@tcu.edu. Oral and poster.
- T22. **General Paleontology.** Arthur Busbey, Texas Christian University, a.busbey@tcu.edu. Oral and poster.
- T23. **Hydrogeology and Water Resources.** Gehendra Kharel, Texas Christian University, g.kharel@tcu.edu. Oral and poster.
- T24. **Graduate Student Research across the Geosciences.** Omar R. Harvey, Texas Christian University, omar.harvey@tcu.edu. Oral and poster.
- T25. **Broadening Community Use of Available Data and Tools for Scientific Exploration and Education (Posters).** *Cosponsored by EarthCube; GSA Geoinformatics and Data Science Division.* Hongjie Xie, The University of Texas at San Antonio, hongjie.xie@utsa.edu; Alberto Mestas-Nunez, The University of Texas at San Antonio, alberto.mestas@utsa.edu. Posters only.
- T26. **Strengthening Student Engagement, Inclusion, and Learning in the Geosciences, K–Higher Education.** *Cosponsored by National Association of Geoscience Teachers—Mid-Continent Section.* Brendan Hanger, Oklahoma State University, brendan.hanger@okstate.edu; Aida Farough, Kansas State University, afarough@ksu.edu; Liane Stevens, Stephen F. Austin State University, stevenslm@sfasu.edu; Wendi Williams, South Texas College, wwilliam@southtexascollege.edu. Oral and poster.
- T27. **Hands-On Teaching Demonstrations in Geoscience Courses.** Michael T. DeAngelis, University of Arkansas at Little Rock, mtdeangelis@ualr.edu; René A. Shroat-Lewis, University of Arkansas at Little Rock, rashroatle@ualr.edu. Oral only.

- T28. **Enhancing Diversity in Geoscience Graduate Student Programs.** Samuel L. Moore, The University of Texas at Austin, slmoore@jsg.utexas.edu; Elizabeth J. Catlos, The University of Texas at Austin, ejcatlos@jsg.utexas.edu; Katherine K. Ellins, The University of Texas at Austin, kellins@jsg.utexas.edu; Dana L. Thomas, The University of Texas at Austin, dthomas@jsg.utexas.edu. Oral only.
- T29. **Undergraduate Student Research (Posters).** *Cosponsored by Council on Undergraduate Research.* Omar R. Harvey, Texas Christian University, omar.harvey@tcu.edu.

FIELD TRIPS

For additional information, please contact the Field Trip co-chairs: Richard Hanson, r.hanson@tcu.edu, and Helge Alseleben, h.alseleben@tcu.edu.

- F1. **A View into the Igneous Rift Materials of the Wichita Mountains, Oklahoma: Origins, Emplacement, and Alteration.** Sat.–Sun., 7–8 March. Max.: 20 participants. US\$232. **Principal Organizer:** Jonathan D. Price, Midwestern State University, jonathan.price@msutexas.edu. **Co-organizers:** Erin Summerlin-Donofrio, Southern Methodist University, esummerlindonofrio@smu.edu; Matthew Hamilton, University of Oklahoma, matt.hamilton@ou.edu; Amber Quevy, Rigaku Americas Corporation, amberquevy@gmail.com; Alexandria Stevenson, Midwestern State University, alexandria.weiskircher@gmail.com.
- F2. **Geology of Paleozoic Outcrops in the Hill Country of Central Texas.** Sat.–Sun., 7–8 March. Max.: 20 participants. Cost TBA. **Principal Organizer:** Bo Henk, Texas Christian University, bhenk@icloud.com.
- F3. **Wanderings in the Pangaea Wastelands of Permian-Triassic West Texas.** Sat.–Sun., 7–8 March. Max.: 20 participants. US\$390. **Principal Organizer:** John Holbrook, Texas Christian University, john.holbrook@tcu.edu. **Co-organizers:** Neil Tabor, Southern Methodist University, ntabor@mail.smu.edu; Anthony Skaleski, Texas Christian University, a.skaleski@tcu.edu.
- F4. **Building Stones of Downtown Fort Worth.** Tues., 10 March. US\$45. **Principal Organizer:** Tom Dill, GSA member, tdill@att.net.
- F5. **Middle and Upper Pennsylvanian Strata of the Fort Worth Basin.** Wed., 11 March. Max.: 20 participants. US\$75. **Principal Organizer:** Michael Read, The University of Texas at Arlington, michael.read@uta.edu. **Co-organizer:** Majie Fan, University of Texas at Arlington, mfan@uta.edu.
- F6. **Geology of the Woodbine Formation in Outcrop along the Shores of Lake Grapevine, North-Central Texas.** Wed., 11 March. Max.: 20 participants. Cost TBA. **Principal Organizer:** Bo Henk, Texas Christian University, bhenk@icloud.com.

SHORT COURSES

- SC1. **An Overview of Earth-Science Applications in the Shimadzu Institute for Research Technologies at The University of Texas at Arlington.** Sun., 8 March, 10 a.m.–3 p.m. Free. **Principal Organizer:** Matthew Loocke, The University of Texas at Arlington, matthew.loocke@uta.edu. **Co-organizer:** Jeff Campbell, The University of Texas at Arlington, jeff.campbell@uta.edu.
- SC2. **Making Geoscience Animations and Videos and Assessing Them in the Classroom.** Sun., 8 March, 10 a.m.–4 p.m. Free. **Instructors:** Robert Stern, The University of Texas at Dallas, rjstern@utdallas.edu; Jeffrey Ryan, University of South Florida, ryan@usf.edu; Ning Wang, The University of Texas at Dallas, Ning.Wang@utdallas.edu; Siloa Willis, The University of Texas Dallas, Siloa.Willis@utdallas.edu.
- SC3. **Seismic Modeling, Imaging, and Inversion.** Sun., 8 March, 1–5 p.m. US\$50 (includes snacks and course materials). **Instructor:** Jingyi Chen, The University of Tulsa, jingyi-chen@utulsa.edu.
- SC4. **Mudstones in Core and Thin-Section.** Wed., 11 March, 9 a.m.–4 p.m. Max.: 20 participants. US\$25. **Principal Organizer:** Richard Denne, Texas Christian University, r.denne@tcu.edu.

STUDENT OPPORTUNITIES

Career Mentoring Luncheons

Ask your career-related questions and learn about non-academic pathways in the geosciences while networking with professionals at the Roy J. Shlemon and John Mann Mentor Luncheons. Students and early career professionals are welcome.

Career Workshop Series

This three-part series will feature career development planning, an exploration of geoscience job sectors, and information on best practices for crafting a résumé and cover letter. Non-technical skills and workforce statistics will be reviewed. The series will be led by workshop presenters and geoscientists. No registration is required, and everyone is welcome.

To learn more about mentors and career workshops, go to www.geosociety.org/mentors/ or contact Jennifer Nocerino at jnocerino@geosociety.org.

ACCOMMODATIONS

Hotel registration deadline: 17 Feb.

A block of rooms has been reserved at the Omni Fort Worth Hotel at 1300 Houston Street, Fort Worth, Texas 76102, USA, at a special meeting rate of US\$209 per night plus tax. Reservations should be made online (<https://www.omnihotels.com/hotels/fort-worth/meetings/geological-society-of-america>) or by calling Omni Reservations at +1-800-THE-OMNI (toll free) and referencing the group name “Geological Society of America.”

LOCAL COMMITTEE

Co-Chairs: Omar Harvey, omar.harvey@tcu.edu, and Arne Winguth, awinguth@tcu.edu

Technical Program Co-Chairs: Xiangyang Xie, x.xie@tcu.edu, and Arne Winguth, awinguth@tcu.edu

Student Volunteer Chair: Helge Alsleben, h.alseleben@tcu.edu

Sponsorship Chair: Richard Denne, r.denne@tcu.edu

Field Trip Co-Chairs: Richard Hanson, r.hanson@tcu.edu, and Helge Alsleben, h.alseleben@tcu.edu

Judging Coordinator: John Holbrook, john.holbrook@tcu.edu

Exhibits Chair: Majie Fan, mfan@uta.edu

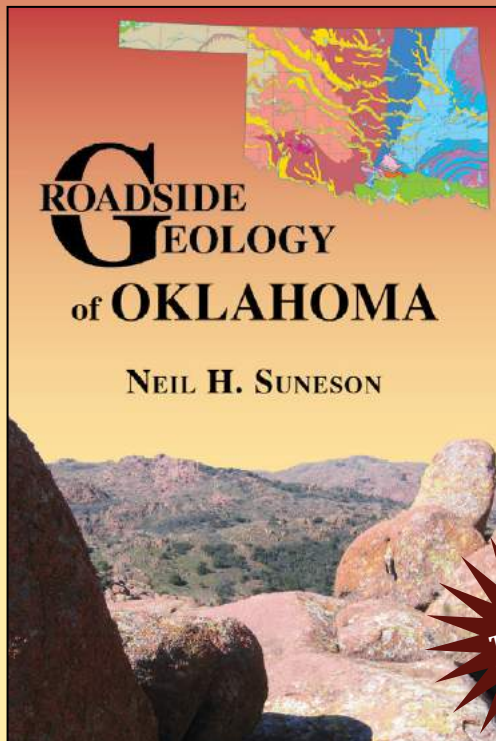
Budget/Finance Chair: Omar Harvey, omar.harvey@tcu.edu

Education Program (K-12) Chair: Arne Winguth, awinguth@tcu.edu

Media Chair: Bob Stern, rjstern@utdallas.edu

Meeting Secretary: Cornelia Winguth, cwinguth@uta.edu

Take this book along for a ride as you roll across the red plains east to the Ozark Plateau, west to the Panhandle, or south to the Ouachita, Arbuckle, and Wichita Mountains.



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NEIL H. SUNESON

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Southeastern and Northeastern Sections Joint Meeting

69th Annual Meeting of the Southeastern Section, GSA
55th Annual Meeting of the Northeastern Section, GSA
Reston, Virginia, USA
20–22 March 2020

www.geosociety.org/se-mtg



Great Falls Park. Photo by Visit Fairfax.

Sediments, Structures, Shores, and Storms: Keeping a Keen Eye on Eastern Geology

LOCATION

The joint meeting of GSA's Southeastern and Northeastern Sections will be held in Reston, Virginia, USA. Reston is a modern, planned community located in northern Virginia. The numerous historic and cultural attractions of Washington, D.C., are just a short distance away and ready to be explored. A mix of bistros, restaurants, and shops on an extensive pedestrian mall are just out the door of the Hyatt Regency Reston, the conference venue. Situated at the Fall Zone and the transition from the southern to the central and northern Appalachians, Reston provides a unique vantage point to examine all aspects of eastern geology. We have developed a robust and diverse technical program that links the geology of the southeastern and northeastern U.S.—a program that ranges from the crust to mantle, data to policy, mountains to coastal processes, paleontology to energy. We invite you to join us at Reston 2020 for a field trip across D.C. or the Appalachian orogen, a short course on applied micropaleontology or storm-water management, and a broad scope of technical sessions and symposia that will help us keep a keen eye on eastern geology.

REGISTRATION

Early registration deadline: 18 Feb.

Cancellation deadline: 24 Feb.

Registration fees are in U.S. dollars. For further information or if you need special accommodations, please contact one of the general co-chairs: Arthur Merschat, amerschat@usgs.gov, or Patrick Burkhardt, patrick.burkhardt@sru.edu.

REGISTRATION FEES (all fees are in U.S. dollars)

	Early		Standard	
	Full Mtg.	One Day	Full Mtg.	One day
Professional Member	\$225	\$150	\$250	\$170
Professional Member 70+	\$115	\$95	\$145	\$115
Professional Nonmember	\$250	\$170	\$275	\$200
Early Career Professional Member	\$175	\$110	\$185	\$125
Student Member	\$80	\$65	\$100	\$80
Student Nonmember	\$105	\$95	\$130	\$110
K–12 Professional	\$80	\$65	\$100	\$75
Guest or Spouse	\$70	\$65	\$80	\$75
Field Trip/Short Course Only	\$75	n/a	\$40	n/a

ACCOMMODATIONS

Hotel registration deadline: 26 Feb., 5 p.m. Eastern Time

A block of rooms has been reserved at the Hyatt Regency Reston, 1800 Presidents Street, Reston, Virginia, 20190, USA, located in the vibrant Reston Town Square. The meeting rate is US\$159 per night plus tax. The hotel offers many amenities (restaurants, bar, pool, Wi-Fi) and a complimentary shuttle to/from Dulles International Airport. Reservations can be made by calling +1-703-709-1234. Please be sure to identify yourself with the group code SEGSA20 and note that you are attending the GSA Southeastern and Northeastern Sections Joint Meeting. Parking is available at the hotel and at Reston Town Parking Garage next to the hotel.

TECHNICAL PROGRAM

Symposia

- S1. **The Past Is the Key to the Present—The Role of Paleontology and Geology in Management and Decision Making.** G. Lynn Wingard, U.S. Geological Survey, lwingard@usgs.gov; Chris Bernhardt, U.S. Geological Survey, cbernhardt@usgs.gov.

- S2. **The Appalachians, from North to South, from Crust to Mantle.** *Cosponsored by GSA Structural Geology and Tectonics Division; GSA Geophysics and Geodynamics Division.* Allison Severson, Colorado School of Mines, aseverson@mymail.mines.edu; Yvette Kuiper, Colorado School of Mines, ykuiper@mines.edu; Maureen Long, Yale University, maureen.long@yale.edu; Lara Wagner, Carnegie Institution of Washington, lwagner@carnegiescience.edu; Chuck Bailey, College of William & Mary, cmbail@wm.edu.
- S3. **From the Margins to the Deep: A Tribute to the Science and Art of A. Conrad Neumann.** Blair R. Tormey, Western Carolina University, btormey@wcu.edu; Paul J. Hearty, The University of Texas at Austin, kaisdad04@gmail.com.
- S4. **New Developments in Diversity and Inclusion in the Geosciences.** Alexander Gates, Rutgers University, agates@rutgers.edu; Marilyn Suiter, National Science Foundation, msuiter@nsf.gov.
- S5. **Radionuclides: Biogeochemistry, Transport, and Geological Applications.** Jim Kaste, College of William & Mary, jmkaste@wm.edu.; Joshua Landis, Dartmouth College, joshua.d.landis@dartmouth.edu.
- S6. **Stratigraphic Problems and Solutions in the Appalachian Basin.** *Cosponsored by GSA Energy Geology Division; GSA Sedimentary Division; GSA Hydrogeology Division; GSA Karst Division.* Daniel Doctor, U.S. Geological Survey, dhdoctor@usgs.gov; Randall Orndorff, U.S. Geological Survey, romdorff@usgs.gov; David Weary, U.S. Geological Survey, dweary@usgs.gov.
- S7. **The Grenville Orogen in Eastern North America.** Greg Walsh, U.S. Geological Survey, gwalsh@usgs.gov; John Aleinikoff, U.S. Geological Survey, jaleinikoff@usgs.gov; Paul Mueller, University of Florida, pamueller@ufl.edu; Richard Tollo, George Washington University, rtollo@gwu.edu; Arthur Merschat, U.S. Geological Survey, amerschat@usgs.gov; Peter Valley, pvvalley@gmail.com; Mike Williams, University of Massachusetts Amherst, mlw@geo.umass.edu.
- T4. **Geoarchaeology of Dynamic Landscapes.** *Cosponsored by Eastern Section–SEPM (Society for Sedimentary Geology).* Daria Nikitina, West Chester University of Pennsylvania, dnikitina@wcupa.edu; Ilya Buynevich, Temple University, coast@temple.edu; Heather Wholey, West Chester University of Pennsylvania, hwholey@wcupa.edu.
- T5. **Drill Baby, Drill! A Tribute to USGS Drillers Eugene “Big Gene” Cobbs, Eugene “Little Gene” Cobbs, III, and Jeff Grey, and Their Contributions to Geologic Research East of the Mississippi River.** Jean M. Self-Trail, U.S. Geological Survey, jstrail@usgs.gov; Kenneth G. Miller, Rutgers University, kgm@rci.rutgers.edu.
- T6. **Engineering and Environmental Geology of Karst Terranes.** *Cosponsored by GSA Karst Division.* Wendell Barner, Barner Consulting, wendell.barner@gmail.com.
- T7. **Conservation Paleobiology: Insights into the Preservation and Sustainability of Ecosystems.** *Cosponsored by Paleontological Society.* Jacalyn M. Wittmer, SUNY Geneseo, malinowski@geneseo.edu; Andrew Michelson, SUNY Maritime College, amichelson@sunymaritime.edu.
- T8. **Mega-Traces: Advances in Ichnology and Zoogeomorphology.** *Cosponsored by Eastern Section–SEPM (Society for Sedimentary Geology).* Ilya V. Buynevich, Temple University, coast@temple.edu; Stephen T. Hasiotis, University of Kansas, hasiotis@ku.edu; Logan A. Wiest, Mansfield University, Logan_Wiest@baylor.edu.
- T9. **Neoproterozoic to Cambrian Transitions on the Appalachian, Laurentian Margin.** *Cosponsored by Paleontological Society.* Steven J. Hageman, Appalachian State University, hagemansj@appstate.edu; Edward L. Simpson, University of Pennsylvania Kutztown, simpson@kutztown.edu.
- T10. **Provenance of the Eastern North American Margin: From Triassic Rifting to Modern Sedimentation.** Zachary Foster-Baril, The University of Texas at Austin, zfosterbaril@utexas.edu.

Theme Sessions

- T1. **Abiotic-Biotic Interactions in the Critical Zone.** Justin Richardson, University of Massachusetts Amherst, jbrichardson@umass.edu.
- T2. **Wetlands in a Changing World: Impacts of Environmental Change on Wetland Function and Ecosystem Services.** Miriam Jones, U.S. Geological Survey, miriamjones@usgs.gov; Debra Willard, U.S. Geological Survey, dwillard@usgs.gov.
- T3. **Paleolimnological Records of Climate and Environmental Change.** Timothy L. Cook, University of Massachusetts Amherst, tcook@geo.umass.edu; Nicholas L. Balascio, College of William & Mary, nbalascio@wm.edu.
- T11. **Integrating Field and Modeling Approaches to Understand Changing Coastal Systems.** Justin Shawler, Virginia Institute of Marine Science, jshawler@vims.edu; Rose Palermo, Massachusetts Institute of Technology and Woods Hole Oceanographic Institution, rpalermo@mit.edu; Arye Janoff, Montclair State University, janoffa2@montclair.edu; Isamar Cortes, Montclair State University, cortesil@montclair.edu
- T12. **Shale Production in the Eastern U.S.—E³: Environmental, Economic & Energy System Impacts.** Timothy R. Carr, West Virginia University, tim.carr@mail.wvu.edu; Shikha Sharma, West Virginia University, shikha.sharma@mail.wvu.edu.
- T13. **Developing and Using Open Educational Resources in the Geosciences (Posters).** *Cosponsored by National Association*

of Geoscience Teachers; Virtual Library of Virginia. Elizabeth Johnson, James Madison University, johns2ea@jmu.edu; Karen M. Layout, Reynolds Community College, klayout@reynolds.edu.

- T14. **Out of the Classroom, Out of the Box: Innovative Approaches to Geoscience Education.** *Cosponsored by National Association of Geoscience Teachers Southeastern Section.* Patricia Kelley, University of North Carolina Wilmington, kelley@uncw.edu; Michelle Casey, Towson University, mcasey@towson.edu.
- T15. **Active Learning and the Use of Technology in the Geoscience Classroom.** *Cosponsored by National Association of Geoscience Teachers.* Tarin Weiss, Westfield State University, tweiss@westfield.ma.edu; Lori Weeden, University of Massachusetts–Lowell, Lori_Weeden@uml.edu.
- T16. **Reimagining Earth-Science Teacher Education: Reworking Veteran Approaches for Innovations in Preparing Geoscience Teachers.** *Cosponsored by National Association of Geoscience Teachers Teacher Education Division.* Christopher Roemmele, West Chester University, croemmele@wcupa.edu.
- T17. **NAGT and NESTA Share-a-Thon: I've Got an Activity (Lab or Demo) for That!** *Cosponsored by National Association of Geoscience Teachers; National Earth Science Teachers Association.* Christopher Roemmele, West Chester University, croemmele@wcupa.edu.
- T18. **Undergraduate Research (Posters).** *Cosponsored by Council on Undergraduate Research Geosciences Division.* Lee Phillips, University of North Carolina at Greensboro, plphilli@uncg.edu; Jeff Ryan, University of South Florida, ryan@mail.usf.edu.
- T19. **Eastern Activities of the USGS Earth Mapping Resources Initiative.** *Cosponsored by U.S. Geological Survey; Association of American State Geologists.* Nora K. Foley, U.S. Geological Survey, nfoley@usgs.gov; Arthur Merschat, U.S. Geological Survey, amerschat@usgs.gov; William L. Lassetter, Virginia Division of Geology and Mineral Resources, william.lassetter@dmme.virginia.gov; Anjana K. Shah, U.S. Geological Survey, ashah@usgs.gov; Gregory J. Walsh, Florence Bascom Geoscience Center, gwalksh@usgs.gov.
- T20. **Defining 3D Geologic Mapping in Eastern North America.** Christopher Bernhardt, U.S. Geological Survey, cbernhardt@usgs.gov; Peter Chirico, U.S. Geological Survey, pchirico@usgs.gov.
- T21. **Geologic Maps, Digital Geologic Maps, Geophysical Maps, and Derivatives from Geologic and Geophysical Maps (Posters).** Randy L. Kath, University of West Georgia, rkath@westga.edu; Thomas J. Crawford, University of West Georgia, crawfordthomasj@gmail.com.
- T22. **What Are We Dating?: The Utility of Petrochronology in Linking Accessory Mineral Dates to Rock Forming Processes.** Thomas “Alex” Johnson, University of California Santa Barbara, tajohnson@ucsb.edu; Ryan McAleer, U.S. Geological Survey, rmcaleer@usgs.gov.
- T23. **New Developments in the Understanding of Pre-Appalachian Rocks of Eastern North America.** Brent Miller, Texas A&M University, bvmiller@geo.tamu.edu; Brent Owens, College of William & Mary, beowen@wm.edu; Sandra Barr, Acadia University, sandra.barr@acadiau.ca.
- T24. **Timescales and Conditions of Appalachian Metamorphism.** *Cosponsored by GSA Geochronology Division; GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division; GSA Structural Geology and Tectonics Division.* Calvin Mako, Bates College, cmako@bates.edu; Alexandra Nagurney, Virginia Tech, nagurney@vt.edu.
- T25. **Using Microstructural Analysis to Investigate Macroscale Structural Features.** *Cosponsored by GSA Structural Geology and Tectonics Division.* Jamie Levine, Appalachian State University, levinejs@appstate.edu; Jeffrey Rahl, Washington & Lee University, RahlJ@wlu.edu.
- T26. **Deciphering Active Tectonics and Seismic Hazard in Eastern North America.** Lisa S. Schleicher, independent, lisasschleicher@gmail.com; J. Wright Horton, U.S. Geological Survey, whorton@usgs.gov; Chris Cramer, University of Memphis, ccramer@memphis.edu; Christine A. Powell, University of Memphis, capowell@memphis.edu.
- T27. **Appalachian Petrology: A Session to Honor the Career of Dr. Robert J. Tracy.** Willis Hames, Auburn University, hameswe@auburn.edu; Nicholas M. Ratcliffe, U.S. Geological Survey, ratcliffe2@gmail.com; Craig Dietsch, University of Cincinnati, dietscc@ucmail.uc.edu; Mark Caddick, Virginia Tech University, caddick@vt.edu.
- T28. **Geoscience Careers for New Geoscience Graduates.** Michael D. Lawless, Draper Aden Associates, Inc., mlawless@daa.com; and Ron Wallace, Georgia Department of Natural Resources (retired), rw30075@yahoo.com.
- T29. **Chemostratigraphic, Biotic, and Sedimentologic Changes through Earth History.** Nevin P. Kozik, Florida State University, npk15@my.fsu.edu; Chelsie N. Bowman, Florida State University, cnb09@my.fsu.edu; Sean M. Newby, Florida State University, smn17b@my.fsu.edu; Selva M. Marroquín, Virginia Tech University, selva@vt.edu.
- T30. **Private Wells—Current Challenges and Opportunities.** Sille Larsen, Vermont Dept. of Health, sille.larsen@vermont.gov; Patti Casey, Vermont Agency of Agriculture, patti.casey@vermont.gov; Jonathan J. Kim, Vermont Geological Survey, jon.kim@vermont.gov; Joseph D. Ayotte, U.S. Geological Survey, jayotte@usgs.gov.

FIELD TRIPS

For additional information, please check the meeting website or contact the Field Trip co-chairs: Mark Carter, mcarter@usgs.gov, and Chris Swezey, cswezey@usgs.gov.

Pre-Meeting

1. **The Central Appalachian Orogen: From Ancient Tectonics to Modern Seismicity.** Mon.–Thurs., 16–19 March. US\$300. Leaders: Christopher M. Bailey, College of William & Mary, cmbail@wm.edu; Callan Bentley, Northern Virginia Community College, cbentley@nvcc.edu; Frank J. Pazzaglia, Lehigh University, fjp3@lehigh.edu; Allan Pitts, University of Camerino, pitts.alan@gmail.com.
2. **Military Geology of the Manassas Battlefield Area, Virginia.** Thurs., 19 March. US\$58. Leader: John C. Jens, U.S. Army Geospatial Center, jcjens@earthlink.net.
3. **Accreted Forearc, Continental, and Oceanic Rocks of Maryland's Eastern Piedmont: The Potomac Terrane, Baltimore Terrane, and Baltimore Mafic Complex.** Thurs., 19 March. US\$100. Leaders: Rebecca Kavage Adams, Maryland Geological Survey, rebecca.adams@maryland.gov; William Junkin, Maryland Geological Survey, william.junkin@maryland.gov; David K. Brezinski, Maryland Geological Survey, david.brezinski@maryland.gov.
4. **Age and Tectonic Significance of Diamictites at the Devonian–Mississippian Transition in the Central Appalachian Basin.** Thurs., 19 March. US\$160. Leaders: F.R. Etensohn, University of Kentucky, fettens@uky.edu; Clay Seckinger, University of Kentucky, clayseckinger@icloud.com.

Post-Meeting

5. **The Geology of Washington, D.C.** Sun., 22 March. US\$70. Leaders: Callan Bentley, Northern Virginia Community College, cbentley@nvcc.edu; Christopher Roemmele, West Chester University, croemmele@wcupa.edu.
6. **Geology and the Civil War at the North Anna River Fall Zone, Virginia.** Mon., 23 March. US\$110. Leader: Christopher M. Bailey, William & Mary, cmbail@wm.edu.
7. **Geology and Geomorphology of the Trout Rock Caves (Hamilton Cave, Trout Cave, New Trout Cave), Pendleton County, West Virginia.** Mon.–Tues., 23–24 March. US\$255. Leader: Christopher Swezey, U.S. Geological Survey, cswezey@usgs.gov.
8. **Proterozoic and Paleozoic Evolution of the Blue Ridge Geologic Province in Northern Virginia.** Mon., 23 March. US\$76. Leaders: Steve Schindler, U.S. Geological Survey, sschindler@usgs.gov; Bill Burton, U.S. Geological Survey, bburton@usgs.gov.

SPECIAL EVENT

Experience Capitol Hill: Geoscience and Public Policy in Washington, D.C. Thurs., 19 March. US\$45. Leader: Kasey White, Geological Society of America, kwhite@geosociety.org.

SHORT COURSES

Clastic and Carbonate Petrology—From Hand Samples to Thin Sections. Thurs., 19 March. US\$50 for professionals; US\$25 for students. Leaders: John Haynes, James Madison University, haynesjx@jmu.edu; Mercer Parker, U.S. Geological Survey, mercerparker@usgs.gov.

Applied Micropaleontology for Non-Paleontologists: How to Interpret and Use Fossil Data. Thurs., 19 March. US\$50 for professionals; US\$25 for students. Location: USGS National Center, Reston, Virginia. Leaders: Marci Robinson, U.S. Geological Survey, mmrobinson@usgs.gov; Jean Self-Trail, U.S. Geological Survey, jstrail@usgs.gov.

Stormwater Management in Karst Terrain. Thurs., 19 March. US\$50 for professionals; US\$25 for students. Location: Hyatt Regency Reston. Leader: Robert K. Denton Jr., Terracon, robert.denton@terracon.com.

GSA On To the Future (OTF) Professional Skills Workshop for Students. Thurs., 19 March. Free to OTF students (limit 20). Leaders: Stephen K. Boss, University of Arkansas, sboss@uark.edu; Tahlia Bear, Geological Society of America, tbear@geosociety.org; Katherine Ellins, The University of Texas at Austin, kellins@jsg.utexas.edu.

OPPORTUNITIES FOR STUDENTS AND EARLY CAREER PROFESSIONALS

Career Mentoring Luncheons

Ask your career-related questions and learn about non-academic pathways in the geosciences while networking with professionals at the Roy J. Shlemon and John Mann Mentor luncheons. Students and early career professionals are welcome.

Career Workshop Series

This three-part series will feature career development planning, an exploration of geoscience job sectors, and information on best practices for crafting a résumé and cover letter. Non-technical skills and workforce statistics will be reviewed. The series will be led by workshop presenters and geoscientists. No registration is required, and everyone is welcome.

To learn more about mentors and career workshops, go to www.geosociety.org/mentors/ or contact Jennifer Nocerino at jnocerino@geosociety.org.

Student Volunteers

Take advantage of work opportunities to earn free meeting registration. Students interested in helping with the various aspects of the meeting should contact Wilma B. Aleman Gonzalez, U.S. Geological Survey, waleman@usgs.gov.

Travel Grants

Application deadline: 18 February

Students who are GSA members and who register for the meeting are eligible to apply for student travel grants from their respective sections. For further information see <https://www.geosociety.org/gsa/about/sections/GSA/Sections/se/students.aspx#travel> for the Southeastern Section and <https://www.geosociety.org/gsa/about/sections/gsa/Sections/ne/home.aspx> for the Northeastern Section.

PROFESSIONALS

If you like to share your interest, enthusiasm, and experience in applied geology, consider being a GSA mentor at the joint meeting. Being a mentor is a rewarding experience. To learn more, contact Jennifer Nocerino at jnocerino@geosociety.org.

This meeting also offers an excellent opportunity to earn CEUs toward your continuing education requirements for your employer, K-12 school, or professional registration. The CEU

certificate can be downloaded from the meeting website after the meeting.

LOCAL COMMITTEE

General Co-Chairs: Arthur Merschat, amerschat@usgs.gov;
Patrick Burkhart, patrick.burkhart@sru.edu

Technical Program Co-Chairs: Chuck Bailey, cmbail@wm.edu;
Wendell Barner, wendell.barner@gmail.com

Field Trip Co-Chairs: Mark Carter, mcarte@usgs.gov;
Chris Swezey, cswezey@usgs.gov

Sponsorships Chair: Patrick Burkhart, patrick.burkhart@sru.edu


Short Course Co-Chairs: Daniel H. Doctor, dhdoctor@usgs.gov;
Katie Tamulonis, ktamulonis@allegheny.edu

Exhibits Chair: Daniel Harris, harris_d@calu.edu

Treasurer: Patrick Burkhart, patrick.burkhart@sru.edu

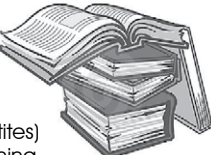
Student Volunteer Chair: Wilma Aleman Gonzalez,
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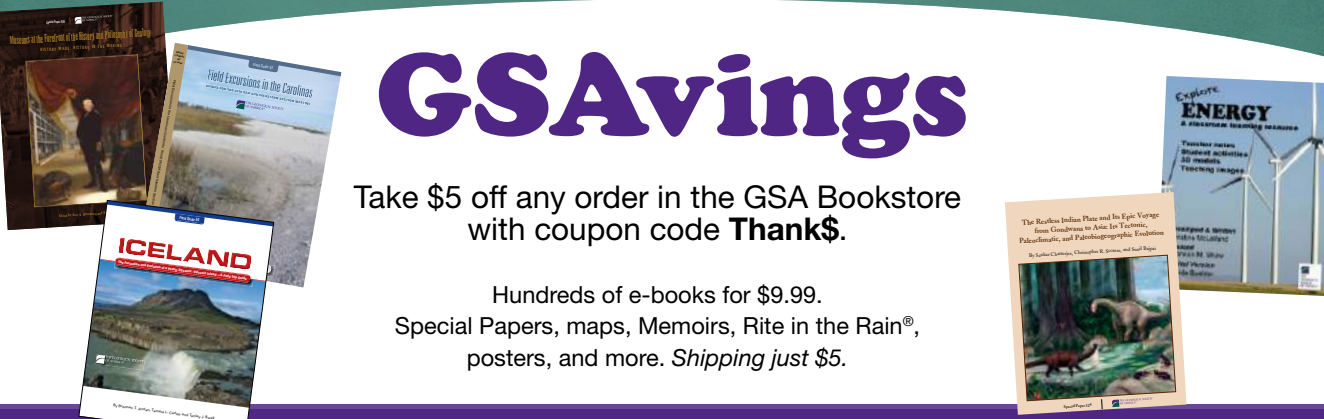
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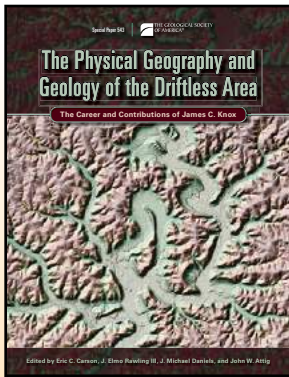
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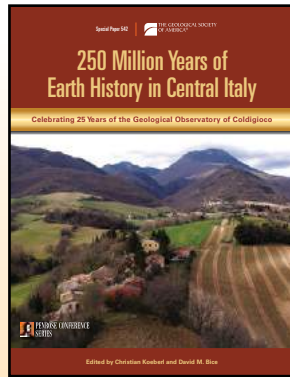


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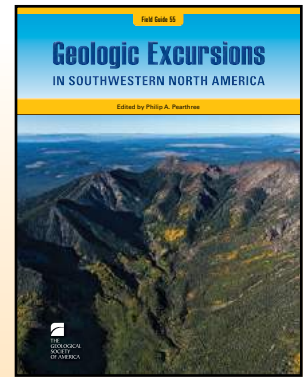
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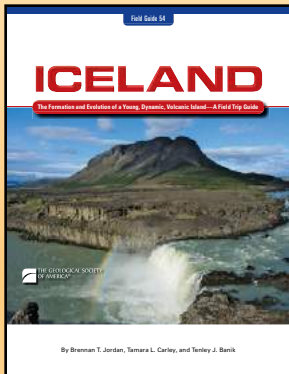
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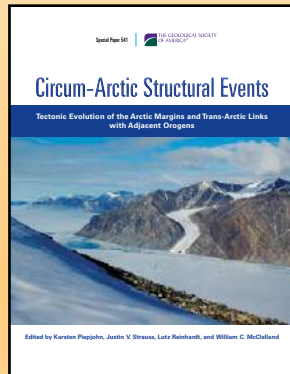
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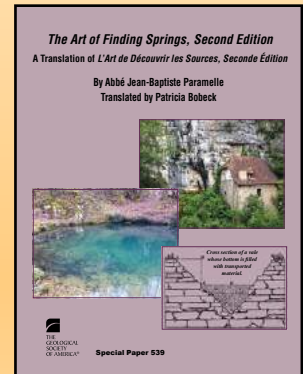
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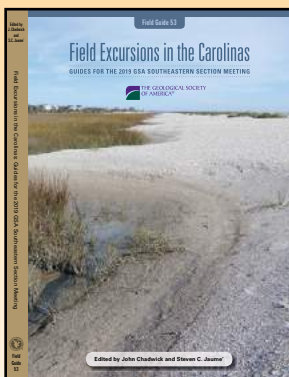
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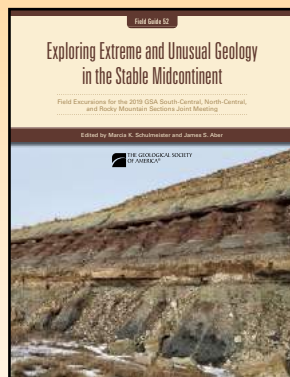
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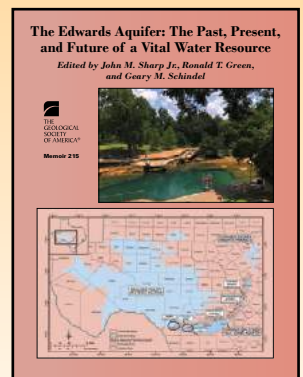
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POSITIONS OPEN

Assistant Professor of Environmental Studies, The University of the South

The Department of Earth and Environmental Systems at The University of the South in Seawee, Tenn., seeks a tenure-track professor at the assistant level with demonstrated talent for teaching and an expertise in Environmental Studies.

The standard teaching load is five courses per year. Candidates should be enthusiastic about developing a teaching and research program in the context of the liberal arts tradition in education.

Expertise in climate change, sustainable land use, food production systems, watersheds, environmental health, energy or other areas that complement or expand the existing strengths of the faculty are desirable. Applicants must have their Ph.D. in hand by the time of appointment.

Review of applications will begin January 5, 2020.

Send a letter of application, curriculum vitae, statements of teaching and research interests, transcripts (unofficial accepted), and three letters of reference through the online application portal at: <https://jobs.sewanee.edu/postings/3893>.

The University of the South comprises a well-regarded College of Liberal Arts and Sciences and a distinguished School of Theology. It is an institution of the Episcopal Church that welcomes individuals of all backgrounds. The University is located on a striking, 13,000-acre campus on Tennessee's Cumberland Plateau.

The University of the South is an equal opportunity educational institution that is committed to creating and maintaining a diverse and inclusive campus environment.

Three Positions in Sedimentary Geology, University of Houston

The University of Houston Department of Earth and Atmospheric Sciences invites applications for three tenure-track positions in the general field of sedimentary geology. Hiring will be at the assistant professor level with up to one hire at the associate professor level. Experience and qualifications will be used to determine the appropriate title of assistant or associate. This is a cluster hire that will focus on interpretation of records of changing environments on Earth's surface.

We are particularly interested in researchers with a focus on the areas of paleoclimate, paleoceanog-

raphy, paleogeography, biogeochemistry, carbon cycles and proxies, the role of tectonics in building the sedimentary record, source to sink processes, and coastal evolution. The research of successful applicants may concentrate on either chemical or clastic sedimentary rocks and may use data from outcrops, cores, modern environments, the subsurface, or experimental or modeling studies. Integration of geophysical data, petrographic observations, and facies analysis is particularly encouraged.

The successful candidates will be expected to build active collaborations within and outside the university, to develop internationally recognized, externally funded research programs, to teach graduate and undergraduate level courses that bridge theory and practical applications in the geosciences, and to use their research to enhance experiential learning at UH.

The University of Houston is an equal opportunity/affirmative action employer. Minorities, women, veterans, and persons with disabilities are encouraged to apply.

The University of Houston is responsive to the needs of dual career couples. Furthermore, we welcome candidates whose experience in teaching, research, or community service has prepared them to contribute to our commitment to diversity and excellence. More information about the department can be found at <http://www.uh.edu/nsm/earth-atmospheric/>. Candidates must have a Ph.D. or equivalent in earth science or a related field at the time of the appointment.

Review of applications will begin on October 31st, 2019, and continue until the positions are filled. Candidates should submit: (1) a statement of teaching and research interests, (2) a curriculum vitae, (3) a list of at least three possible references and their contact information. Applications should be submitted online through <https://jobs.uh.edu/>. A background check is required prior to interviewing. Questions about these positions may be directed to search committee chair Julia Wellner (jwellner@uh.edu).

Notes to Applicant: Official transcripts are required for a faculty appointment and will be requested upon selection of the final candidate. All positions at the University of Houston are security sensitive and will require a criminal history check.

Tenure-Track, Assistant Professor Geophysics, Northwestern University

Individuals are invited to submit applications to our open tenure-track faculty position at the rank of Assistant Professor in the field of geophysics, broadly considered. We seek a scholar whose expertise and creativity will complement and expand the Department's strengths. Area(s) of specialization within solid-Earth, environmental or planetary geophysics are open and may include any aspect of geodesy, seismology, dynamic topography, geophysical fluid dynamics, hazards, climate, or planetary science across spatiotemporal scales. Applicants are likely to employ emerging technologies in remote sensing, machine learning, numerical methods, and/or field instrumentation. Applicants whose research reveals linkages

between physical processes and societal impacts are particularly encouraged to apply. The deadline for applications is 12/16/19. Applicants should visit <http://bit.ly/NUEARTH-faculty-position> for submission instructions.

Northwestern University is an Affirmative Action Employer, and is committed to fostering a diverse faculty.

Faculty Positions at the Department of Geosciences, National Taiwan University

The Department of Geosciences at the National Taiwan University (NTU) is seeking active scientists to fill two to three faculty positions starting from August 1st, 2020. The positions are open to candidates from all fields in geosciences, but those who have strong background in the fields of (1) structural and field geology; (2) sedimentology and stratigraphy; (3) mineralogy and petrology; and (4) geological resources or hydro- and applied geology will receive more favorable consideration. Applicants are requested to send the following documents: CV, list of publications, statements of teaching and research interests, copies of diploma and transcript, names and contact information of three referees, and three to five articles published within the recent seven years (one of which needs to be designated as representative paper and must be published after August 1st, 2015). Application materials should be sent by email to Professor J. Bruce H. Shyu, the Chair of the Searching Committee, at jbhs@ntu.edu.tw.

Deadline for application: January 5th, 2020. For more information, please refer to the website: <http://web.gl.ntu.edu.tw/>

NTU ranks in the top 100 universities worldwide (QS 2019), and Taipei was recently named the World's Friendliest and Safest City for Expats (InterNations 2018). Within Taipei there is easy access, through a world class transit system, to a vibrant city life and to numerous outdoor activities such as hiking, snorkeling, fishing, and mountain biking. The Department of Geosciences offers a dynamic and supportive working environment with a wide range of state-of-the-art research facilities. Generous start-up funding is available for new faculty members.

Associate Director, Environmental Division, Bureau of Economic Geology

The Bureau of Economic Geology (Bureau) in the Jackson School at The University of Texas at Austin seeks a highly talented individual to lead its Environmental Research Division.

Responsibilities

- Serve as part of a small, integrated administrative team of Directors
- Set vision for and manage and grow the Environmental Division staff of approximately 50 staff
- Create and pursue a vision for multidisciplinary environmental research
- Work with Principal Investigators (PI's) to develop sources of funding for existing and new multidisciplinary programs in the areas of sustainable water resources, coastal geology, natural hazards, induced and naturally occurring earthquakes, car-

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- bon sequestration, and geologic mapping
- Build relationships with global federal and state agencies, industry, foundations, NGOs, and international groups that will ensure that new program opportunities are created and funded
 - Manage staffing and scheduling; coordinate with administrators and project PI's to ensure that projects are on schedule, on budget, and research groups are collaborating appropriately
 - Represent the Bureau at conferences and UT meetings.

Required Qualifications. Advanced degree with major course work in the field of earth science. Ph.D. with minimum of 12 years work experience, or master's degree with minimum 17 years experience, in a field related to the Bureau's core areas of environmental research, as per responsibilities outlined above. Excellent management, administrative, leadership and organizational abilities. Previous experience as a successful leader of major research programs. Acknowledged contributions in one or more aspects of environmental research. Relevant education and experience may be substituted as appropriate.

Preferred Qualifications. Proven record of research and leadership, preferably related to the Bureau's core areas of environmental research. Demonstrated ability to attract and administer external funds from a variety of sources, including federal agencies, state and local governments, and industry. A strong record of research publication and presentations. Evidence of innovation and ability to think creatively.

Salary Range. \$180,000 + depending on qualifications.

About the Bureau of Economic Geology. Established in 1909, the Bureau of Economic Geology in the Jackson School of Geosciences is the oldest and second-largest organized research unit at The University of Texas at Austin. The Bureau is the State Geological Survey of Texas, and conducts basic and applied research around the world focusing on the intersection of energy, the environment, and the economy. The Bureau partners with federal, state, and local agencies, academic institutions, industry, nonprofit organizations, and foundations to conduct high-quality research and disseminate the results to the scientific and engineering communities as well as to the broad public. The Bureau provides technical, educational, and publicly accessible information via a myriad of media forms to Texas, the nation, and the world.

Talented people are the Bureau's formula for success. Our staff of over 250 includes scientists, engineers, economists, graduate students and support staff, representing 27 countries, often working in integrated, multi-disciplinary research teams. The Bureau's facilities and state-of-the-art equipment include more than fifteen individual laboratories hosting researchers investigating everything from nanoparticles to basin-scale phenomena.

To apply and for more information, please go to <http://bit.ly/2rEH3p>.

The search will remain open until filled. Please direct queries to the search committee chair, Mark Shuster at recruiting@beg.utexas.edu.

Assistant Professor of Instruction, Mineralogy/Petrology, University of Akron

The Department of Geosciences, University of Akron, Ohio, has an opening for a non-tenure track position in mineralogy/petrology (job# 11999). Candidates must possess a Ph.D. (or ABD with a previously earned master's in geosciences) in the geosciences and have the ability to teach mineralogy, petrology, introductory-level earth science and summer Geology Field Camp courses. For complete required and preferred qualifications and to apply visit: <http://www.uakron.edu/jobs>. When completing the application attach: (1) a CV; (2) a brief statement of teaching philosophy that describes your pedagogical approaches and how your teaching and research experiences will contribute to the growth and success of the department; (3) unofficial transcripts; (4) contact information for at least 3 references. Review of applications will begin January 14, 2020. Questions can be directed to John Peck at jpeck@uakron.edu. The University of Akron is an equal education and employment institution committed to affirmative action. It is university policy that there shall be no unlawful discrimination.

Assistant Professor, Igneous Petrology or High-Temperature Geochemistry, University of Toronto

The Department of Earth Sciences [<https://www.es.utoronto.ca/>] in the Faculty of Arts and Science at the University of Toronto invites applications for a full-time tenure stream position in the area of igneous petrology or high-temperature geochemistry, particularly (but not exclusively) related to mineral deposits research. The appointment will be at the rank of Assistant Professor, and will commence on July 1, 2020, or shortly thereafter.

Applicants must have earned a Ph.D. degree in geology or a related area by the time of the appointment, or shortly thereafter, with a demonstrated record of excellence in research and teaching. The University of Toronto has an outstanding international reputation for research in the Earth Sciences. We seek candidates in any dynamic and evolving sub-discipline of igneous petrology or high-temperature geochemistry, and specifically application of the research to the study of economic geology or ore deposits will be an asset. The successful candidate's research program will further complement and develop the Department's strengths [<https://www.es.utoronto.ca/research/faculty-interests/>] in understanding Earth materials through novel empirical, experimental, analytical and/or theoretical approaches. The successful candidate will be expected to pursue innovative and independent research at the highest international level and to establish an outstanding, competitive and externally funded research program. The Department houses a collection [<https://www.es.utoronto.ca/research/>] of modern experimental and analytical facilities which the successful candidate would have an opportunity to take advantage of and further develop.

Candidates must provide evidence of research excellence as demonstrated by a record of publi-

cations in top-ranked and field relevant journals or forthcoming publications meeting high international standards, the submitted research statement, presentations at significant conferences, awards and accolades and strong endorsements from referees of high standing.

The candidate must also show a strong commitment to excellence in undergraduate and graduate level teaching. Evidence of excellence in teaching will be demonstrated by teaching accomplishments, the teaching dossier, the teaching statement, sample course materials, and teaching evaluations, or other evidence of superior performance in teaching-related activities submitted as part of the application, as well as strong endorsements by referee. Other teaching-related activities include performance as a teaching assistant or course instructors, experience leading successful workshops or seminars, student mentorship, or excellent conference presentations or posters. Primary teaching responsibilities may include any sub-disciplines within petrology, mineralogy, and high-temperature-geochemistry as well as introductory-level courses within the broader field of Earth sciences. In addition, field-based courses will be integral parts of the teaching assignments.

Salary will be commensurate with qualifications and experience.

All qualified candidates are invited to apply online by clicking the link below. Applicants must submit a cover letter, a current curriculum vitae, a research statement outlining current and future research interests, up to three sample papers, and teaching dossier to include a statement of teaching philosophy and experience (3-5 pages for each statement), sample course materials, teaching evaluations, or evidence of superior performance in other teaching-related activities as listed above.

Applicants must also arrange to have three letters of reference sent directly by the referee by email (on letterhead and signed) to geol_sec@es.utoronto.ca. The application materials and letters of reference must be received by December 16, 2019.

Submission guidelines can be found at <http://uoft.me/how-to-apply>. We recommend combining attached documents into one or two files in PDF/MS word format. If you have any questions about this position, please contact Ampy Tolentino at geol_sec@es.utoronto.ca.

The University of Toronto is strongly committed to diversity within its community and especially welcomes applications from racialized persons/ persons of colour, women, Indigenous/Aboriginal People of North America, persons with disabilities, LGBTQ persons, and others who may contribute to the further diversification of ideas

As part of your application, you will be asked to complete a brief Diversity Survey. This survey is voluntary. Any information directed related to you is confidential and cannot be accessed by search committees or human resources staff. Results will be aggregated for institutional planning purposes. For more information, please see <http://uoft.me/UP>.

All qualified candidates are encouraged to apply, however, Canadians and permanent residents will be given priority.

President, Incorporated Research Institutions for Seismology (IRIS)

The Incorporated Research Institutions for Seismology (IRIS) invites applications and nominations for the next President of the Consortium. The President is the public face of IRIS and represents the Consortium through leadership and management activities with the geosciences community, federal agencies, partners, and member institutions.

Founded in 1984 with support from the National Science Foundation (NSF), IRIS is a consortium of 125 U.S. universities dedicated to advancing research and education in seismology to understand our dynamic planet and to benefit society. IRIS programs contribute to new discoveries within our planet, natural hazard mitigation, national security, environmental monitoring, advances in geocomputation, networking and communications, and in building a scientifically and technologically proficient workforce. The IRIS membership comprises virtually all U.S. universities with research programs in seismology and includes a growing number of Educational Affiliates, U.S. Affiliates, and Foreign Affiliates. IRIS management is currently headquartered in Washington, D.C., but IRIS facilities are distributed internationally and operated in cooperation with the U.S. Geological Survey and other partner organizations and institutions. IRIS has annual revenues of approximately \$30 million, and the Consortium employs roughly 53 full-time professional staff.

Candidates for the President position will have significant management experience as well as a background in leading complex research or facilities programs in academia, related government agencies, or industry. Candidates should be able to collaborate and negotiate strategically with other scientific and educational facilities and organizations. This is particularly critical at this time given NSF's 2019 decision to support a single seismic and geodetic facility starting in 2023. The ideal candidate will have a Ph.D. in Earth Science, or equivalent professional expertise, along with experience in the administration of federal awards, a comprehensive understanding of federal funding structures and requirements, and an ability to identify and pursue new and diverse funding sources.

The President should be a dynamic leader who is able to communicate effectively with the IRIS community, federal agency leadership, and other sponsors and scientists. The ideal candidate will have a demonstrated record of successful scientific and administrative leadership and be able to proficiently engage with and build consensus across the geophysical community. The President will be capable of vision, planning, and executive management in partnership with the governing IRIS Board of Directors. Candidates must promote and embrace diversity and inclusion, global awareness, and ethical values.

A more in-depth position description may be found at <https://www.iris.edu/hq/employment/job/president1>.

Requests for additional information should be directed to Professor Charles J. Ammon, Chair, IRIS President Search Committee, hr@iris.edu.

Applications should include a full vita; a statement describing the applicant's vision for IRIS for the immediate term and for the period beyond the 2023 expiration of the current SAGE2 cooperative agreement; a statement addressing past and/or potential contributions to diversity, equity, and inclusion; and the names and contact information of three references. Applications and nominations will be accepted until a new President is selected. For optimal consideration, interested parties are encouraged to apply by 15 December 2019 at the address below.

Presidential Search Committee c/o IRIS, 1200 New York Avenue, NW, Suite 400, Washington, DC 20005.

The IRIS Consortium believes a diverse staff makes us a stronger organization. We are committed to hiring people of all ages, races, ethnicities, genders, sexual orientation or gender identities, marital status, veteran status, religions, and disabilities. All qualified candidates are encouraged to apply.

Tenure Track, Remote Sensing, Montana State University

The Department of Land Resources and Environmental Sciences at Montana State University, Bozeman (<http://landresources.montana.edu/>), is seeking applicants for a tenure track faculty position in remote sensing (45% research, 45% teaching, 10% service). We intend to hire a talented and enthusiastic individual who will: (1) provide leadership in the acquisition, analysis, characterization and application of remotely sensed imagery at multiple scales; (2) actively contribute to sustaining and enhancing the department's research, teaching, and outreach programs related to remote sensing as applied to land resources and environmental sciences; and (3) contribute to the MSU Spatial Sciences Center and its mission to advance academic research and instructional programs and to participate in campus-wide synergistic collaboration.

Candidates should have outstanding research and teaching experience (or potential) and fundamental training in remote sensing and quantitative analysis as applied to a relevant agricultural/natural resources/environmental sciences field. Examples of potential research foci include ecosystem and landscape processes, environmental restoration, climate change, environmental biology, pest ecology and management, and sustainable and precision agricultural systems. The successful candidate will complement existing departmental strengths, and will be expected to develop a nationally competitive research program supported by extramural grant funds. The successful candidate will teach undergraduate and graduate courses in remote sensing, and mentor undergraduate and graduate students.

Applications can be submitted at <https://jobs.montana.edu/postings/18304> where more details about the position are also available. Screening will begin 15 December 2019, and applications will be accepted until an adequate applicant pool has been established. Montana State University values diverse perspectives and is committed to continually supporting, promoting, and building an inclusive and culturally diverse campus environment.

Salary. Salary commensurate with experience, education, and qualifications.

Location—Bozeman, Montana.

Geohydrology, Binghamton University

Binghamton University invites applications for a tenure-track appointment in the area of Geohydrology at the assistant professor level to begin in Fall 2020. We are seeking an earth scientist who studies physical, chemical or biological processes involving surface water or groundwater by using a combination of field measurements, observations, and modeling. We are particularly interested in candidates whose research area includes investigation of water-related near-surface geophysical processes, though individuals with other research areas in the broad field of geohydrology are also encouraged to apply. Priority will be given to candidates who demonstrate a commitment to interdisciplinary and transdisciplinary teaching and scholarship.

In particular, we seek candidates who will strengthen our existing research and teaching programs in Geological Sciences (<https://www.binghamton.edu/geology/>), Environmental Studies (<https://www.binghamton.edu/environmental-studies/>), Sustainable Communities (<https://www.binghamton.edu/Sustainable-Communities/>) and the Center for Integrated Watershed Studies (<https://www.binghamton.edu/centers/ciws/>). The position will be part of a new interdisciplinary initiative that brings together faculty from geology, environmental science, ecology, and sustainability sciences to study the earth and the challenges facing the planet. This position is also affiliated with the Sustainable Communities Transdisciplinary Area of Excellence (TAE), one of six TAEs that Binghamton University has developed as areas of focused interdisciplinary research across the university (<https://www.binghamton.edu/transdisciplinary-areas-of-excellence/sustainable-communities/>).

Candidates must have a Ph.D. in geology, environmental science, or a related field at the time of appointment. The successful candidate must develop and sustain a nationally-recognized, externally-funded research program in their area. We also expect the candidate to develop a strong record of teaching, thesis advising, and mentoring of students and to offer undergraduate/graduate level courses in their area of expertise. Our preferred candidate will also be able to translate their research to broader audiences in water resources and water resources policy courses.

To apply, please submit a curriculum vita; a cover letter describing experience and interest in the position; statements of research and teaching interests, and names and contact information of at least three references. All documents should be submitted to: <https://binghamton.interviewexchange.com>. Completed applications received by December 15, 2019 will receive full consideration. Applications arriving after this date will be reviewed as needed until the position is filled.

Binghamton University is an Equal Opportunity/Affirmative Action Employer. It is the policy of Binghamton University to provide for and promote

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equal opportunity employment, compensation, and other terms and conditions of employment without discrimination on the basis of sex, age, race, color, religion, disability, national origin, gender identity or expression, sexual orientation, veteran or military service member status, marital status, domestic violence victim status, genetic predisposition or carrier status, or arrest and/or criminal conviction record unless based upon a bona fide occupational qualification or other exception.

One-Year Visiting Assistant Professor, Paleoclimate/Global Change, Colby College, Waterville, Maine

The Colby College Department of Geology invites applications for a one-year Visiting Assistant Professor specializing in paleoclimate, paleoceanography, global environmental change, or a related field to begin September 1, 2020. The successful candidate will teach a sophomore-level undergraduate course on Earth's climate and paleoclimate history with a lab, as well as an introductory geology course and an upper-level elective in their area of specialty (a total of four course equivalents). Our ideal candidate will be able to offer both field- and lab-based study of past environmental change in Maine to give students hands-on experience with paleoclimate research. The successful candidate will have access to instrumentation and facilities in the Departments of Geology and Chemistry for research and teaching. These include a powder-XRD, micro-XRF, SEM-EDS, CHNSO Elemental Analyzer, ICP-OES, petrographic and binocular microscopes, and sediment-sieving equipment. The search committee is especially interested in candidates with a demonstrated ability to teach and mentor a diverse student population. A Ph.D. at the time of appointment is preferred, but ABD candidates will be considered.

Complete applications will include: (1) a brief cover letter, (2) a curriculum vitae, (3) a statement of teaching philosophy illustrating commitment to diversity and inclusive teaching, and (4) three confidential letters of recommendation. Please submit all materials via Interfolio at: apply.interfolio.com/69710. Applications received by January 6, 2020 will receive full consideration, but applications will be reviewed until the position is filled. Inquiries may also be directed to paleoclimate20@colby.edu.

Colby is a private, coeducational liberal arts college that admits students and makes employment decisions on the basis of the individual's qualifications to contribute to Colby's educational objectives and institutional needs. Colby College does not discriminate on the basis of race, color, gender, sexual orientation, gender identity or expression, disability, religion, ancestry or national origin, age, marital status, genetic information, or veteran's status in employment or in our educational programs. Colby is an Equal Opportunity employer, committed to excellence through diversity, and encourages applications from qualified persons of color, women, persons with disabilities, military veterans and members of other under-represented groups. Colby complies with Title IX, which prohibits discrimina-

tion on the basis of sex in an institution's education programs and activities. Questions regarding Title IX may be referred to Colby's Title IX coordinator or to the federal Office of Civil Rights. For more information about the College, please visit our website: www.colby.edu.

Assistant Professor, Earth Materials, School of the Environment, Washington State University

The School of the Environment at Washington State University invites applications for an Assistant Professor in Earth Materials, to begin August 2020, with an emphasis in petrology, mineralogy, volcanology, magmatic processes, or tectonic processes. The candidate will take a leadership role in developing and funding research initiatives that take advantage of WSU's Peter Hooper Geo-Analytical Laboratory and the Radiogenic Isotope and Geochronology Laboratory, which maintain state-of-the-art capabilities in whole rock and micro-scale major and trace element analysis, geochronology, and radiogenic and stable isotope geochemistry. Lab facilities include current generation electron microprobe, X-ray fluorescence, inductively-coupled plasma mass spectrometer, and laser ablation facilities (<https://environment.wsu.edu/facilities/geoanalytical-lab/>).

The successful candidate will: (i) develop an externally funded research program; (ii) publish research in top quality journals; (iii) teach undergraduate and graduate courses in Earth Materials; (iv) mentor graduate students; (v) take a leadership role in the GeoAnalytical Laboratory; (vi) work with faculty and mentor students from a wide range of backgrounds; and (vii) serve university and professional organizations. To learn more and apply, visit: <https://www.wsujobs.com/postings/48041>.

WSU is an EO/AA Educator and Employer.

Tenure Track Assistant Professor, Remote Sensing/Geospatial Technology, California State Polytechnic University, Pomona

The Geological Sciences Department at California State Polytechnic University, Pomona (Cal Poly Pomona), invites applications for a tenure-track, ASSISTANT PROFESSOR position, beginning in the 2020–2021 academic year. We invite applications from geoscientists whose research incorporates data from ground-based remote sensing or observations from unmanned aerial vehicles or satellites, and the position is open to a broad range of research specializations, such as natural hazards, active tectonics, environmental geoscience, and/or climate change. A Ph.D. in geology, geophysics, environmental geoscience or a directly related science or engineering discipline is required. The successful candidate will have the potential for excellence in undergraduate and graduate teaching, and for developing an externally-funded research program that will involve undergraduate and master's students. Teaching responsibilities will typically include a mix of geoscience courses at the lower division, upper division, and graduate levels, and will incorporate classes in Geographic Information Systems, Remote Sensing or other specialty

courses in the candidate's area of expertise. Demonstrated experience with data collection and analysis using modern instrumentation is expected. Preferred qualifications include demonstrated success with external funding, established ties to research institutions, industry or government agencies and interest in developing intradepartmental and cross-campus collaborations. At Cal Poly Pomona we cultivate student and faculty success through a diverse culture of experiential learning, discovery, and innovation. Cal Poly Pomona is committed to being the model for an inclusive polytechnic university that inspires creativity and innovation, embraces local and global challenges, and transforms lives. The position is open until filled. First consideration will be given to completed applications received no later than December 30, 2019. Full position description and application procedure: <http://www.cpp.edu/~faculty-affairs/open-positions/>.

Igneous Petrology, Western Washington University

The Geology Department at Western Washington University (WWU) invites applications for a tenure-track, assistant professor position with specialty in Igneous Petrology to begin Sept 16, 2020. We seek individuals who are enthusiastic about teaching and who will establish a vigorous research program, and are particularly interested in those who will combine field and analytical, experimental or modeling approaches in their research, and who will involve undergraduate and Masters-level students in their research.

The ideal candidate will enhance our existing strengths in geoscience teaching and research by developing new courses and research avenues in igneous petrology. Broad areas of interest include, but are not limited to, the timescales of magmatic processes, the evolution of the continental crust, mantle, oceanic lithosphere/ocean island/mid-ocean ridge processes, the recycling of elements and volatiles within arc magmas and subduction systems, and links between tectonic and magmatic processes.

For details about the position, application information and instructions, go to the WWU Employment website <http://employment.wvu.edu/cw/en-us/job/497184/assistant-professor-of-igneous-petrology>.

Review of applications begins December 15, 2019 and continues until position is filled. Please contact the search committee chair, Susan DeBari (debari@wvu.edu) for questions about this position.

Assistant Professor, Geology—Marine and Coastal Science, Western Washington University

The Geology Department and the Marine and Coastal Science (MACS) program at Western Washington University (WWU) invite applications for two tenure-track, assistant professor positions with specialties in one of three fields:

Coastal Geomorphology/Coastal Geohazards. The ideal candidate will enhance our existing strengths in geoscience teaching and research by developing new courses and research avenues in coastal geomorphology, coastal tectonics and geohazards. Broad areas of interest include, but are not limited to, coastal erosion and sediment trans-

port, delta evolution, beach/tidal morphodynamics, marine geohazards, and tectonic processes that impact coastal zones, including uplift, subsidence, and tsunami generation and impacts.

Paleoceanography/Paleoclimate. The ideal candidate will enhance our existing strengths in geoscience teaching and research by developing new courses and research avenues in paleoceanography/paleoclimatology. Broad areas of interest include, but are not limited to, oceanic circulation and heat transport, micropaleontology/paleoecology, the carbon cycle, and geochemical processes that are related to climate variations on geological timescales. Tools and techniques used to address these problems can include geochemical or sedimentological proxies of climate variations, paleontological proxies/indicators of climate variations, physical oceanographic data, or other appropriate techniques.

Marine Geologist. The ideal candidate will enhance our existing strengths in geoscience teaching and research by developing new courses and research avenues in marine geology with a focus on crustal/lithospheric evolution and/or tectonic processes. Broad areas of interest include, but are not limited to, formation of the oceanic lithosphere and crustal evolution, geodynamics of the ocean basins, hydrothermal circulation at mid-ocean ridges, geochemistry of rock-water interactions, submarine volcanic systems, or tectonic processes associated with oceanic plate boundaries. Tools and techniques used to address these problems can include geochemical analyses, geophysical methods, geospatial analysis, textural rock analysis, numerical models, or other appropriate techniques.

These positions will begin Sept 16, 2020. As members of the group of initial faculty hires into the MACS program, the successful applicant will foster an interdisciplinary approach to teaching and research in geology and marine science. We seek individuals who are enthusiastic about teaching and who will establish a vigorous research program, and are particularly interested in those who will combine field, experimental, and/or modeling approaches in their research program, and who will involve undergraduate and Masters-level students in their research.

To apply, and for further details regarding qualifications and position responsibilities, please see <http://employment.wvu.edu/cw/en-us/job/497185/assistant-professor-geology-marine-and-coastal-science>.

Please contact the search committee chair, Bernie Housen (bernieh@wvu.edu) for questions about these positions. Review of applications begins October 14, 2019 and continues until the positions are filled.

Geology Faculty, Hope College

The Department of Geological & Environmental Sciences seeks applicants for a full-time non-tenure track position for up to three years, beginning in the Fall of 2020. The applicant must be able to teach courses in either structural geology or geomorphology as well as introductory level courses in geology and environmental science. The applicant will also be expected to collaborate with undergraduate students on research projects.

Qualifications: The candidate must either have a Ph.D. in geology or a reasonable prospect of having a Ph.D. by the Fall of 2020.

Application Instructions: Applications are accepted online at www.hope.edu/employment/faculty. As part of the online application candidates will upload a cover letter, curriculum vitae, transcripts (unofficial transcripts accepted for the initial application), and a statement of teaching philosophy and competencies. Applicants will also submit a statement describing their fit to the mission of Hope College (<https://hope.edu/about/mission.html>). As it may not be addressed elsewhere in the application, applicants should devote particular attention to the Christian aspect of the mission statement and their personal engagement with faith and/or a faith community.

In addition, names and contact information for three references will be entered into the application. Those references will be contacted upon application to submit letters of reference.

Application deadline is January 15, 2020.

For a full job description and to read about Hope College please visit our website at www.hope.edu/employment/faculty.

Hope College seeks to be a community that affirms the dignity of all persons as bearers of God's image. It is Hope College policy not to discriminate on the basis of age, color, disability, family status, genetic information, height, national origin, pregnancy, race, religion, sex, or weight, except in the event of a bona fide occupational qualification. Hope College is an equal opportunity employer.

OPPORTUNITIES FOR STUDENTS

Multiple Ph.D. student positions in Geomechanics at The University of Texas at Austin. We are currently seeking Ph.D. students to join the Geomechanics and GeoFluids research program in the Department of Geological Sciences, Jackson School of Geosciences, The University of Texas at Austin. Our group works on a wide range of problems related to stress, fault and rock strength, coupled deformation and fluid flow, and rock and sediment physical properties in the Earth's crust, through integration of experimental, theoretical modeling, and field-based approaches. Active research projects provide an opportunity to engage and are strongly allied with Scientific Ocean Drilling efforts offshore New Zealand, Japan, Costa Rica, the Gulf of Mexico, and several other continental margins; these projects also offer outstanding opportunities to engage with research in the energy industry. Current areas of focus include mechanical and hydrological processes in active tectonic environments, such as subduction zones and transform systems; deformation, material properties, and pore pressure in regions with complex stress histories; flow and mechanical properties of mudrocks, and gas hydrate systems. Tuition, stipend, and other fees will be fully funded for these research positions. For information please contact Demian Saffer (demian.saffer@austin.utexas.edu) or Peter Flemings (pflerings@jsg.utexas.edu).

All applications must be completed in the Gradu-

ate and International Admissions Center (GIAC) by the appropriate deadline (December 1st 2019 for fellowship consideration and January 1st for all applications). See

<https://gradschool.utexas.edu/admissions/how-to-apply>.

More information about the application process can be found at The University of Texas at Austin, Jackson School of Geosciences admissions portal: <http://www.jsg.utexas.edu/education/graduate/admissions/>.

For additional information concerning the application process, contact the Jackson School of Geosciences graduate Program Coordinator, Philip Guerrero: philipp@jsg.utexas.edu.

Graduate Student Opportunities (MS), Ohio University.

The Department of Geological Sciences at Ohio University invites applications to its research thesis-based MS degree in Geology for the Fall of 2020. The Geological Sciences faculty at Ohio University collaborate in three research clusters: paleobiology and sedimentary geology, solid earth and planetary dynamics, and environmental and surficial processes. Prospective students are encouraged to contact faculty directly to discuss potential research topics. Qualified students are eligible to receive teaching assistantships that carry a full tuition scholarship and a competitive stipend. For program and application information, visit the department website at <http://www.ohio.edu/cas/geology/graduate> or contact the graduate chair, Dr. Daniel Hembree (hembree@ohio.edu). Review of applications begins February 1, 2020.

Graduate Student Opportunities (Online MS), Ohio University.

The Department of Geological Sciences at Ohio University invites applications to its online, non-thesis MS degree in Geology for the Fall of 2020. The program includes courses on research methods, paleobiology and sedimentary geology, Earth materials and planetary geology, and environmental and surface processes. The program is designed for students planning to enter or already in the geoscience workforce (industry, government, non-profit) that do not require research experience as well as K-12 educators seeking additional training in the geosciences. For program and application information, visit the department website at <http://www.ohio.edu/cas/geology/graduate> or contact the graduate chair, Dr. Daniel Hembree (hembree@ohio.edu). Review of applications begins February 1, 2020.

Graduate Student Opportunities, Baylor University.

The Department of Geosciences at Baylor University invites applications for full-time Ph.D. and MS students starting in August 2020. Admission to the program includes 5 years of financial support for Ph.D. students and 2 years of financial support for MS students through research and teaching assistantships and fellowships. Admitted students also receive a full tuition waiver, 80% health insurance subsidy, annual travel funding from department and university for conference attendance, and research funding for graduate stu-

GEOSCIENCE JOBS & OPPORTUNITIES

dents on a competitive basis. Candidates should have at least an undergraduate degree in geology, geophysics, or in a related area and excellent analytical and writing skills.

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

Applications are due by January 15, 2020 for Fall 2020 program entry. Details about the application process can be found here: <https://www.baylor.edu/geosciences/index.php?id=952059>. Please contact our Graduate Program Director for more information or with questions at geosciences@baylor.edu or visit our booth at the AGU fall meeting.

Ball State University. The Department of Environment, Geology & Natural Resources at Ball State University in Muncie, Indiana, invites applications for full-time Ph.D., master of science and/or master of arts students starting in August 2020. We seek highly motivated students with excellent written and analytical skills. Graduate assistant positions are available on a competitive basis. Faculty research covers the spectrum of environmental and geological sciences, and natural resource management. Please contact Dr. K. Nicholson knichols@bsu.edu for details. Additional information can be found at <https://www.bsu.edu/academics/collegesanddepartments/environment-geology-natural-resources>.

Doctoral Student Opportunities, Duke University. The Division of Earth and Ocean Sciences at Duke University invites intellectually engaged and motivated students to apply to our doctoral pro-

gram. We particularly seek applicants in the fields of biogeochemical oceanography, geochemical hydrology, coastal processes and geomorphology, atmospheric dynamics, climate change, and energy and resources. As part of Duke's Nicholas School of the Environment, our graduate students interact with faculty and students in diverse fields related to the earth, oceans, atmosphere, biosphere and environment. We offer 5 years of financial support through research and teaching assistantships and fellowships. For more information, please visit <https://nicholas.duke.edu/academics/doctoral-programs/earth-ocean-sciences-eos> or email our Director of Graduate Studies at: abmurray@duke.edu.

Graduate Assistantship, New Mexico Highlands University. Graduate assistantships are available for students wishing to pursue an MS in Geology–Environmental Science beginning Spring or Fall 2020 term. The NMHU Environmental Geology Program strengths are in Petrology, Environmental geochemistry, Water Resources & Water Quality, Paleomagnetism, Volcanology, and collaborative endeavors with the New Mexico Forest and Watershed Restoration Institute. The Paleomagnetism–Rock Magnetism, Powder X-Ray Diffraction, and Water Chemistry laboratories support wide-ranging analytical and field research. The NMHU campus is situated at the boundary of the Great Plains and the Sangre de Cristo Mountains. Campus is located within one to two hours from Cenozoic volcanic fields, Precambrian rock exposures, glaciated valleys, desert terrains, and several world-renowned geologic features - the Valles Caldera and the Rio Grande Rift. A low student:faculty ratio, state-of-the art laboratory facilities, and committed faculty provide students with a superior learning experience. The graduate assistantship includes a nine-month stipend and tuition waiver per academic year. Application review begins

01/10/19 Spring and 01/02/20 Fall. For more information, contact Dr. Petronis, Environmental Geology, NRM Department, New Mexico Highlands University, Box 9000, Las Vegas, New Mexico 87701, mmpetro@nmhu.edu. For disabled access or services call 505-454-3513 or TDD# 505-454-3003. AA/EOE Employer.

Graduate Student Opportunities at Case Western Reserve University. Students with backgrounds in geology, physics, chemistry, biology, engineering, and related fields are encouraged to apply for our Ph.D. and MS programs in Earth, Environmental, and Planetary Sciences. Areas of active research in the Department include planetary geology and geodynamics, planetary materials, high-pressure mineral physics and geochemistry, core and mantle processes, environmental science, sedimentary geology, and sediment transport. For more information, please visit <http://eeps.case.edu> or write to eeps-gradinfo@case.edu. Financial assistance is available. Application deadline: 1/15/2020.

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Support the GSA Programs You Are Passionate About with These Tax-Wise Tools

If you are like me, the end of the year presents a difficult choice—whom should I support philanthropically, and how can I do so in the most tax-effective manner? One method several GSAF donors have chosen is charitable rollovers from traditional individual retirement accounts. Through IRA rollovers, you can make a generous gift during your lifetime from assets that could otherwise be subject to multiple levels of taxation.

The requirements and benefits to an IRA rollover contribution are simple. If you are at least 70½ years of age, you can direct a transfer from your traditional IRA to the Geological Society of America Foundation. This transfer will count toward your required minimum distribution for the calendar year. Because your funds are going from your IRA directly to GSAF, your gift amount can be excluded from your income for federal tax purposes. An additional benefit is the immediate and dramatic impact you will make in the lives of students and GSA members through supporting the GSA programs that matter to you.

Of course, before pursuing this avenue of giving, you should consult your own professional advisors to discuss your specific situation, as IRS limitations may apply.

For long-time Foundation supporter Charles Ross, IRA rollover contributions have become his preferred way to support GSA—a desire he shared with his wife, June, who passed away in 2012. As Charles recounts, GSA had been a continual, supportive funding source for his and June’s work throughout their careers. In recognition of this, they started the Charles A. and

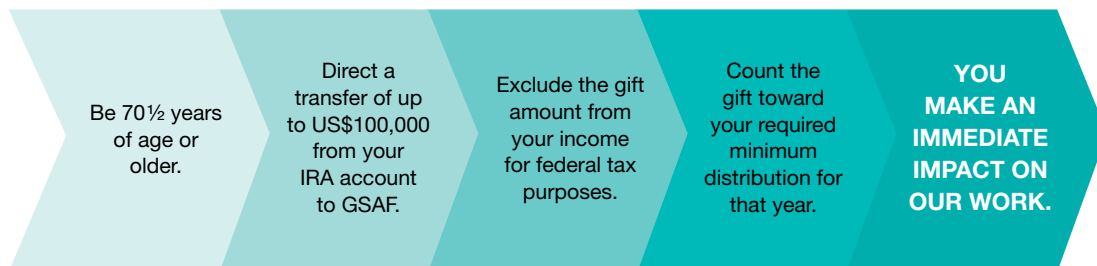
June R.P. Ross Award, which supports research grants in paleontology, paleogeography, and paleobiogeography. When June passed, Charles decided to strengthen his commitment to GSA. He consulted his tax professional, and after determining that it was the best giving option for him, committed to supporting his fund by giving through IRA rollover contributions. Charles believes in GSA and its mission, so he gives happily, saying, “I feel good about the way the money is being used and the work it is supporting.”



For those who have yet to reach 70½ there are still plenty of ways to support GSA this year end! You can visit <https://gsa-foundation.org/donate/> to make an immediate online gift. If you are shopping for the holidays, please consider using AmazonSmile and designating GSAF as the recipient—Amazon will donate 0.5% of the price of your purchases to GSAF. Finally, you may work for one of the thousands of companies who will match employees’ gifts to non-profit organizations like GSAF—contact your HR department for details about their program and double your impact!

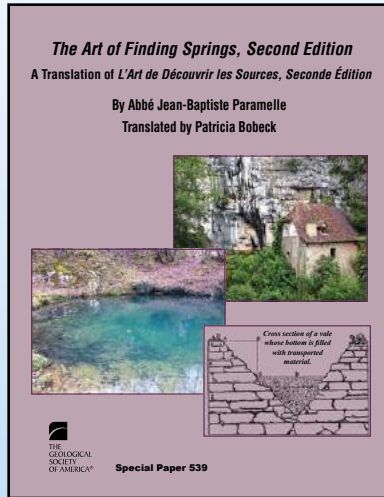
These are just some of the ways you can support the projects you are passionate about this December. For more details on traditional IRA rollover contributions and related material, or to discover more ways that you can give, visit <https://gsa-foundation.org/ways-to-give/> or contact Clifton Cullen at +1-303-357-1007 or ccullen@geosociety.org.

Basics of IRA Charitable Rollover

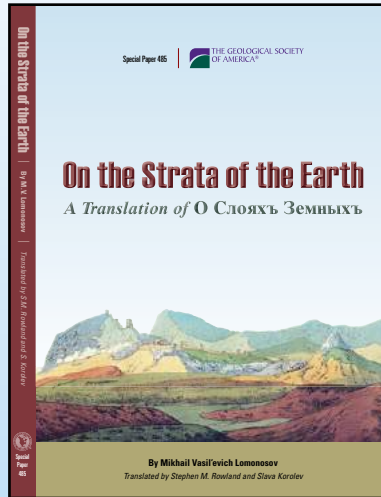


Evolution of the Geosciences

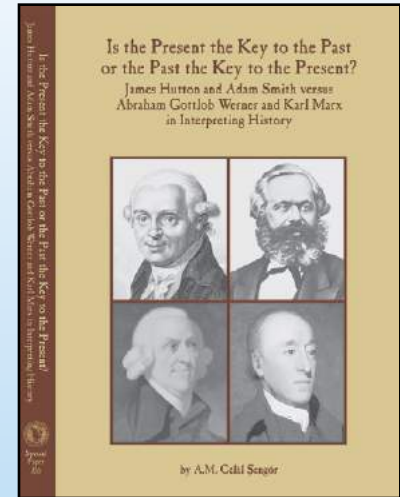
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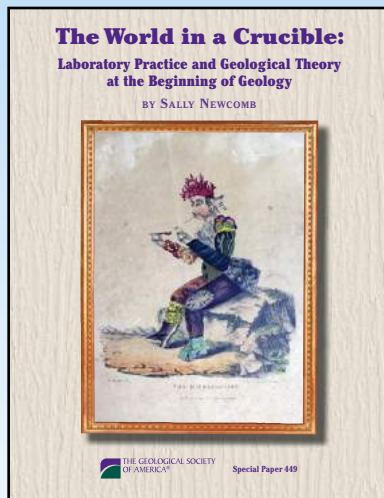
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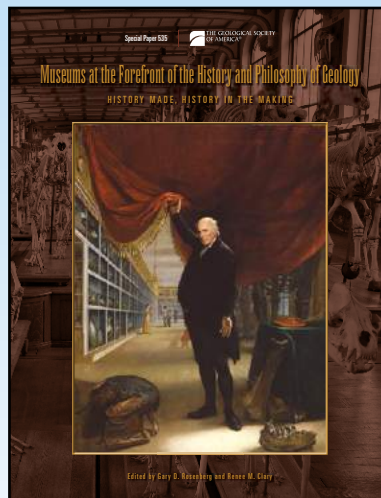
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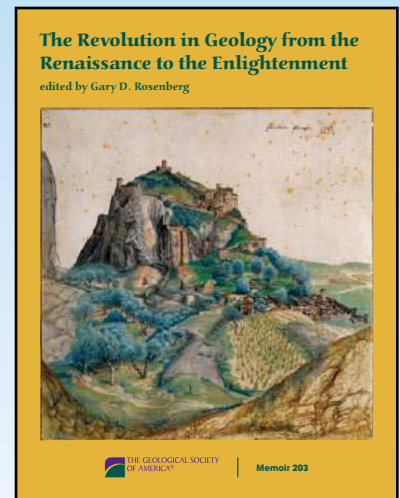
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25–28 October
GSA 2020

Montréal, Québec, Canada

GSA 2020 Annual Meeting & Exposition



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Call for Short Course and Technical Session Proposals

It's time to plan for our 2020 Annual Meeting in Montréal, Québec, Canada. We look forward to highlighting the geology in the area. We challenge you to propose a short course and/or a technical session that will teach your colleagues and promote discussion about the incredible regional geology.

Exchange the geology by organizing and chairing a Technical Session.

Technical Session deadline: 1 Feb. 2020

Proposals are being taken for both Pardee Symposia and Topical Sessions.

<https://gsa.confex.com/gsa/2020AM/cfs.cgi>

Share the geology as an instructor through a Short Course.

Short Course proposal deadline: 1 Feb. 2020

Courses run the Friday and Saturday before the Annual Meeting and are typically a half day to two full days.

<https://gsa.confex.com/gsa/2020AM/shortcourse/cfs.cgi>



A MESSAGE FROM THE GSA EXECUTIVE DIRECTOR

Dear Colleagues,

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

I invite you to prepare a proposal for a technical session for the 2020 Annual Meeting that reflects your expertise and research but also pushes the boundaries of the discipline. Without expanding our horizon, we will not move the geosciences forward and keep our relevance. I also challenge you to broaden your reach with whom you collaborate by including diversity in all ways—discipline, career progression, and individuals.

Thank you for considering sharing your science and work at the GSA Annual Meeting.

Vicki S. McConnell

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This 12-month, 9.5" × 12.5" calendar showcases compelling submissions to the GSA calendar photo search. Featuring images of coral at Moor Reef, Westmoreland (Jamaica), Peyto Lake and the Mistaya River Valley, Banff National Park, Alberta (Canada), White Pocket, Vermilion Cliffs National Monument (Arizona), and Rub' Al-Khali desert (Saudi Arabia), this serene calendar will spruce up your home or office.

- Dates of many noteworthy eruptions & earthquakes
- Birthdates of famous geoscientists
- Calendar of GSA events, meetings, & deadlines



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